EFFECTS OF VEGETATION STRUCTURE AND ELEVATION ON LOWER KEYS MARSH RABBIT DENSITY

A Thesis

by

ANGELA JANE DEDRICKSON

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2011

Major Subject: Wildlife and Fisheries Sciences

Effects of Vegetation Structure and Elevation on Lower Keys Marsh Rabbit Density

EFFECTS OF VEGETATION STUCTURE AND ELEVATION ON

LOWER KEYS MARSH RABBIT DENSITY

A Thesis

by

ANGELA JANE DEDRICKSON

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Approved by:

Co-Chairs of Committee,	Nova J. Silvy
	Roel R. Lopez
Committee Member,	Donald S. Davis
Interim Head of Department,	John B. Carey

December 2011

Major Subject: Wildlife and Fisheries Sciences

ABSTRACT

Effects of Vegetation Structure and Elevation on Lower Keys

Marsh Rabbit Density. (December 2011)

Angela Jane Dedrickson, B.S., Texas A&M University

Co-Chairs of Advisory Committee: Dr. Nova J. Silvy
Dr. Roel R. Lopez

The Lower Keys marsh rabbit (*Sylvilagus palustris hefneri*, LKMR), 1 of 3 subspecies of *Sylvilagus palustris*, is endemic to the Lower Florida Keys. The LKMR is listed as an endangered species due to predation by feral and free roaming domestic cats (*Felis catus*) and raccoons (*Procyon lotor*), road mortality, effects of storm surges, sea level rise, the small declining metapopulation size, and possible habitat loss from hardwood encroachment. The purpose of this study was to determine the current LKMR density on lands managed by the United States Navy, Naval Air Station Key West and evaluate how vegetation structure and patch elevation effect LKMR population density. I conducted fecal pellet counts to determine LKMR density, collected vegetation data using percent composition of ground cover, Robel range pole, and point-centered quarter methods, and obtained data on patch area and elevation. I used simple linear regression to assess the relationship between LKMR density and 9 measured vegetation characteristics, patch area, and patch elevation to determine which variables have an influence on LKMR density and the relationship between them.

In my examination of the simple regression models, 6 out of the 11 variables appeared to influence LKMR population density. The average per patch percent composition of nonliving material and grasses, maximum height of vegetation at the range pole, distance to nearest woody vegetation, patch elevation, and visual obstruction readings (VOR) individually accounted for 26.4%, 30.4% , 18.1%, 8.5%, 6.8%, and 1.4% of the variability in LKMR density, respectively. According to the regression models, LKMR density increased in patches with greater amounts of grasses and with greater distance to woody vegetation. Habitat management is vital to the recovery of the LKMR and needs to focus on providing greater amounts of grasses and reducing the amount of woody vegetation encroachment to enhance LKMR population density.

DEDICATION

To my Mom and in memory of my Dad

ACKNOWLEDGEMENTS

I thank my committee co-chair, Dr. Nova J. Silvy, for going above and beyond in providing guidance, assistance, support, and encouragement both academically and personally; words cannot express my gratitude. I thank my committee co-chair, Dr. Roel R. Lopez, for his guidance, assistance with data, providing the opportunity to work on this project, and his recommendation to U.S. Fish and Wildlife Service for the Student Career Experience Program position. Thanks also goes to my committee member, Dr. Donald S. Davis, for his willingness to be a part of my committee, providing a different perspective, and his sense of humor. I would like to thank the faculty and staff of the Department of Wildlife and Fisheries Sciences for making my time at Texas A&M University a wonderful and memorable experience.

I want to extend my gratitude to the U.S. Navy for granting access to the LKMR patches, providing the funding for this research, and to Edward Barham and Carrie Backlund of Naval Air Station Key West for their support and assistance. Thank you to Anne Morkill at National Key Deer Refuge for proving housing while I was conducting my research. I would also like to thank the Institute of Renewable Natural Resources for providing technical support.

I thank my fellow graduate students for their friendship and support. Thanks to Jason and Paige Schmidt for the field experience as their technician and for providing assistance while I was conducting my own research. Also, thank you to my technicians, Logan Gallant and Beau Voelkel, for braving the vegetation and mosquito ditches of the Lower Keys.

I want to extend my appreciation to the staff at Merritt Island NWR for allowing me the time to complete my thesis, their interest in my project including proof reading, and for the continued encouragement. A very special thank you goes to my family and friends for their love, support, understanding, and encouragement throughout this journey.

TABLE OF CONTENTS

LIST OF FIGURES

Page

LIST OF TABLES

CHAPTER I

INTRODUCTION

BACKGROUND

The purpose of this chapter is to provide general background information on the Lower Keys marsh rabbit (*Sylvilagus palustris hefneri*, LKMR). This chapter begins with a description of the LKMR followed by a description of its habitat, distribution, conservation issues, and current status. It concludes with a summary of the research objectives for this thesis.

The Lower Keys marsh rabbit is 1 of 3 subspecies of *Sylvilagus palustris*. It morphologically differs from *S. p. palustris* and *S. p. paludicola* in having a shorter maliform tooth row, an elongate dentary symphysis, a higher and more convex frontonasal profile, and a broader cranium (Lazell 1984). The LKMR is distinguishable from other marsh rabbits by its dark fur and it is the smallest in size of the marsh rabbit subspecies (U.S. Fish and Wildlife Service [USFWS] 1999). The distribution of *S. p. palustris* is from southeastern Virginia to the Georgia-Florida border and *S. p. paludicola* ranges throughout the Florida mainland to the Upper Florida Keys. The LKMR is endemic to the Lower Florida Keys (Lazell 1984, Fig. 1).

The Lower Florida Keys are a string of limestone islands located between 24°41′N and 24°33′N latitude forming the end of the Florida Keys archipelago and have a mild, tropical-maritime climate due to their location in relation to the Gulf Stream

---

This thesis follows the style of The Journal of Wildlife Management.

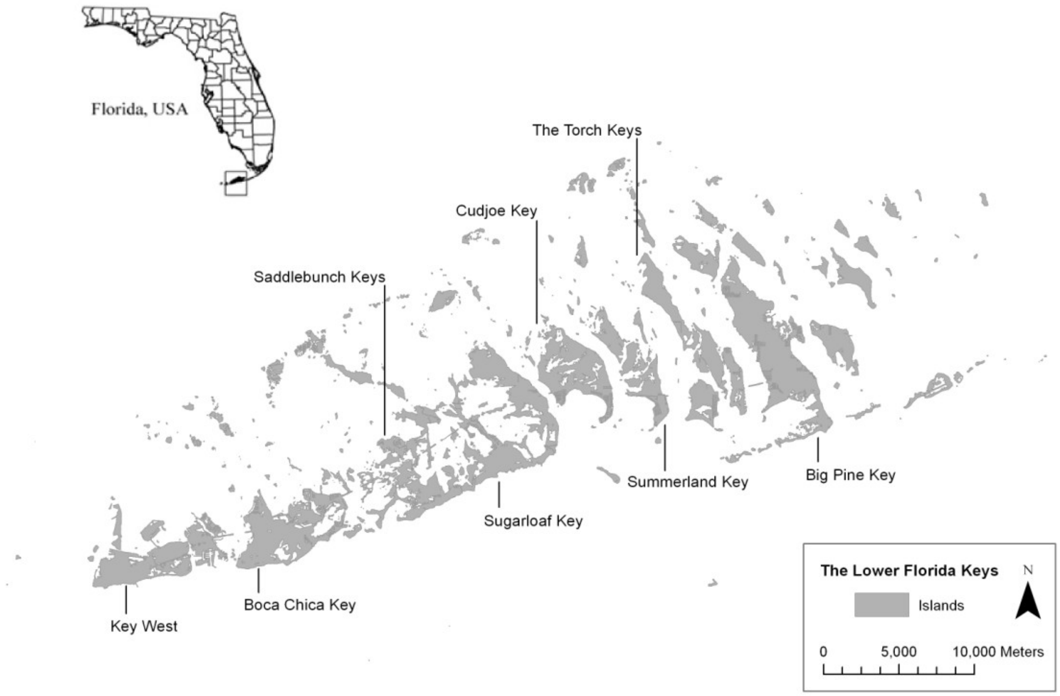

Figure 1. The Lower Florida Keys, USA.

and influence of the Gulf of Mexico (Ross et al. 1992, National Climatic Data Center 2010). This group of islands begins at Big Pine Key and terminates at Key West. The Middle and Lower Florida Keys are separated by the Moser Channel which is approximately 11 km wide. The LKMR does not occur east of the Moser Channel (USFWS 1990). The LKMR was most likely isolated from the Florida mainland approximately 10,000 years ago when sea levels rose and separated the Keys. This geographic isolation probably led to speciation of the LKMR (Lazell 1984).

The LKMR utilizes various habitats including saltmarsh–buttonwood (*Conocarpus erectus*) transition zones, brackish and freshwater wetlands, and coastal beach berms (Forys and Humphrey 1996; USFWS 1999; Faulhaber et al. 2006, 2007). The habitat is highly fragmented patches ranging in size from 0.1 ha to 51.2 ha with few connected areas >5 ha (Forys et al. 1996, Faulhaber et al. 2008). The LKMR exist as a metapopulation with each local population spending their lives in 1 patch socially isolated from other populations with subadults dispersing at sexual maturity to other patches (Forys and Humphrey 1996, USFWS 1999).

Historically, the LKMR range extended from the islands of Big Pine Key to Key West (dePourtales 1877, Layne 1974). Most likely the LKMR was present on all of the islands throughout the Lower Keys that provided suitable habitat (USFWS 1999). Currently, the LKMR is found on 4 islands connected to U.S. Highway 1 ranging from Big Pine Key to Boca Chica Key and on 2 backcountry islands (USFWS 2007). The distribution surveys conducted 1991–1993, 1995 found 125 occupied and potential LKMR habitat patches totaling 317 ha (Forys et al. 1996). Updated distribution surveys conducted 2001–2005 delineated 228 habitat patches totaling >800 ha (Faulhaber et al. 2007, 2008). A recent population survey conducted by Schmidt (2009) found almost 67% of the entire LKMR metapopulation inhabited Boca Chica Key.

Habitat loss, destruction, and fragmentation caused by human development, predation by feral domestic cats (*Felis catus*), and road mortality by vehicles led to the LKMR being listed as a federally endangered species in 1990 (USFWS 1990, 1999). The number of occupied patches continues to decline and the LKMR metapopulation is likely declining in proportion to the patch extinction rate (USFWS 2007). Schmidt et al. (2011) estimated the total LKMR metapopulation was 317 individuals. Current threats to the LKMR survival include predation by feral and free roaming domestic cats and raccoons (*Procyon lotor*), road mortality, effects of storm surges, sea level rise, the small declining metapopulation size, and possible habitat loss from hardwood encroachment (USFWS 2007). Recent research suggests habitat succession of hardwood encroachment which results in a decrease of grasses and forbs is detrimental to the LKMR survival (Perry 2006, Schmidt et al. 2010). A population viability analysis predicted the entire metapopulation of the LKMR could become extinct in as few as 50 years (Forys and Humphrey 1999*a*).

RESEARCH OBJECTIVES

The purpose of my study was to determine how vegetation structure and elevation influence LKMR populations in order to enhance understanding of LKMR ecology and habitat management strategies.

My objectives were:

1. Determine the current LKMR density on lands managed by the United States Navy, Naval Air Station Key West facility.
2. Evaluate how vegetation structure and patch elevation effect LKMR density.

CHAPTER II

EFFECTS OF VEGETATION STRUCTURE AND ELEVATION ON LOWER KEYS MARSH RABBIT DENSITY

INTRODUCTION

The Lower Keys marsh rabbit (*Sylvilagus palustris hefneri*, LKMR) is 1 of 3 subspecies of *Sylvilagus palustris* and is endemic to the Lower Florida Keys (Lazell 1984). The LKMR utilizes various habitats including saltmarsh–buttonwood (*Conocarpus erectus*) transition zones, brackish and freshwater wetlands, and coastal beach berms (Forys and Humphrey 1996; U.S. Fish and Wildlife Service [USFWS] 1999; Faulhaber et al. 2006, 2007). The habitat is highly fragmented patches ranging in size from 0.1 ha to 51.2 ha with few connected areas >5 ha (Forys et al. 1996, Faulhaber et al. 2008). Currently, the LKMR is found on 4 islands connected to U.S. Highway 1 ranging from Big Pine Key to Boca Chica Key and on 2 backcountry islands (USFWS 2007). A recent population survey conducted by Schmidt (2009) found almost 67% of the entire LKMR metapopulation inhabited Boca Chica Key.

Habitat loss, destruction, and fragmentation caused by human development, predation by feral domestic cats (*Felis catus*), and road mortality by vehicles led to the LKMR being listed as a federally endangered species in 1990 (USFWS 1990, 1999). The number of occupied patches continues to decline and the LKMR metapopulation is likely declining in proportion to the patch extinction rate (USFWS 2007). Schmidt et al. (2011) estimated the total LKMR metapopulation was 317 individuals. Current threats to the LKMR survival include predation by feral and free roaming domestic cats and raccoons (*Procyon lotor*), road mortality, effects of storm surges, sea level rise, the small declining metapopulation size, and possible habitat loss from hardwood encroachment (USFWS 2007). Recent research suggested habitat succession of hardwood encroachment which results in a decrease of grasses and forbs was detrimental to the LKMR survival (Perry 2006, Schmidt et al. 2010).

Vegetation structure has been shown to be an important factor in LKMR habitat use and suitability. Characteristics such as biomass, height, and density of ground cover vegetation as well as canopy cover are influencing factors in the LKMR habitat (Forys and Humphrey 1996, Perry 2006, Faulhaber et al. 2008, Schmidt et al. 2010). Woody vegetation encroachment has been identified as a threat to the LKMR habitat and little habitat related research has been conducted to assess this threat (USFWS 2007).

Previous research has investigated vegetation structure within the LKMR habitat to include percentage of ground cover, height of ground cover, and height of overstory vegetation. Forys and Humphrey (1999*b*) measured vegetation characteristics <1.5 m and >1.5 m in 59 sites using line intercept of ten 5–m long transects. Perry (2006) and Faulhaber et al. (2008) measured vegetation characteristics in 4 and 8 patches within a 4–m and 1–m radius, respectively. Schmidt et al. (2010) measured percent cover of herbaceous and woody vegetation <0.5 m in height within a 1–m radius throughout 150 LKMR habitat patches. Extensive measurement of vegetation structure within the LKMR habitat patches was needed to evaluate the effects on LKMR density. My goal for this study was to determine how vegetation structure and patch elevation influence

LKMR population density in order to enhance understanding of LKMR ecology and habitat management strategies. My objectives were to (1) conduct fecal pellet counts to determine LKMR density, (2) collect data on vegetation structure and elevation within the LKMR habitat patches, and (3) determine what variables and how these variables influence LKMR density.

STUDY AREA

This study was conducted on Naval Air Station Key West property on Boca Chica, Geiger, and East Rockland keys located in the Lower Florida Keys (Fig. 2). The Lower Florida Keys are a string of limestone islands located between 24°41′N and 24°33′N latitude forming the end of the Florida Keys archipelago and have a mild, tropical-maritime climate due to their location in relation to the Gulf Stream and influences of the Gulf of Mexico (Ross et al. 1992, National Climatic Data Center 2010). Distinct wet and dry seasons are evident. The dry season occurs November through April in which 33% of the annual precipitation is received (Forys and Humphrey 1996). The average monthly temperature was 18° C and the average monthly precipitation was 0.7 cm during this study (National Climatic Data Center 2010). Elevation seldom exceeds 2 m and minor changes in elevation result in distinct vegetation types. As elevation increases, vegetation types transition from red (*Rhizophora mangle*), black (*Avicennia gerimans*), and white (*Laguncularia racemosa*) mangroves to saltmarsh–buttonwood transition zones to upland slash pine (*Pinus elliotii*) rocklands or hardwood

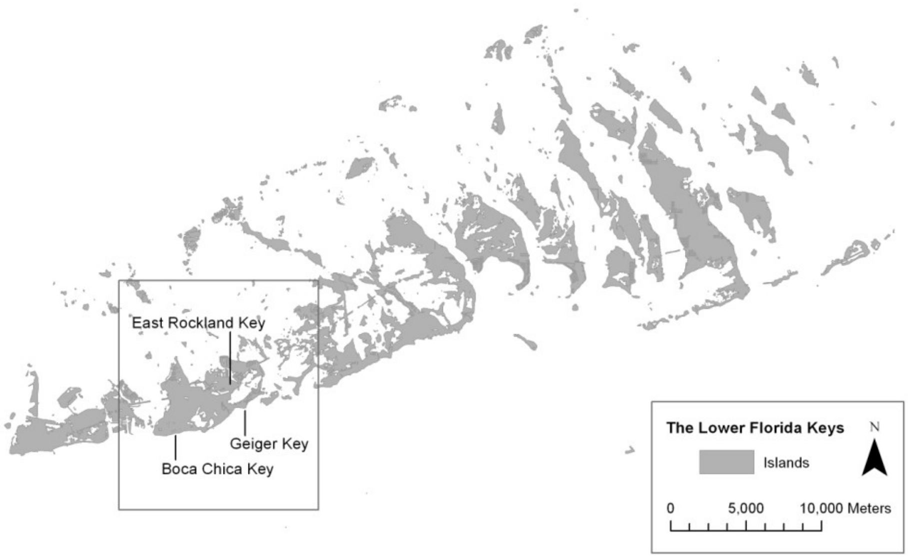

Figure 2. Location of Boca Chica, Geiger, and East Rockland keys in the Lower Florida Keys, USA.

hammocks dominated by gumbo limbo (*Bursera simaruba*), Jamaican dogwood (*Piscidia piscipula*), and poisonwood (*Metopium toxiferum*; Ross et al. 1992; McGarry MacAulay et al. 1994; Faulhaber et al. 2007, 2008).

The LKMR predominantly occupy patches in the saltmarsh–buttonwood transition zones although they also inhabit freshwater wetlands and coastal beach berms (Forys and Humphrey 1996, 1999*b*; USFWS 1999; Faulhaber et al. 2006, 2007, 2008). The saltmarsh–buttonwood transition zones are generally dominated by cordgrass

(*Spartina* spp.) and buttonwood. Herbaceous halophytic plant species within the transition zone also change as elevation increases and transition from glasswort (*Salicornia spp.*), key grass (*Monanthochloe littoralis*), and saltwort (*Batis maritima*) to sea daisy (*Borrichia frutescens*), seashore dropseed (*Sporobolus virginicus*), saltmarsh fringe-rush (*Fimbristylis castanea*), saltgrass (*Distichilis spicata*), gulf cord grass (*Spartina spartinae*), and saltmeadow cordgrass (*Spartina patens*), to seashore dropseed, sea daisy, sea oxeye (*Borrichia arborescens*), and saltgrass (Faulhaber 2003, Faulhaber et al. 2007). Freshwater wetland vegetation is dominated by sedges such as sawgrass (*Cladium jamaicense*) and gulf coast spikerush (*Eleocharis cellulosa*), grasses such as seashore dropseed and cordgrass, and woody vegetation includes saw palmetto (*Serenoa repens*) with buttonwood interspersed. Coastal beach berm vegetation includes sparse grasses and sedges, shrubs, and tropical hardwoods such as blolly (*Guapira discolor*), Spanish stopper (*Eugenia foetida*), blackbead (*Pithecellobium guadalupense*), sea grape (*Coccoloba uvifera*), and Jamaican dogwood (Ross et al. 1992, USFWS 1999, Faulhaber et al. 2007, Schmidt et al. 2010, Schmidt et al. 2011).

Vegetation not previously described for the LKMR was found in some patches on Boca Chica Key. Areas were dominated by wire bluestem (*Schizachyrium gracile*) and lead tree (*Leuaena leuocephala*) and others by gulf coast spikerush (Faulhaber et al. 2007).

METHODS

Pellet Density Estimation

I used Faulhaber's (2003) updated LKMR habitat patch delineations for Boca Chica, Geiger, and East Rockland keys (Fig. 3). Also, I used protocols establish by Schmidt et al. (2011) that place a digital grid with nodes (points) placed 30 x 30 m apart over the updated LKMR habitat patches to obtain points to survey for rabbit fecal pellets. The points were uploaded from the Geographic Information System (GIS) to a global positioning system which I used to navigate to the points. During January–February 2010, I surveyed the 49 LKMR habitat patches located on Naval Air Station Key West property. Thirty-one of the 49 LKMR patches had less than 25 points and each point was surveyed in those patches. Eighteen LKMR habitat patches had greater than 25 survey points and because Schmidt (2009) determined that 25 points were more than sufficient to predict marsh rabbit density, only 25 points (randomly selected) were surveyed in these 18 habitat patches. I searched within a 1–m^2 radius circular plot of each point (sample unit) and counted all LKMR fecal pellets present with the plot (pellets/sample unit).

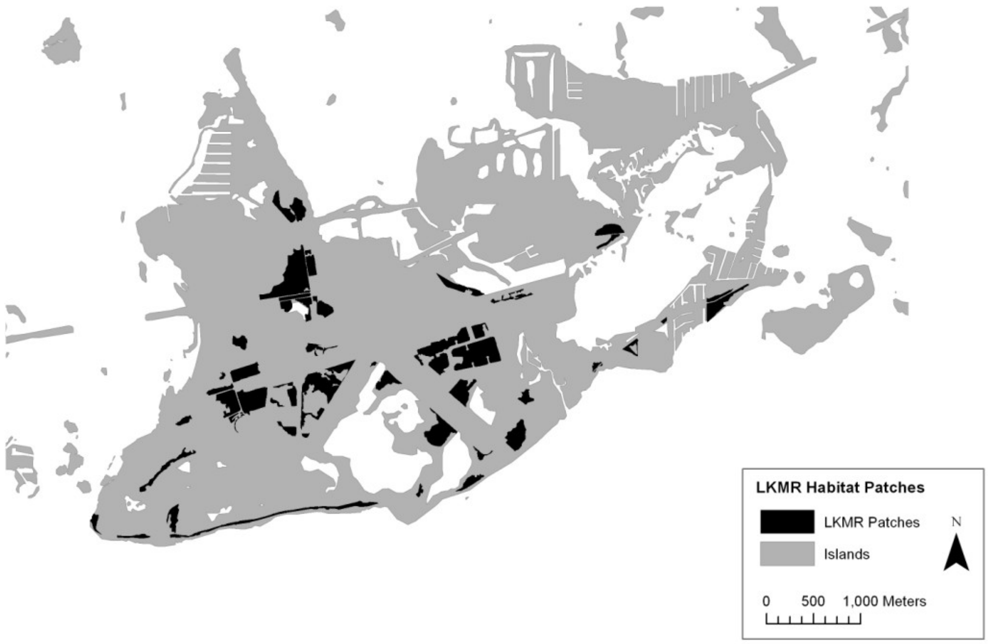

Figure 3. Lower Keys marsh rabbit patches on Boca Chica, Geiger, and East Rockland keys, Florida, USA.

Vegetation Sampling

I visually estimated and recorded the percent composition of nonliving material (soil, rock, litter), grasses, forbs, and woody vegetation within the 1–m^2 radius circular plot to the nearest 10% at each point (sample unit). In addition, I collected vegetation height and visual obstruction data at each sample unit using a Robel range pole method (Robel et al. 1970). Visual obstruction reading (VOR) in each cardinal direction and maximum height of the vegetation at the range pole was recorded. I also used a point-centered quarter method at each sample unit to estimate density, dominance, and frequency of woody vegetation with a height greater than 1.5 m (Cottam and Curtis 1956). Distance, height, and canopy cover were measured and recorded for woody vegetation with a height greater than 1.5 m that was nearest to the point within a maximum distance of 15 m in each quadrant of the sample unit. I measured the distance to the nearest woody vegetation using a range finder or measuring tape and height and canopy cover using a measuring tape or visual estimation.

Data Analysis

The LKMR fecal pellets per square meter are strongly correlated with marsh rabbit density estimates (Schmidt et al. 2011) and this relationship was used to determine the LKMR density within each of the 49 LKMR habitat patches. The LKMR density was derived from the total number of LKMR fecal pellets observed at the sample units in the patch divided by the total number of sample units in the patch.

I summed and averaged vegetation data for all sample units within a patch to obtain patch average totals for each of the 49 LKMR patches. I used the updated patch area from the LKMR habitat patch delineations completed 2001–2003 by Faulhaber (2003). Airborne Light Detection and Ranging (LIDAR) data were obtained from the International Hurricane Research Center at Florida International University (0.5 foot vertical accuracy). Texas A&M Institute of Renewable Natural Resources processed the data and provided average elevation for each of the 49 LKMR habitat patches.

I used simple linear regression (Minitab 14, State College, PA) to assess the relationship between LKMR density and 9 measured vegetation characteristics, patch area, and patch elevation to determine which variables have an influence on LKMR density and the relationship between them.

RESULTS

I conducted LKMR fecal pellet counts and collected vegetation structure data at 810 sample units across 133 ha in 49 patches of LKMR habitat from 5 January through 3 February 2010. Patch area ranged from 0.09 ha to 12.8 ha (Table 1). Average patch elevation ranged from -0.03 m to 3.77 m (Table 1).

Table 1. Lower Keys marsh rabbit fecal pellet survey results, patch area, and average patch elevation on Naval Air Station Key West property on Boca Chica, Geiger, and East Rockland keys, Florida, USA, January–February 2010.

Patch number	Total number of points surveyed	Total number of pellets at sample unit	Pellets per sample unit	Patch area (ha)	Average elevation (m)
1	25	1	0.04	2.58	0.37
2	9	0	0.00	0.92	0.30
3	20	25	1.25	1.70	0.86
4	23	32	1.39	1.73	0.90
5	11	37	3.36	1.08	0.83
6	6	0	0.00	0.51	-0.01
7	18	41	2.28	1.64	1.05
8	25	67	2.68	4.28	0.55
9	25	305	12.20	6.33	0.38
10	5	86	17.20	0.44	0.75
11	11	1	0.09	0.96	0.15
12	15	198	13.20	1.34	0.48
13	25	43	1.72	3.74	0.89
14	17	163	9.59	1.38	1.17

Table 1. Continued.

Patch number	Total number of points surveyed	Total number of pellets at sample unit	Pellets per sample unit	Patch area (ha)	Average elevation (m)
15	25	18	0.72	2.49	0.18
16	14	104	7.43	1.27	0.50
17	12	37	3.08	1.01	1.23
18	25	189	7.56	4.41	0.42
19	25	519	20.76	11.25	2.44
20	25	190	7.60	4.11	1.29
21	25	359	14.36	9.60	1.19
22	14	2	0.14	1.40	0.36
23	25	6	0.24	10.86	0.13
24	24	73	3.04	2.03	0.16
26	25	52	2.08	5.14	1.56
60	25	74	2.96	5.75	1.42
71	8	54	6.75	1.00	0.73
82	24	24	1.00	2.15	0.00
93	25	156	6.24	5.89	0.68
102	25	56	2.24	2.83	0.62
152	25	0	0.00	12.80	0.22
153	2	71	35.50	0.29	1.00
155	14	0	0.00	1.15	2.56
156	15	0	0.00	1.25	1.33
157	22	227	10.32	1.91	1.37
160	25	272	10.88	2.82	1.45
161	3	31	10.33	0.31	1.24
169	7	5	0.71	0.71	0.69
170	11	2	0.18	0.89	0.05
171	15	432	28.80	1.39	0.76
172	18	115	6.39	1.74	3.77
173	25	2	0.08	3.66	0.19
174	25	103	4.12	2.43	0.59
175	5	24	4.80	0.47	0.43
176	2	0	0.00	0.20	0.48
177	3	0	3.43	0.28	0.12
178	7	24	0.00	0.70	-0.03
210	4	0	0.00	0.23	0.98
211	1	0	0.00	0.09	1.10

I detected pellets in the sample unit in 40 of 49 LKMR patches surveyed. Total pellet counts per patch ranged from 0 to 519 and pellets per sample unit ranged from 0 to 35.5 (Table 1). In 9 patches, no pellets were observed so these patches were excluded from the data analysis. Average percent composition of nonliving material, grasses, forbs, and woody vegetation per patch ranged from 20% to 97%, 0 to 55%, 0 to 37%, and 2% to 32%, respectively (Table 2). Average VOR and maximum height of vegetation at the range pole per patch ranged from 0.5 dm to 9.5 dm and 0.9 dm to 15 dm, respectively (Table 3). Average distance, height, and canopy cover of nearest woody vegetation per patch ranged from 1.3 m to 8.0 m, 1.8 m to 4 m, and 1.2 m to 3.7 m, respectively (Table 3).

Table 2. Average percent composition of ground cover estimated within 10% for each Lower Keys marsh rabbit patch surveyed on Naval Air Station Key West property on Boca Chica, Geiger, and East Rockland keys, Florida, USA, January–February 2010.

Patch number	Nonliving material	Grasses	Forbs	Woody vegetation
1	40	37	4	19
2	43	32	1	23
3	49	29	0	22
4	61	9	17	13
5	53	17	5	25
6	37	13	37	13
7	70	19	0	11
8	46	28	15	10
9	68	22	4	6
10	32	50	0	18
11	54	3	21	23
12	47	22	9	22
13	60	19	4	18
14	41	2	34	24

Table 2. Continued.

Patch number	Nonliving material	Grasses	Forbs	Woody vegetation
15	50	24	11	16
16	71	14	1	14
17	65	3	9	23
18	55	27	11	6
19	48	28	12	12
20	59	16	2	23
21	52	32	4	12
22	71	24	2	3
23	60	17	3	20
24	66	16	1	17
26	65	24	2	10
60	80	0	13	8
71	81	0	9	10
82	75	0	0	25
93	62	23	2	13
102	44	31	11	14
152	74	14	4	8
153	20	55	0	25
155	47	45	5	3
156	84	7	0	9
157	45	39	5	10
160	33	36	15	16
161	33	47	3	17
169	51	24	13	11
170	55	12	1	32
171	41	35	5	19
172	73	8	1	18
173	97	0	1	2
174	79	15	0	6
175	58	26	4	12
176	55	30	0	15
177	77	10	0	13
178	57	14	7	21
210	60	13	3	25
211	90	0	0	10

Table 3. Average vegetation characteristics collected using Robel range pole and point-centered quarter methods for each Lower Keys marsh rabbit patch surveyed on Naval Air Station Key West property on Boca Chica, Geiger, and East Rockland keys, Florida, USA, January–February 2010.

Patch number	Robel range pole VOR (dm)	Robel range pole maximum height (dm)	Distance to nearest woody vegetation > 1.5m in height (m)	Height of nearest woody vegetation > 1.5m in height (m)	Canopy cover of nearest woody vegetation > 1.5m in height (m)
1	2.0	3.4	5.0	2.3	1.5
2	2.7	3.3	5.5	2.0	2.0
3	3.1	8.1	2.7	3.3	1.9
4	1.3	2.3	4.3	2.8	3.1
5	6.2	7.9	3.4	3.1	3.7
6	2.2	3.0	4.4	1.8	1.6
7	2.0	3.5	3.7	2.8	2.1
8	1.1	2.9	4.9	2.2	1.5
9	1.4	3.5	5.2	3.3	2.1
10	5.8	9.3	8.0	2.8	2.4
11	2.1	3.9	4.9	3.0	1.9
12	2.0	4.2	6.0	2.0	1.6
13	1.5	4.4	3.1	3.1	2.4
14	2.0	4.7	3.4	3.7	2.8
15	1.5	2.6	4.5	1.9	1.9
16	0.7	2.3	4.5	2.6	2.5
17	1.2	2.8	3.0	3.6	3.3
18	1.2	3.3	4.6	2.1	2.0
19	4.2	6.2	4.6	2.4	2.1
20	3.5	6.5	2.9	2.9	1.8
21	1.5	5.0	5.1	2.2	1.9
22	1.6	2.4	2.2	2.0	1.3
23	1.2	3.6	4.8	2.0	1.7
24	1.6	4.4	4.3	3.2	2.9
26	1.0	2.7	6.1	2.3	1.9
60	1.5	3.4	3.2	2.7	2.2
71	1.8	4.2	3.3	2.8	2.3
82	2.7	4.2	2.2	2.3	1.7
93	0.9	2.2	2.5	2.5	1.8
102	1.1	3.2	3.2	2.7	2.8
152	1.1	2.9	4.8	2.5	1.8
153	1.6	6.5	5.2	2.2	2.8

Table 3. Continued.

Patch number	Robel range pole VOR (dm)	Robel range pole maximum height (dm)	Distance to nearest woody vegetation > 1.5m in height (m)	Height of nearest woody vegetation > 1.5m in height (m)	Canopy cover of nearest woody vegetation > 1.5m in height (m)
155	2.2	6.3	5.4	2.8	2.0
156	0.9	2.8	2.5	2.7	1.8
157	1.5	4.6	7.7	2.6	2.8
160	3.2	6.1	4.8	3.3	2.5
161	3.4	8.0	4.8	2.5	1.7
169	1.4	2.5	4.4	2.7	2.1
170	0.9	4.1	2.5	2.9	2.1
171	1.3	4.7	4.1	2.2	1.8
172	4.7	2.4	2.2	2.6	1.5
173	0.5	0.9	6.7	2.8	2.1
174	1.5	2.9	2.8	2.8	2.5
175	1.7	3.2	3.6	2.6	1.3
176	1.6	3.8	4.4	1.8	1.2
177	0.9	4.2	3.1	3.3	2.1
178	1.5	4.6	3.2	2.6	1.4
210	2.1	6.1	4.5	4.0	2.1
211	9.5	15.0	1.3	2.8	2.7

In my examination of the simple regression models, 6 out of the 11 variables appeared to influence LKMR density (Table 4). The percentage of variability in LKMR

Table 4. Variables correlating Lower Keys marsh rabbit density to patch characteristics on Naval Air Station Key West property on Boca Chica, Geiger, and East Rockland keys, Florida, USA, January–February 2010.

Variable	*P*-value	R^2 (adj) %
Nonliving material (%)	≤ 0.001	26.4
Grasses (%)	≤ 0.001	30.4
Forbs (%)	0.771	0.0
Woody vegetation (%)	0.512	0.0
Visual obstruction readings	0.220	1.4
Maximum height at range pole	0.004	18.1
Distance to nearest woody vegetation	0.038	8.5
Nearest woody vegetation height	0.277	0.6
Nearest woody vegetation canopy cover	0.500	0.0
Patch area	0.710	0.0
Patch elevation	0.057	6.8

density was assessed using individual variables. According to the results of the regression models, the average percent composition of forbs and woody vegetation, nearest woody vegetation height, and nearest woody vegetation canopy cover as well as patch area did not influence LKMR density. I found a negative relationship between LKMR density and average percent composition of nonliving material (Fig. 4). I found a positive relationship between LKMR density and average percent composition of grasses (Fig. 5), VOR (Fig. 6), maximum height of vegetation at the range pole (Fig. 7), distance to nearest woody vegetation (Fig. 8), and elevation (Fig. 9).

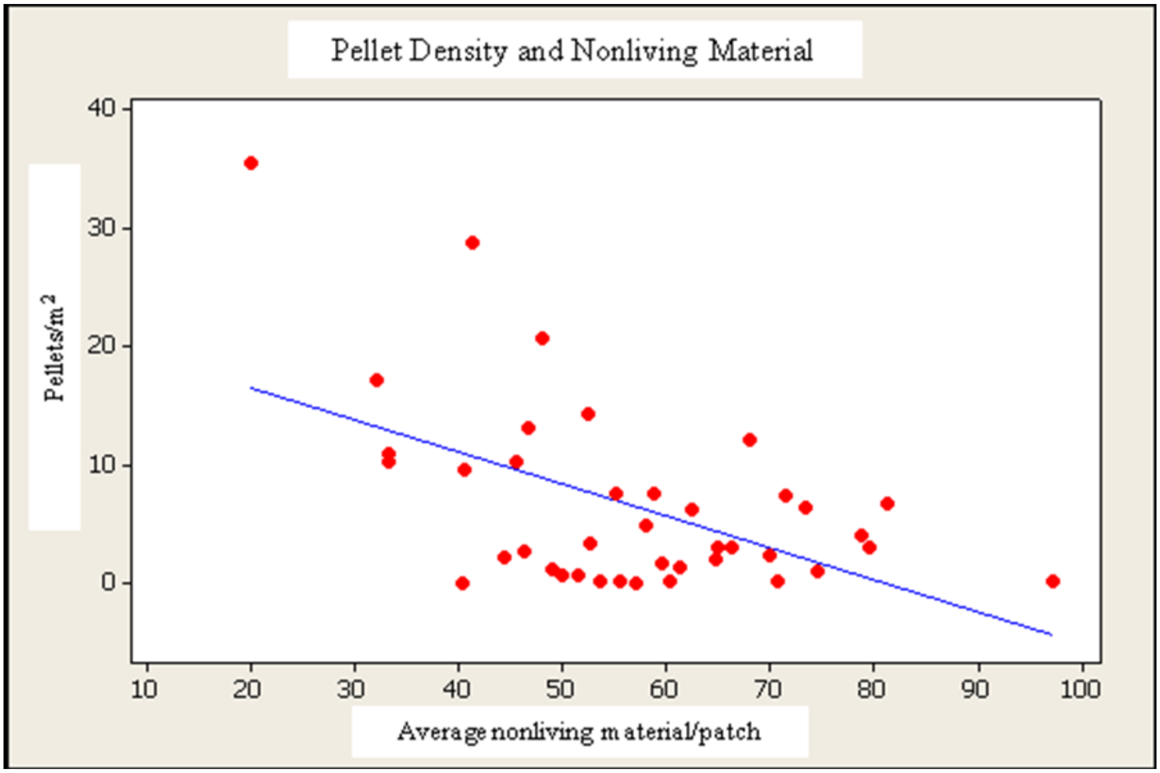

Figure 4. Linear relationship between Lower Keys marsh rabbit density (fecal pellets per square meter) and average percent composition of nonliving material (soil, rock, litter) found in the sample unit in each marsh rabbit patch surveyed on Boca Chica, Geiger, and East Rockland keys in the Lower Keys, Florida, USA, January–February 2010.

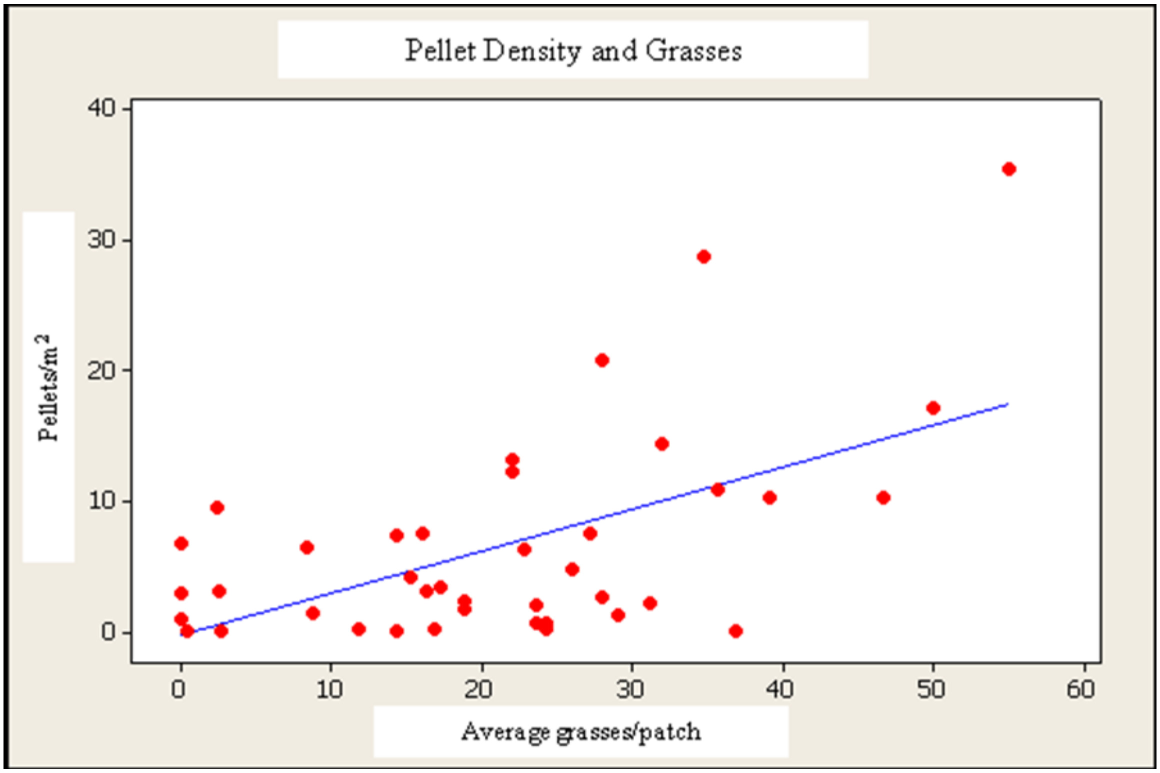

Figure 5. Linear relationship between Lower Keys marsh rabbit density (fecal pellets per square meter) and average percent composition of grasses found in the sample unit in each marsh rabbit patch surveyed on Boca Chica, Geiger, and East Rockland keys in the Lower Keys, Florida, USA, January–February 2010.

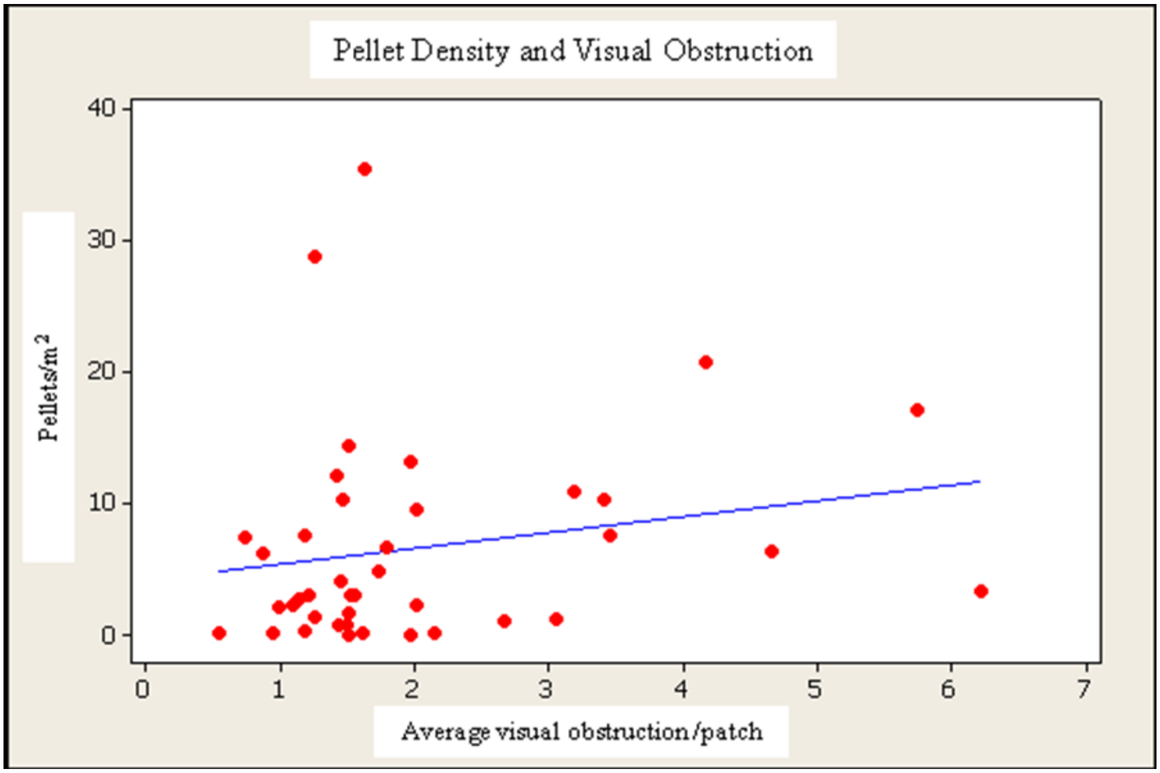

Figure 6. Linear relationship between Lower Keys marsh rabbit density (fecal pellets per square meter) and average visual obstruction readings of the range pole found in the sample unit in each marsh rabbit patch surveyed on Boca Chica, Geiger, and East Rockland keys in the Lower Keys, Florida, USA, January–February 2010.

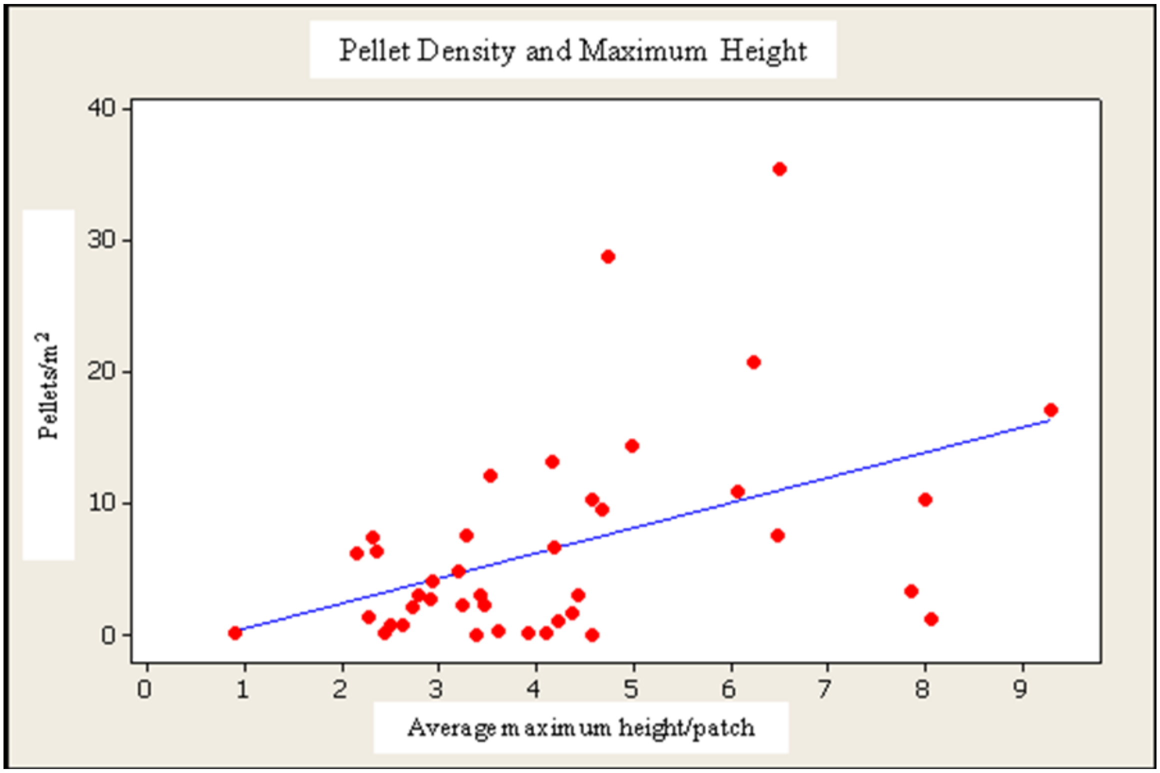

Figure 7. Linear relationship between Lower Keys marsh rabbit density (fecal pellets per square meter) and average maximum height of vegetation at the range pole found in the sample unit in each marsh rabbit patch surveyed on Boca Chica, Geiger, and East Rockland keys in the Lower Keys, Florida, USA, January–February 2010.

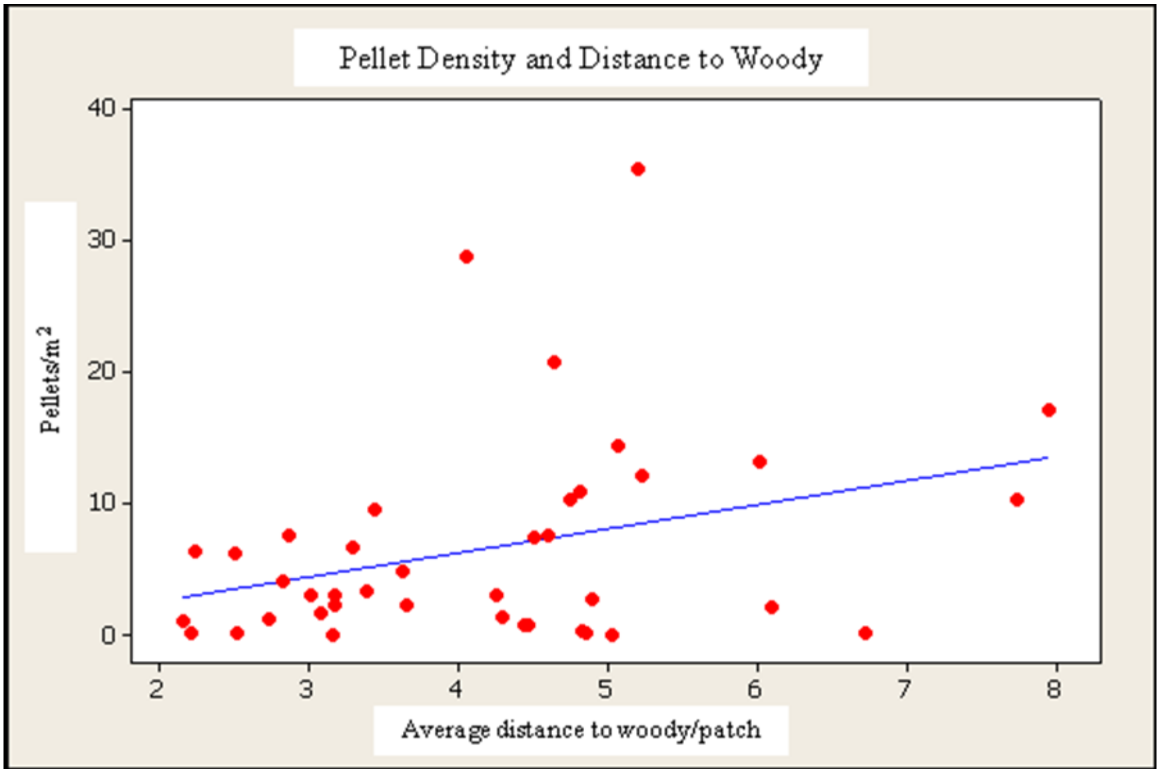

Figure 8. Linear relationship between Lower Keys marsh rabbit density (fecal pellets per square meter) and average distance to the nearest woody vegetation found in the sample unit in each marsh rabbit patch surveyed on Boca Chica, Geiger, and East Rockland keys in the Lower Keys, Florida, USA, January–February 2010.

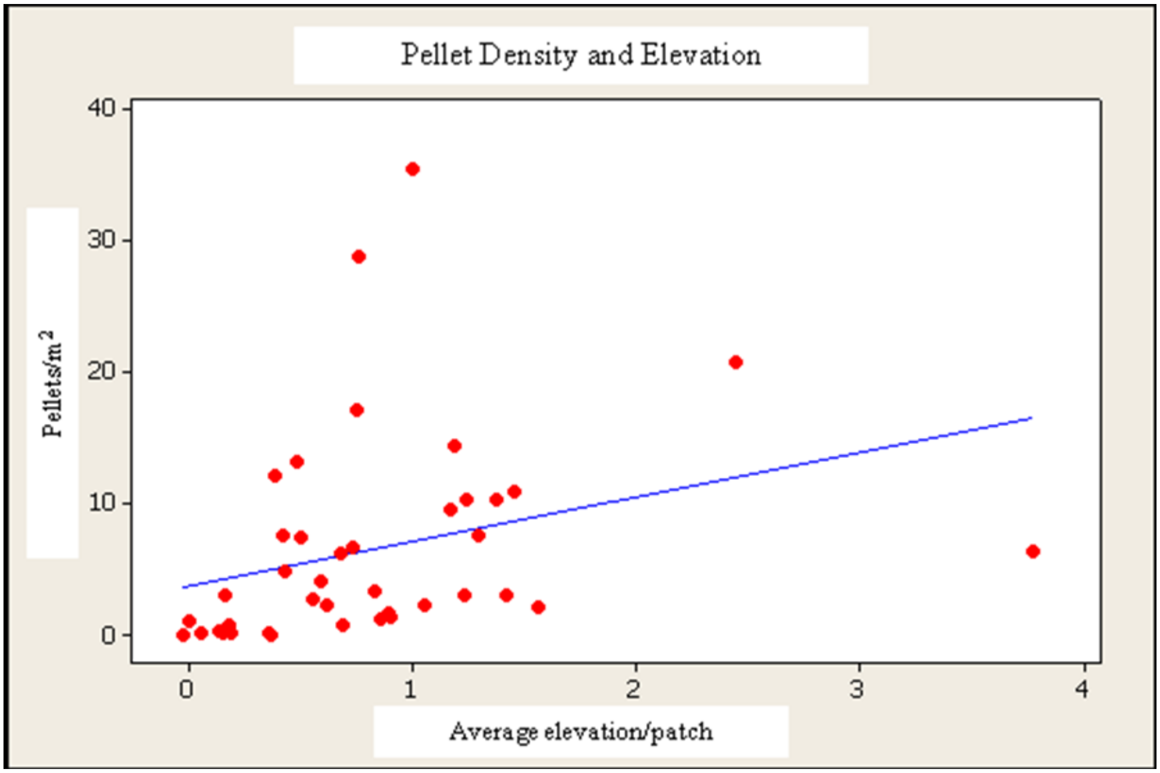

Figure 9. Linear relationship between Lower Keys marsh rabbit density (fecal pellets per square meter) and average elevation found in the sample unit in each marsh rabbit patch surveyed on Boca Chica, Geiger, and East Rockland keys in the Lower Keys, Florida, USA, January–February 2010.

DISCUSSION

According to the results of the regression models, the average percent composition of forbs and woody vegetation, nearest woody vegetation height, and nearest woody vegetation canopy cover as well as patch area did not influence LKMR density. Schmidt et al. (2010) combined percent composition of grass and forb data into 1 category for analysis and found a positive relationship between herbaceous plants and LKMR density. My study analyzed grass and forb data separately which may account for the difference in results. My results showed patch area did not influence LKMR density. Forys and Humphrey (1999*b*) also found patch area explained substantially less of the variance of occupied and vacant marsh rabbit habitat patches.

The 2 most important variables related to LKMR density were average percent composition of nonliving material and grasses. I found a negative relationship between the average percent composition of nonliving material accounting for 26.4% of the variability in LKMR density indicating increased amount of nonliving material leads to decreased LKMR density. Apparently, as the percent of nonliving material increases, the percent of living material decreases, thus providing less forage for the LKMR.

I found a positive relationship between average percent composition of grasses accounting for 30.4% of the variability suggesting as the amount of grasses present increased LKMR density increased. Thick ground cover was found to be related to LKMR occupancy and important for nesting, forage, diurnal use, and predator escape (Forys and Humphrey 1999*b*, Faulhaber et al. 2008, Schmidt et al. 2010). Forys and Humphrey (1999*b*) found the amount of thick grass was the most important variable in predicting LKMR patch occupancy which is consistent with my findings.

I found a positive relationship with both average maximum height of vegetation at the range pole and VOR and LKMR density. Average maximum height of vegetation accounted for 18.1% of the variability of LKMR density. Consistently occupied patches tended to have greater cover of bunchgrasses and other clump forming plant species (Forys and Humphrey 1996) and Faulhaber et al. (2008) found these vegetation types are most often utilized by the LKMR, diurnally. Cord grasses dominated the LKMR habitat of saltmarsh–buttonwood transition zones (Faulhaber 2003, Faulhaber et al. 2007) where

LKMR predominantly used gulf cord grass (Faulhaber et al. 2008) which reached 2 m at maturity (NRCS 2011). This appears to corroborate my findings of the relationship between average maximum height of vegetation to pellet density. It would be suspected given the importance of clump forming vegetation that average VOR would account for a greater amount of variance, however, only 1.4% of variation in LKMR density was explained by average VOR.

Average distance to nearest woody vegetation had a positive relationship with LKMR density and accounted for 8.5% of the variability. Distance appeared to be the influencing variable rather than height and canopy cover of the nearest woody vegetation which were not predictors of LKMR density. The regression model implied as the distance to woody vegetation increased so did LKMR density. It has been suggested that hardwood encroachment and succession may have negative impacts on the LKMR habitat (Perry 2006, Forys and Humphrey 1999*b*, USFWS 2007, Faulhaber et al. 2008, Schmidt et al. 2010). Perry (2006) found as hardwood encroachment and succession progressed in LKMR habitat, the density of herbaceous clump forming vegetation decreased and LKMR avoided areas with >30% canopy cover.

Average elevation showed a positive relationship with LKMR density. The saltmarsh–buttonwood transition zones, the predominant habitat of the LKMR, was located between the mangroves and upland vegetation types and was periodically inundated with seasonal rise in sea level and windblown tides (Ross et al. 1992, Faulhaber 2003). LaFever et al. (2007) found, through conducting simulation models, a general trend of decreasing LKMR habitat with increasing sea level rise. Faulhaber et al. (2008) suggested LKMR habitat might be destroyed due to sea level rise. My results suggest 6.8% of the variability in LKMR density is explained by patch elevation.

CHAPTER III

CONCLUSION

This study sought to determine how vegetation structure and patch elevation influence LKMR population density in order to enhance understanding of LKMR ecology and habitat management strategies. This study was an extensive analysis of vegetation structure and based on the results of this research the 2 most important variables related to LKMR population density were average percent composition of nonliving material and grasses followed by average maximum height of vegetation at the range pole and distance to nearest woody vegetation. According to the regression models, LKMR density increased in patches with greater amounts of grasses and with greater distance to woody vegetation.

LKMR habitat management needs to focus on providing greater amounts of grasses and reducing the amount of woody vegetation encroachment to enhance LKMR density. Mechanical removal of woody vegetation and prescribed burns would reduce the amount of woody vegetation and lead to growth of grasses. Habitat management is vital to the recovery of the LKMR and without it the LKMR population density is likely to further decline.

LITERATURE CITED

Cottam, G., and J. T. Curtis. 1956. The use of distance measures in phytosociological sampling. Ecology 37:451–460.

dePourtales, L. F. 1877. Hints of the origin of the flora and fauna of the Florida Keys. American Naturalist 11:137–144.

Faulhaber, C. A. 2003. Updated distribution and reintroduction of the Lower Keys marsh rabbit. Thesis, Texas A&M University, College Station, USA.

Faulhaber, C. A., N. D. Perry, N. J. Silvy, R. R. Lopez, P. A. Frank, and M. J. Peterson 2006. Reintroduction of Lower Keys marsh rabbits. Wildlife Society Bulletin 34:1198–1202.

Faulhaber, C. A., N. D. Perry, N. J. Silvy, R. R. Lopez, P. A. Frank, P. T. Hughes, and M. J. Peterson. 2007. Updated distribution of the Lower Keys marsh rabbit. Journal of Wildlife Management 71:208–212.

Faulhaber, C. A., N. J. Silvy, R. R. Lopez, D. H. LaFever, P. A. Frank, and M. J. Peterson. 2008. Diurnal habitat use by Lower Keys marsh rabbits. Journal of Wildlife Management 72:1161–1167.

Forys, E. A., P. A. Frank, and R. S. Kautz. 1996. Recovery actions for the Lower Keys marsh rabbit, silver rice rat, and Stock Island tree snail. Office of Environmental Services, Florida Game and Fresh Water Fish Commission, Tallahassee, Florida, USA.

Forys, E. A., and S. R. Humphrey. 1996. Home range and movement of the Lower Keys marsh rabbit in a highly fragmented environment. Journal of Mammalogy 77:1042–1048.

Forys, E. A., and S. R. Humphrey. 1999*a*. Use of population viability analysis to evaluate management options for the endangered Lower Keys marsh rabbit. Journal of Wildlife Management 63:251–260.

Forys, E. A., and S. R. Humphrey. 1999*b*. The importance of patch attributes and context to the management and recovery of an endangered lagomorph. Landscape Ecology 14:177–185.

LaFever, D. H., R. R. Lopez, R. A. Feagin, and N. J. Silvy. 2007. Predicting the impacts of future sea-level rise on an endangered lagomorphs. Environ Manage 40:430–437.

Layne, J. N. 1974. The land mammals of South Florida. Memoirs of the Miami Geological Society 2:386–413.

Lazell, J. D., Jr. 1984. A new marsh rabbit (*Sylvilagus palustris*) from Florida's Lower Keys. Journal of Mammalogy 65:424–432.

McGarry MacAulay, G., T. J. Leary, F. J. Sargent, M. M. Colby, E. J. Prouty, and C. A. Friel. 1994. Advanced identification of wetlands in the Florida Keys, final report. Florida Department of Environmental Protection, Division of Marine Resources, Florida Marine Research Institute, Marathon, Florida, USA.

National Climatic Data Center. 2010. NCDC / Climate-Radar Data Inventories / Locate Station / Search, Key West Boca Chica Airport. <http://www4.ncdc.noaa.gov/cgi-in/wwcgi.dll?wwDI~StnSrch~StnID~ 10013247>. Accessed 14 May 2010.

Natural Resources Conservation Service (NRCS). 2011. Plants database. Conservation plant characteristics. U.S. Department of Agriculture. <http://plants.usda.gov/java/charProfile?symbol=SPSP>. Accessed 3 Oct 2011.

Perry, N. D. 2006. The Lower Keys marsh rabbit and silver rice rat: steps toward recovery. Thesis, Texas A&M University, College Station, USA.

Robel, R. J., J. N. Briggs, A. D. Dayton, and L. C. Hulbert. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management 23:295–297.

Ross, M. S., J. J. O'Brien, and L. J. Flynn. 1992. Ecological site classification of the Florida Keys terrestrial habitats. Biotropica 24:488–502.

Schmidt, J. A. 2009. Population status and evaluation of landscape change for the Lower Keys marsh rabbit. Thesis, Texas A&M University, College Station, USA.

Schmidt, J. A., R. A. McCleery, P. M. Schmidt, N. J. Silvy, and R. R. Lopez. 2011. Population estimation and monitoring of an endangered lagomorph. Journal of Wildlife Management 75:151–158.

Schmidt, P. M., R. A. McCleery, R. R. Lopez, N. J. Lopez, and J. A. Schmidt. 2010. Habitat succession, hardwood encroachment, and raccoons as limiting factors for Lower Keys marsh rabbits. Biological Conservation 143:2703–2710.

U.S. Fish and Wildlife Service (USFWS). 1990. Endangered and threatened wildlife and plants; endangered status for the Lower Keys marsh rabbit and threatened status for the Squirrel Chimney cave shrimp. Federal Register 55:25588–25591.

U.S. Fish and Wildlife Service (USFWS). 1999. South Florida multi-species recovery plan. U.S. Fish and Wildlife Service. Atlanta, Georgia, USA.

U.S. Fish and Wildlife Service (USFWS). 2007. Lower Keys marsh rabbit (*Sylvilagus palustris hefneri*) 5-year review: summary and evaluations. U.S. Fish and Wildlife Service. Vero Beach, Florida, USA.

VITA

Name: Angela Jane Dedrickson

Address: Texas A&M University
Department of Wildlife and Fisheries Sciences
210 Nagle Hall
2258 TAMU
College Station, TX 77843-2258

Email Address: ajdedrickson@gmail.com

Education: B.S., Wildlife and Fisheries Sciences, Texas A&M University, 2009
M.S., Wildlife and Fisheries Sciences, Texas A&M University, 2011

Experience: Biologist, U.S. Fish and Wildlife Service, July 2010-present

Graduate Teaching Assistant, Texas A&M University, August 2009-December 2009, August 2010-May 2011

Graduate Research Assistant, Texas A&M University, December 2009-May 2010

Research Technician, Institute of Renewable Natural Resources, March 2009-July 2009

Volunteer, Texas Cooperative Wildlife Collection, November 2007-May 2009

Research Technician, Texas A&M University, May 2008-July 2008

Volunteer, Wildlife Rehab and Education, January 2007-June 2007

Volunteer, U.S. Fish and Wildlife Service, September 2005-November 2006