FOOD HABITS OF HUNTER COLLECTED NORTHERN BOBWHITE QUAIL (*COLINUS VIRGINIANUS*) AT THE CHAPARRAL WILDLIFE MANAGEMENT AREA IN SOUTH TEXAS

THESIS

Presented to the Graduate Council of
Texas State University-San Marcos
in Partial Fulfillment
of the Requirements

for the Degree

Master of SCIENCE

by

Rachel E. Barlow, B.S.

San Marcos, Texas
May 2008

ACKNOWLEDGEMENTS

I thank Thomas R. Simpson, John T. Baccus, and Floyd W. Weckerly for support and advisement. I thank Texas State University-San Marcos for supplies and funding. I thank the Chaparral Wildlife Management Area (CWMA), Texas Parks and Wildlife Department (TPWD), David Synatzske (TPWD), Chris Mostyn (TPWD), and Jimmy Rutledge (TPWD) for access to my study site, help in the field, and advisement. I thank John Abbot (University of Texas-Austin), David Lemke (Texas State University-San Marcos), Lawrence Gilbert (University of Texas-Austin), Andy Blair, Chris Best (U.S. Fish and Wildlife Service), David Bonner (Texas State University-San Marcos) and Michael Small (Texas State University-San Marcos) for aid in identification and advisement. I thank Drew Larson, Timothy Fullbright (Texas A&M University-Kingsville) and Susan Schwinning (Texas State University-San Marcos) for use of supplies and reference collections. I thank Esther Chanovec, Steven Gibson, Arlene Kalmbach, Katie Richardson, Stephen LeClair, Cindy Sperry, Stephanie Myers, Aikiko Fujii, and Elena Lopez (TPWD) for help in the field.

This manuscript was submitted on March 21, 2008.

TABLE OF CONTENTS

Page

LIST OF TABLES

Table **Page**

LIST OF FIGURES

Figure **Page**

ABSTRACT

FOOD HABITS OF HUNTER COLLECTED

NORTHERN BOBWHITE QUAIL (*COLINUS VIRGINIANUS*)

AT THE CHAPARRAL WILDLIFE MANAGEMENT AREA IN SOUTH TEXAS

by

Rachel E. Barlow, B.S.

Texas State University-San Marcos

May 2008

SUPERVISING PROFESSOR: THOMAS R. SIMPSON

I investigated the feeding habits of wild northern bobwhites (*Colinus virginianus*) harvested from the Chaparral Wildlife Management Area in south Texas in October 2004 and January 2005. The contents of 200 crops were dried, sorted, and weighed to the nearest 0.0001 gram. Percent dry weight was used to assess differences among season harvested, sex, and age. About 76% of the fall diet consisted of seeds, with approximately 64 plant species represented. Queen's delight (*Stillingia sylvatica*), woolly croton (*Croton capitatus*), and browntop signalgrass (*Urochloa fusca*) composed greater than 50% by weight of seeds found in the fall diet. Fruit, almost entirely spiny hackberry (*Celtis ehrenbergiana*), composed 17% of the fall diet. Invertebrates made up about 5% and green vegetative matter contributed 0 1% to the fall diet. No differences in

feeding habits between sexes or age class were detected for fall. The winter diet consisted of 63% green vegetative matter, 28% seeds, 5% invertebrates, and 0.40% fruit. Common yellow oxalis (*Oxalis stricta*) and a species of pellitory (*Parietaria sp*) made up over 50% of the green vegetative matter. Percent green vegetation consumed by females (78%) exceeded ($P = 0.007$) that of males (53%) in winter. Additionally, in winter green vegetation consumed by adults (70%) exceeded ($P = 0.016$) that of juveniles (59%). Differences by sex in the winter diet might be due to differences in nutritional requirements in the pre-breeding period.

CHAPTER I

INTRODUCTION

Hunting northern bobwhite quail (*Colinus virginianus*) generates hundreds of millions of dollars in economic benefits for rural communities in the southeastern United States (Burger et al., 1999). As quail populations have declined throughout most of the southeastern U.S., the sales of non-resident five-day quail hunting licenses in Texas have increased 263% since their inception in 1987. Economic benefits of quail hunting in Texas include revenue to landowners for hunting leases, rural economic benefits via ecotourism, and impacts on rural real estate values (Brennan et al., 2005).

Annual variations in bobwhite populations are hypothesized to be associated with fluctuations in the amounts and patterns of rainfall (Lehmann, 1953; Kiel, 1976), and the resulting alterations in food supply (Wood et al., 1986; Guthery, 2000; Perez et al., 2002). In south Texas, numerous bobwhite food habit studies have been performed to gather information about seasonal fluctuations in bobwhite productivity and to supply critical information needed for land managers to create optimal bobwhite habitat (Lehmann and Ward, 1941; Campbell-Kissock and Blankenship, 1985; Wood et al., 1986; Harveson et al., 2004). Most studies concentrated on seasonal variations in overall diet over numerous sites. No study focused on dietary differences due to sex and age during two seasons within a specific site. Dietary research separating factors such as sex and age

could reveal relationships, such as food partitioning, that are not apparent with combined data. Additionally, concentrating research efforts on one site may be helpful in understanding bobwhite dietary needs on a local level.

The objective of this study was to report food habits of northern bobwhites harvested on the Chaparral Wildlife Management Area in south Texas during the 2004-2005 hunting season and to assess dietary differences by season, sex, and age.

CHAPTER II

METHODS

Study Area

The study area was the Chaparral Wildlife Management Area (hereafter, CWMA), near Artesia Wells, Texas, located within the Rio Grande Plains Ecological Region. The CWMA, owned and operated by Texas Parks and Wildlife Department, encompasses 6,151 ha on the county line between La Salle and Dimmit counties (99°25'W, 28°20'N). The soils are predominantly Duval fine sandy loam and Dilley very fine sandy loam (Perez et al., 2002). The plant community is a mesquite (*Prosopis glandulosa*)-spiny hackberry (*Celtis ehrenbergiana*) association. Other woody species found on the site include acacia (*Acacia* spp.), brasil (*Condalia hookeri*), and prickly pear (*Opuntia* spp.) scattered throughout a grassland. Herbaceous species include Lehmann lovegrass (*Eragrostis lehmanniana*), fringed signalgrass (*Brachiaria cilliatissima*), hairy grama (*Bouteloua hirsuta*), croton (*Croton* spp.), coreopsis (*Coreopsis nuecensoides*), lazydaisy (*Aphanostephus* spp.) and partridge pea (*Chamaecrista fasciculata*) (Ruthven and Synatszke, 2002).

The Rio Grande Plains Ecological Region is characterized by long hot summers and short mild winters with a mean winter temperature of 12.7°C, and a mean summer temperature of 29.4°C. The mean annual precipitation is 55.4 cm per year (Perez et al.,

2002). Peak rainfall occurs during the late spring (May-June) and early fall (September-October). Times of low rainfall can be severe, often resulting in drought conditions. The plant community at the CWMA is well adapted to an arid, desert environment (Ruthven, 2001).

Data Collection and Analysis

Over 1000 quail crops were collected from hunters in October 2004 (fall) and January 2005 (winter). I selected the crops in a stratified random manner to produce equal numbers of males, females, juveniles, and adults up to 100 crops per season for identification and analysis. In winter, collected crops were limited to 39 adults, with only 13 adult females, but were otherwise selected to keep categories balanced. I used crops from 25 adult males, 25 adult females, 25 juvenile males and 25 juvenile females for analysis of the fall diet and 26 adult males, 13 adult females, 30 juvenile females, and 31 juvenile males for analysis of the winter diet.

I numbered each crop and recorded the date, time of day, age (adult or juvenile), and sex of the bird. Crops were placed on ice in the field and transferred to a freezer within 12 h. The contents of individual crops were washed through four sieves (screen sizes = 0.035 mm, 0.025 mm, 0.010 mm, and 0.002 mm) to rinse the items and separate them into size classes. Animal matter was separated from vegetative matter and stored in vials of 70% ethanol. Vegetative matter was further separated into green vegetative matter (primarily foliage), seeds, corn, and fruit, then dried for 1-2 h in a dryer and placed in paper coin envelopes. Food items were assigned to the following categories: invertebrates, green vegetation, seeds, fruit, and other. For the purposes of this study, fruit containing seed were considered one unit and placed in the fruit category because

there was no way to discern if those items were eaten for the seed or fruit component. Evidence suggests that seeds such as hackberry (*Celtis* sp.) do not add nutritionally to the diet and are passed through birds undigested (Sternberg and Wilson, 2004). Materials such as unidentifiable seed coats, down feathers, and dirt were labeled as debris. Small rocks presumably used as an aid for grinding food in the gizzard, were labeled as grit. Because corn was found in only three crops during one season, it was combined with debris and grit and categorized as other. After all food items were dried 1-2 h in a dryer, I sorted them by species and used a non-histological method for the identification of undigested food items (Korschgen, 1962). I identified seeds and fruits to species using a reference collection at Texas A&M-Kingsville, plant guides (Jackson, 1969; Landers and Johnson, 1976; Rosene and Freeman, 1988), United States Department of Agriculture, National Resources Conservation Service (http://plants.usda.gov) and reference specimens collected from CWMA. Green vegetation was identified from reference specimens collected at CWMA, United States Department of Agriculture, National Resources Conservation Service (http://plants.usda.gov) and consultation with D. Lemke, Texas State University-San Marcos. Current taxonomic classification of all plants followed the United States Department of Agriculture, Germplasm Resources Information Network (http://www.ars-grin.gov/npgs/searchgrin.html). Insects and other invertebrates were identified by National Audubon Society field guide (1995), J. Abbot (University of Texas-Austin pers. comm.), and A. Blair (Texas State University-San Marcos pers. comm.). Unidentified specimens were labeled as unknown.

I chose not to perform a Multivariate Analysis of Variance (MANOVA) because ambiguity is often present regarding which independent variable affects any particular dependent variable. Additionally, because my dependent variables are expressed as percentages, I suspected high correlation between variables would confound my results. Consequently, I concluded little advantage would be gained by including more than one dependent variable, particularly given the resultant loss in degrees of freedom (Tabachnick and Fidell, 1996).

Therefore, I used a 3-way Analyses of Variance (ANOVA) to test for differences by season, sex, and age on dominant food item categories. I categorized food items as dominant by summing the most abundant categories until $\geq$ 75% of the overall diet were accounted for. I then tested my response variables for normality with a Kolmogorov-Smirnov test and homoscedasticity with an *F*-test. In the event assumptions were violated, I determined I would conduct a $\log_e$ transformation of the data. Tukey's *post hoc* tests will then be performed on the ANOVA results to examine possible effect interactions and isolate significant differences within season, sex, and age. Tests were considered significant at $\alpha = 0.05$.

CHAPTER III

RESULTS

I found 64 species of seeds, three species of fruit, 40 invertebrate families, and green foliage from approximately 20 species of plants in the 200 crops (Appendix). Seeds of queen's delight (*Stillingia sylvatica*), browntop signalgrass (*Urochloa fusca*), and woolly croton (*Croton capitatus*) comprised over 50% of the fall diet, while 16% consisted of spiny hackberry (*Celtis ehrenbergiana*) fruit. The young leaves and shoots of pellitory (*Parietaria* sp.), common yellow oxalis (*Oxalis stricta*), and meadow garlic (*Allium canadense*) comprised 43% of total crop contents for winter. Texas bindweed (*Convolvulus equitans*) seeds constituted an additional 18% of the winter diet. Small seeds, such as fringed signalgrass (*Urochloa cilliatissima*) and plains bristle grass (*Setaria leucopila*), often composed a small percentage by dry weight, yet were present in a large number of crops. However, species which made up the greatest percent of the dry weight, such as queen's delight (*Stillingia sylvatica*) and browntop signalgrass (*Urochloa fusca*) also were generally found in the largest number of crops (Table 1).

Over 75% of overall diet for bobwhite quail was composed of seeds and green vegetation, thus I classified these food categories as dominant for my statistical analyses. Results from the Kolmogorov-Smirnov test indicated that my data was not normally distributed ($D = 0.280$, $P = < 0.001$). Additionally, heteroscadasticity was present

Table 1.--Percent dry weight (g) and percent frequency of primary foods in crops of 200 northern bobwhite quail collected at the Chaparral Wildlife Management Area in October 2004 (fall) and January 2005 (winter).

Food category and species	Fall (n = 100) Weight (%)	Fall (n = 100) Frequency (%)	Winter (n = 100) Weight (%)	Winter (n = 100) Frequency (%)
Seeds of forbs and woody plants				
Queen's delight (*Stillingia sylvatica*)	27 13%	90%	4.18%	27%
Woolly croton (*Croton capitatus*)	10.49%	33%	---	---
Texas bindweed (*Convolvulus equitans*)	5.19%	79%	18 15%	50%
Annual ragweed (*Ambrosia artemisiifolia*)	2.37%	6%	---	---
Sensitive partridge pea (*Chamaecrista nictitans*)	1.16%	23%	0.92%	10%
Camphorweed (*Heterotheca subaxillaris*)	1 14%	5%	0.06%	3%
Other*	3.77%		3.46%	
Seeds of grasses				
Browntop signalgrass (*Urochloa fusca*)	14.29%	77%	0.45%	14%
Plains bristle grass (*Setaria leucopila*)	3.78%	42%	0.11%	6%
Slender panic grass (*Panicum capillarioides*)	2.32%	37%	0.04%	6%
Fringed signalgrass (*Urochloa ciliatissima*)	2.21%	48%	0 97%	27%
Switchgrass (*Panicum virgatum*)	1.10%	23%	0.03%	1%
Other*	0.64%		0.04%	
Fruits				
Spiny hackberry (*Celtis ehrenbergiana*)	16.55%	63%	0.40%	6%
Other*	0.04%		---	
Invertebrates				
Grasshopper (Acrididae)	2.83%	36%	0 12%	2%
Other*	2.54%		5.08%	

Table 1 (con't)-- Percent dry weight (g) and percent frequency of primary foods in crops of 200 northern bobwhite quail collected at the Chaparral Wildlife Management Area in October 2004 (fall) and January 2005 (winter).

Food category and species	Fall (n = 100) Weight (%)	Fall (n = 100) Frequency (%)	Winter (n = 100) Weight (%)	Winter (n = 100) Frequency (%)
Green Vegetation				
Pellitory (*Parietaria* sp.)	---	---	19.98%	86%
Common yellow oxalis (*Oxalis stricta*)	0.01%	9%	14.70%	95%
Meadow garlic (*Allium canadense*)	0 04%	15%	8.43%	86%
Vetch (*Vicia* sp.)	---	---	2.27%	14%
Wild Carrot (*Daucus* sp.)	---	---	1 13%	42%
Other*	0.04%		16.38%	

*Includes items with less than 1 0% dry weight for both seasons

in my data ($F_{199} = 1.273$, $P = 0.05$). Because assumptions of normality and equal variances were violated, I $\log_e$ transformed my data prior to performing the ANOVAs.

I detected differences in food habits of northern bobwhites harvested in fall and winter for seed consumption ($F_{(1,192)} = 277.439$, $P < 0.001$). Additionally, I found differences between seasons for amount of green vegetation consumed ($F_{(1,192)} = 1109.606$, $P < 0.001$). The proportion of seeds represented in the fall diet was estimated to be 2.7 times greater by dry weight than in the winter diet, and green vegetation in the winter diet was 628.8 times greater than in the fall diet (Fig 1, Table 2).

I found no significant differences in seed consumption by season, sex, or age. Additionally, I found no significant differences in green vegetation consumption for either age or sex during fall. In winter, however, females ate more green vegetation than males ($F_{(1,192)} = 4.881$, $P = 0.007$), and adults utilized more green vegetation than juveniles ($F_{(1,192)} = 4.005$, $P = 0.016$) (Fig 2, Table 3, Table 4).

Table 2.—Dry weight and percent dry weight of seeds, fruit, invertebrates, green vegetation, and other found in crops of 200 northern bobwhite quail collected at the Chaparral Wildlife Management Area in October 2004 (fall) and January 2005 (winter).

	October 2004 ($n = 100$)		January 2005 ($n = 100$)		Total ($n = 200$)	
Food Category	wt (g)	%	wt (g)	%	wt (g)	%
Seeds	97.7728	75.59%	9.3828	28.40%	107.1556	65.99%
Fruit	21.4549	16.59%	0.1326	0.40%	21.5875	13.29%
Invertebrates	6.9403	5.36%	1.7167	5.20%	8.6570	5.33%
Green Vegetation	0.1238	0.10%	20.7746	62.88%	20.8984	12.87%
Other	3.0523	2.36%	1.0321	3.12%	4.0844	2.52%
Total*	129.3441	100.00%	33.0388	100.00%	162.3829	100.00%

*Includes corn, grit and debris

Table 3.—Dry weight and percent dry weight of seeds, fruit, invertebrates, green vegetation, and other found in male and female crops of 100 northern bobwhite quail collected at the Chaparral Wildlife Management Area in January 2005 (winter).

	Male (n = 57)		Female (n = 43)		Total (n = 100)	
Food Category	wt (g)	%	wt (g)	%	wt (g)	%
Seeds	7.7987	39.84%	1.5841	11.76%	9.3828	28.40%
Fruit	0.0258	0.13%	0.1068	0.79%	0.1326	0.40%
Invertebrates	1.0480	5.36%	0.6687	4.97%	1.7167	5.20%
Green Vegetation	10.3075	52.66%	10.4671	77.73%	20.7746	62.88%
Other	0.3931	2.01%	0 639	4.75%	1.0321	3.12%
Total*	19.5731	100.00%	13.4657	100.00%	33.0388	100.00%

*Includes corn, grit and debris.

Table 4.—Dry weight and percent dry weight of seeds, fruit, invertebrates, green vegetation, and other found in juvenile and adult crops of 100 northern bobwhite quail collected at the Chaparral Wildlife Management Area in January 2005 (winter)

	Juvenile (n = 61)		Adult (n = 39)		Total (n = 100)	
Food Category	wt (g)	%	wt (g)	%	wt (g)	%
Seeds	6.5879	30.68%	2.7949	24.17%	9.3828	28.40%
Fruit	0.0724	0.34%	0.0602	0.52%	0.1326	0.40%
Invertebrates	1.2612	5.87%	0.4555	3.94%	1.7167	5.20%
Green Vegetation	12.7201	59.23%	8.0545	69.66%	20.7746	62.88%
Other	0.8349	3.89%	0.1972	1.71%	1.0321	3.12%
Total*	21.4765	100.01%	11.5623	100.00%	33.0388	100.00%

*Includes corn, grit and debris

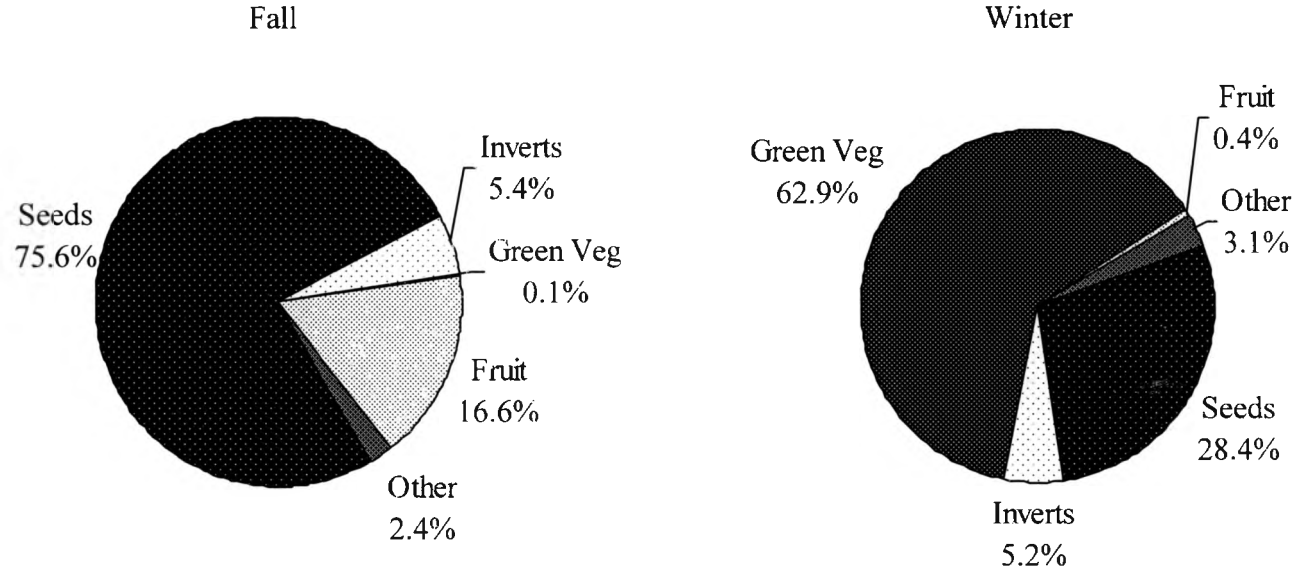

Figure 1. Food habits of northern bobwhites at the Chaparral Wildlife Management Area in October 2004 (fall) and January 2005 (winter). Percent dry weight (g) of each major food category of crop contents for fall (n = 100) and winter (n = 100). The food category labeled 'other' includes corn, debris, and grit.

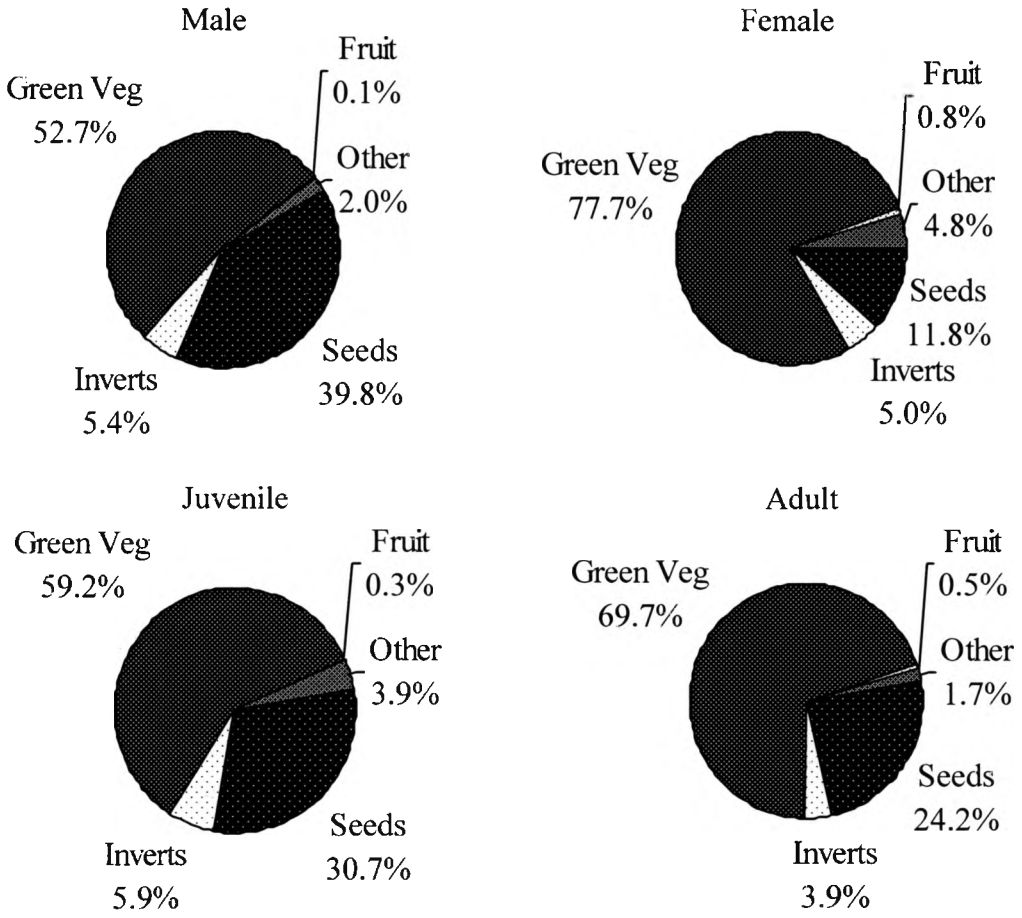

Figure 2. Food habits of northern bobwhites at the Chaparral Wildlife Management Area in January 2005 (winter). Percent dry weight (g) of each major food category of crop contents for males (n = 57), females (n = 43), juveniles (n = 61), and adults (n = 39). The food category labeled 'other' includes debris and grit.

CHAPTER IV

DISCUSSION

My research concurs with previous studies (McRae at al, 1979; Peoples et al., 1994) showing that seeds are the major component of northern bobwhite diets in the fall. Additionally, my research revealed no differences in diets by sex or age during the fall. However, northern bobwhites consumed considerably more green vegetation and fewer seeds during winter. Consumption of green vegetative matter increases during winter in warmer areas, or early spring in cooler climates (Baldwin and Handley, 1946; Jackson, 1969; Wiseman, 1977; McRae et al., 1979; Lehmann, 1984; Campbell-Kissock and Blankenship, 1985; Wood et al., 1986; Peoples et al., 1994). In south Texas, Campbell-Kissock and Blankenship (1985) found that green vegetation was the major component of the diet during October through February, which were lumped together as one time frame in the case of this study.

Due to 80%-90% water content, green vegetation is, by comparison to insects, fruit, and most forb seeds, low in caloric content (Guthery, 2000). Few publications have given much attention to the green vegetative component of northern bobwhite diets, calling it poor quality food eaten mainly because of a reduction in high caloric food availability during winter (Lehmann, 1984; Campbell-Kissock and Blankenship, 1985; Leif and Smith, 1993). In addition, no bobwhite food preference study has included a

green vegetation component (Jensen and Korschgen, 1947; Ellis, 1961; Giuliano et al., 1996; Madison and Robel, 2001). However, in terms of dry weight, green vegetation is high in calcium and protein and contains moderate levels of calories, minerals, and phosphorus (Wood et al., 1986; Leif and Smith, 1993; Guthery, 2000). By contrast, seeds contain less than half the calcium. Grass seeds in particular contain a fraction of the calcium, less phosphorus and approximately half the protein as green vegetative matter (Wood et al., 1986; Leif and Smith, 1993).

My study uncovered a pre-breeding food bias by sex and age within a single population of northern bobwhites. I suggest that increased intake of green vegetative matter prior to egg production is more relevant than a mere mechanism to deal with starvation (Lehmann, 1984; Campbell-Kissock and Blankenship, 1985; Leif and Smith, 1993), but evidence for food utilization based on production needs. Breeding bobwhite females require higher levels of protein, Ca, P, energy, and other nutrients (National Research Council, 1977), and insufficient levels of protein, energy, and possibly calcium/phosphorous associations in the diet may affect northern bobwhite egg production (Cain et al., 1982; Giuliano et al., 1996). Guthery (2000) found water intake by egg producing females must increase by 40-60% in contrast to non-laying birds, and that most of this is obtained through eating insects, greens, and fruit. Wood et al. (1986) demonstrated that during spring, females selected a diet that was 70% higher in calcium than males, while both sexes consume similar percentages during other times of the year. Additionally, because a diet high in greens is low in caloric value and over-winter weight loss and fall weight gain are typical, calories for egg production and daily maintenance

for winter are largely obtained during fall and stored as fat (Guthery et al., 1988; Guthery, 2000).

Although no study has found a significant association between insufficient levels of any single dietary component other than energy and protein with regards to production success, my results suggest that greens may be consumed by adult females prior to egg production for a combination of pre-breeding nutritional requirements such as water, calcium, phosphorus, protein, or other vitamins and minerals. Further studies are needed to better understand the exact mechanisms involved.

APPENDIX

Foods eaten by Northern Bobwhites at the Chaparral Wildlife Management Area, Texas

Food Item	Fall Dry Wt (g)	Fall % Dry Wt	Fall Freq	Winter Dry Wt (g)	Winter % Dry Wt	Winter Freq
Seeds of forbs and woody plants						
Aster Family (Asteraceae)						
Annual ragweed (*Ambrosia artemisiifolia*)	3 064	2 37%	6%	---	---	---
Camphorweed (*Heterotheca subaxillaris*)	1 478	1 14%	5%	0.020	0 06%	3%
Sunflower (*Helianthus* sp)	0 370	0 29%	1%	---	---	---
Cactus Family (Cactaceae)						
Texas prickly pear (*Opuntia engelmannii*)	0.040	0.03%	3%	0 194	0 59%	3%
Carpet-weed Family (Molluginaceae)						
Green carpet-weed (*Mollugo verticiliata*)	0 007	0 01%	1%	---	---	---
Carrot Family (Apiaceae)						
Wild Carrot (*Daucus* sp)	0 009	0 01%	1%	---	---	---
Four o'clock Family (Nyctaginaceae)						
Berlandier's trumpets (*Acleisanthes obtusa*)	0 037	0.03%	2%	---	---	---
Grape Family (Vitaceae)						
Peppervine (*Ampelopsis arborea*)	0 013	0 01%	1%	---	---	---
Madder Family (Rubiaceae)						
Poor Joe (*Diodia teres*)	0 059	0 05%	6%	0 048	0 14%	2%
Mallow Family (Malvaceae)						
Fanpetals (*Sida* sp)	0 050	0 04%	6%	0 025	0 08%	1%
Texas Indian mallow (*Abutilon fruticosum*)	0 022	0 02%	3%	0 003	0 01%	1%
Milkweed Family (Asclepiadaceae)						
Bearded swallow-wort (*Cynanchum barbigerum*)	0 002	Trace	1%	---	---	---
Morning-glory Family (Convolvulaceae)						
Morning glory (*Ipomoea* sp.)	0 020	0.02%	1%	---	---	---
Slender dwarf morning-glory (*Evolvulus alsinoides*)	0 010	0 01%	1%	0 019	0 06%	2%
Texas bindweed (*Convolvulus equitans*)	6 718	5 19%	79%	5 995	18.15%	50%
Mustard Family (Brassicaceae)						
Southern marsh yellowcress (*Rorippa teres*)	0 017	0 01%	4%	---	---	---
Pea Family (Fabaceae)						
Honey mesquite (*Prosopis glandulosa*)	0.073	0 06%	2%	---	---	---
Jerusalem thorn (*Parkinsonia aculeata*)	0 270	0 21%	1%	---	---	---
Milkvetch (*Astragalus* sp)	0 058	0 05%	4%	0.043	0 13%	3%
Partridge pea (*Chamaecrista fasciculata*)	0 014	0 01%	5%	0.049	0.15%	2%
Sensitive partridge pea (*Chamaecrista nictitans*)	1 498	1 16%	23%	0 304	0.92%	10%
Prairie clover (*Dalea* sp)	0 016	0 01%	3%	0 008	0 02%	3%
Sweet acacia (*Acacia farnesiana*)	0 238	0 18%	5%	0 055	0 17%	2%
Poppy Family (Papaveraceae)						
Red prickly poppy (*Argemone sanguinea*)	0 018	0 01%	2%	0 008	0 02%	1%
Potato Family (Solanaceae)						
Groundcherry (*Physalis* sp)	0 945	0 73%	41%	0 039	0 18%	2%

Appendix(con't)—Foods eaten by Northern Bobwhites at the Chaparral Wildlife Management Area, Texas

Food Item	Fall Dry Wt (g)	Fall % Dry Wt	Fall Freq	Winter Dry Wt (g)	Winter % Dry Wt	Winter Freq
Seeds of forbs and woody plants(con't)						
Purslane Family (Portulacaceae)						
Rose moss (*Portulaca grandiflora*)	0 722	0 56%	15%	---	---	---
Spiderwort Family (Commelinaceae)						
Whitemouth dayflower (*Commelina erecta*)	0 875	0 68%	24%	0 011	0 03%	2%
Spurge Family (Euphorbiaceae)						
Queen's delight (*Stillingia sylvatica*)	35 095	27 13%	90%	1 379	4 18%	27%
Leaf flower (*Phyllanthus* sp)	0 030	0 02%	2%		---	---
Sandmat (*Chamaesyce* sp)	0 049	0 04%	3%	0 001	Trace	1%
Three-seed croton (*Croton lindheimerianus*)	0.034	0.03%	2%	---	---	---
Woolly croton (*Croton capitatus*)	13 565	10 49%	33%	---	---	---
Verbena Family (Verbenaceae)						
Vervain (*Verbena* sp)	0 104	0 08%	4%	0 098	0 30%	1%
Wood-Sorrel Family (Oxalidaceae)						
Common yellow oxalis (*Oxalis stricta*)	0 018	0 01%	12%	0 032	0 10%	11%
Unknown (18species)	0 756	0 59%	32%	0 513	1.55%	5%
Seeds of grasses						
Grass family (Poaceae)						
Browntop signalgrass (*Urochloa fusca*)	18 478	14.29%	77%	0 149	0.45%	14%
Fringed signalgrass (*Urochloa ciliatissima*)	2.856	2 21%	48%	0 319	0 97%	27%
Texas signalgrass (*Urochloa texana*)	0 106	0 08%	3%	---	---	---
Crabgrass (*Digitaria* sp)	0 035	0 03%	2%	0.010	0 03%	1%
Johnsongrass (*Sorghum halepense*)	0 187	0 15%	1%	---	---	---
Slender panic grass (*Panicum capillarioides*)	3 002	2 32%	37%	0 013	0 04%	6%
Switchgrass (*Panicum virgatum*)	1.418	1 10%	23%	0 010	0 03%	1%
Panic grass (*Panicum* sp)	0 906	Trace	1%	---	---	---
Panic grass (*Panicum* sp)	0.023	0 02%	2%	---	---	---
Panic grass (*Panicum* sp)	0 007	0 01%	3%	0 002	0.01%	1%
Plains bristle grass (*Setaria leucopila*)	4 893	3 78%	42%	0 036	0 11%	6%
Thin paspalum (*Paspalum setaceum*)	0 466	0 36%	22%	0 001	Trace	3%
Unknown (1 species)	0 003	Trace	1%	---	---	---
Corn						
Zea mays	0 501	0 39%	3%	---	---	---
Fruits						
Elm Family (Ulmaceae)						
Spiny hackberry (*Celtis ehrenbergiana*)	21 403	16.55%	63%	0 133	0 40%	6%
Rue Family (Rutaceae)						
Lime prickly ashe (*Zanthoxylum fagara*)	0 018	0 01%	1%	---	---	---
Sapodilla Family (Sapotaceae)						
Gum elastic (*Sideroxylon lanuginosum*)	0 034	0 03%	2%	---	---	---
Invertebrates						
Mollusca						
Gastropoda	0 011	0 01%	1%	0 018	0.05%	1%
Arthropoda						
Arachnida						

Appendix(con't)—Foods eaten by Northern Bobwhites at the Chaparral Wildlife Management Area, Texas

Food Item	Fall Dry Wt (g)	Fall % Dry Wt	Fall Freq	Winter Dry Wt (g)	Winter % Dry Wt	Winter Freq
Invertebrates (con't)						
Araneae						
Lycosidae	0 006	0 01%	2%	0 095	0.29%	8%
Oxyopidae	---	---	---	0 000	Trace	1%
Tetragnathidae	0 002	Trace	1%	---	---	---
Thomisidae	---	---	---	0 005	0 02%	1%
Unknown	0 001	Trace	1%	---	---	---
Ixodida						
Ixodidae	---	---	---	0 022	0 07%	1%
Chilopoda	---	---	---	0 000	Trace	1%
Insecta						
Coleoptera						
Buprestidae	0 003	Trace	1%	---	---	---
Carabidae						
Scarites sp	0 022	0 02%	1%	---	---	---
Chrysomelidae						
Diabrotica undecimpunctata	0 008	0 01%	2%	---	---	---
Dysonichia sp.	0 020	0 02%	4%	0 005	0 02%	1%
Unknown	0 048	0 04%	1%	0 004	0 01%	1%
Curculionidae	0 293	0 23%	23%	0.297	0 90%	11%
Tenebrionidae	0 166	0 13%	2%	0 029	0.09%	4%
Zopheridae	0 494	0 38%	5%	0 186	0 56%	1%
Diptera						
Muscidae	---	---	---	0 004	0 01%	1%
Syrphidae	---	---	---	0 014	0 04%	1%
Unknown	0 002	Trace	1%	---	---	---
Hemiptera						
Alydidae	0 033	0 03%	3%	---	---	---
Cicadellidae	0 162	0.13%	18%	0 250	0 76%	11%
Coreidae	0 014	0 01%	3%	---	---	---
Cydnidae	0 014	0 01%	2%	0 003	0 01%	1%
Geocoridae	---	---	---	0.002	0 01%	1%
Largidae	0.113	0 09%	14%	0 005	0 01%	1%
Membracidae	0 038	0.03%	11%	---	---	---
Pentatomidae	1 080	0 84%	49%	0 015	0 05%	1%
Rhyparochromidae	0 007	0 01%	2%	0 010	0 03%	1%
Scutelleridae	0 031	0 02%	5%	0 003	0 01%	1%
Unknown	0 009	0 01%	2%	---	---	---
Heteroptera						
Reduviidae	0 014	0 01%	4%	---	---	---
Unknown	0.008	0 01%	4%	---	---	---
Hymenoptera						
Formicidae						
Crematogaster sp.	0.014	0.01%	3%	0 012	0.04%	8%
Odontomachus clarus	---	---	---	0 002	0.01%	1%
Unknown	0 007	0.01%	5%	0 009	0 03%	3%
Unknown	0 001	Trace	1%	---	---	---
Isoptera						

Appendix(con't)—Foods eaten by Northern Bobwhites at the Chaparral Wildlife Management Area, Texas

Food Item	Fall Dry Wt (g)	Fall % Dry Wt	Fall Freq	Winter Dry Wt (g)	Winter % Dry Wt	Winter Freq
Invertebrates (con't)						
Rhinotermitidae						
Reticulitermes flavipes	0 010	0 01%	2%	0 087	0 26%	6%
Lepidoptera						
Geometridae	0 428	0 33%	31%	0 035	0 11%	2%
Noctuidae	0 035	0.03%	1%	0 152	0 46%	5%
Nymphalidae	---	---	---	0 019	0.06%	1%
Unknown	0 004	Trace	1%	0.010	0.03%	1%
Unknown larvae	---	---	---	0 005	0 02%	1%
Orthoptera						
Acrididae	3 656	2.83%	36%	0 039	0 12%	2%
Gryllidae	---	---	---	0 088	0.27%	2%
Unknown larvae	0 046	0 04%	7%	0 027	0 08%	6%
Unknown (~10 species)	0.143	0 11%		0 268	0 81%	
Green Vegetation						
Carrot Family (Apiaceae)						
Wild Carrot (*Daucus* sp)	---	---	---	0 372	1 13%	42%
Lily Family (Liliaceae)						
Meadow garlic (*Allium canadense*)	0 053	0 04%	15%	2 785	8 43%	86%
Nettle Family (Urticaceae)						
Pellitory (*Parietaria* sp)	---	---	---	6 600	19 98%	86%
Pea Family (Fabaceae)						
Vetch (*Vicia* sp)	---	---	---	0 751	2 27%	14%
Wood-Sorrel Family (Oxalidaceae)						
Common yellow oxalis (*Oxalis stricta*)	0 018	0 01%	9%	4 857	14 70%	95%
Unknown (~15 species)	0 053	0 04%		5 411	16 38%	

LITERATURE CITED

BALDWIN, W. P. AND C. O. HANDLEY. 1946. Winter food of bobwhite quail in Virginia. Journal of Wildlife Management 10:142-149.

BRENNAN, L., S. DEMASO, F. GUTHERY, J. HARDIN, C. KOWALESKI, S. LERICH, R. PEREZ, M. PORTER, D. ROLLINS, M. SAMS, T. TRAIL, AND D. WILHELM. 2005. Where Have All the Quail Gone? PWD RP W7000-1025. Texas Parks and Wildlife Department, Austin, Texas.

BURGER, L. W., D. A. MILLER, AND R. I. SOUTHWICK. 1999. Economic impact of northern bobwhite hunting in the southeastern United States. Wildlife Society Bulletin 27:1010-1018.

CAIN, J. R., S. L. BEASON, L. O. ROWLAND, AND L. D. ROWE. 1982. The effects of varying dietary phosphorus on breeding bobwhites. Journal of Wildlife Management 46:1061-1065.

CAMPBELL-KISSOCK, L. AND L. H. BLANKENSHIP. 1985. Plant and animal foods of bobwhite and scaled quail in southwest Texas. Southwestern Naturalist 30:543-553.

ELLIS, J. A. 1961. Consumption of some food items by pen-reared bobwhites. Journal of Wildlife Management 25:258-264.

GIULIANO, W. M., R. S. LUTZ, AND R. PATINO. 1996. Reproductive responses of adult female northern bobwhite and scaled quail to nutritional stress Journal of Wildlife Management 60:302-309.

GUTHERY, F. S. 2000. On Bobwhites. First edition. Texas A&M University Press, College Station, Texas.

GUTHERY, F. S., N. E. KOERTH, AND D. S. SMITH. 1988. Reproduction of northern bobwhites in semiarid environments. Journal of Wildlife Management 52:144-149.

HARVESON, L. A., F. S. GUTHERY, AND E. C. HELLGREN. 2004. Invertebrate consumption by breeding northern bobwhites and its relation to production. Southwestern Naturalist 49:472-477.

JACKSON, A. S. 1969. Handbook for bobwhite quail management in the west Texas rolling plains. Bulletin no. 48. Texas Parks and Wildlife Department, Austin, Texas.

JENSEN, G. H. AND L. J. KORSCHGEN. 1947. Contents of crops, gizzards, and droppings of bobwhite quail force-fed known kinds and quantities of seeds. Journal of Wildlife Management 11:37-43.

KIEL, W. H. 1976. Bobwhite quail population characteristics and management implications in south Texas. Transcontinental North American Wildlife and Natural Resources Conference 41:407-420.

Korschgen, L. J. 1962. Food habits of greater prairie chickens in Missouri. American Midland Naturalist 68:307-318.

LANDERS, J. L. AND A. S. JOHNSON. 1976. Bobwhite quail food habits in the southeastern United States with a seed key to important foods in Miscellaneous Publication No. 4. Tall Timbers Research Station, Tallahassee, Florida.

LEHMANN, V. W. 1953. Bobwhite population fluctuations and vitamin A. Transcontinental North American Wildlife Conference 18:199-246.

LEHMANN, V. W. 1984. Bobwhites in the Rio Grande plains of Texas. First edition. Texas A&M University Press, College Station, Texas.

LEHMANN, V. W. AND H. WARD. 1941. Some plants valuable to quail in southwestern Texas. Journal of Wildlife Management 5:131-135.

LEIF, A. P. AND L. M. SMITH. 1993. Winter diet quality, but morphology and condition of northern bobwhite and scaled quail in west Texas. Journal of Field Ornithology 64:527-538.

MADISON, L. A. AND R. J. ROBEL. 2001. Energy characteristics and consumption of several seeds recommended for northern bobwhite food plantings. Wildlife Society Bulletin 29:1219-1227.

MCRAE, W. A., J. L. LANDERS, J. L. BUCKNER, AND R. C. SIMPSON. 1979. Importance of habitat diversity in bobwhite management. Proceedings from the Annual Conference of the Southeastern Association of Fish & Wildlife Agencies 33:127-135.

NATIONAL AUDUBON SOCIETY. 1995. Field guide to North American insects and spiders. Fourteenth edition. Chanticleer Press, Inc., New York, New York.

NATIONAL RESEARCH COUNCIL. 1977. Nutrient requirements of poultry. Seventh edition. National Academy of Science, Washington, D.C.

PEOPLES, A. D., R. L. LOCHMILLER, J. C. BOREN, D. M. LESLIE, JR., AND D. M. ENGLE. 1994. Limitations of amino acids in diets of northern bobwhites (*Colinus virginianus*). American Midland Naturalist 132:104-116.

PEREZ, R. M., J. F. GALLAGHER, AND M. C. FRISBIE. 2002. Fine scale influence of weather on northern bobwhite abundance, breeding success, and harvest in south Texas. Pages 106-110 *in* S. J. DeMaso, W. P. Kuvleksy, Jr., F Hernandez, and M. E. Berger, eds. Quail V: proceedings of the fifth national quail symposium. Texas Parks and Wildlife Department, Austin, Texas.

ROSENE, W. AND J. D. FREEMAN. 1988. A guide to and culture of flowering plants and their seed important to bobwhite quail. Morris Communications Corporation, Augusta, Georgia.

RUTHVEN, D. C. 2001. Herbaceous vegetation diversity and abundance beneath honey mesquite (*Prosopis glandulosa*) in the south Texas plains. Texas Journal of Science 53:171-186.

RUTHVEN, D C. AND D. R. SYNATZSKE. 2002. Response of herbaceous vegetation to summer fire in the western south Texas plains. Texas Journal of Science 54:195-210.

STERNBERG, G. AND J. W. WILSON. 2004. Native trees for north American landscapes: from the Atlantic to the Rockies. Portland: Timber Press.

TABACHNICK, B. G AND L. S. FIDELL. 1996. Using Mutivariate Statistics. Harper Collins College Publishers, New York, New York.

WISEMAN, D. S. 1977. Food habits and weights of bobwhite from northeastern Oklahoma tall grass prairie. Proceedings from the Oklahoma Academy of Science 57:110-115.

WOOD, K. N., F. S. GUTHERY, AND N. E. KOERTH. 1986. Spring-summer nutrition and condition of northern bobwhites in south Texas. Journal of Wildlife Management 50:84-88.

VITA

Rachel Barlow was born in Florence, Alabama, the daughter of Martha Ray Newberry and Joe Ray Barlow. After graduating from Iuka High School, Iuka, Mississippi, she entered the University of Southern Mississippi-Hattiesburg. She received her degree of Bachelor of Science from the University of Southern Mississippi in December 1996. In August, 2004, she entered the Graduate College of Texas State University-San Marcos. While in graduate school, she worked as an intern at the United States Fish and Wildlife Service Field Office, Austin, Texas and Travis County Transportation and Natural Resources, Austin, Texas.

Permanent Address: 1903 Cedar Ridge Dr., #B

Austin, Texas 78741

This thesis was typed by Rachel E. Barlow.