

**RANGES, MOVEMENTS, AND SPATIAL DISTRIBUTION OF RADIO-  
TAGGED RIO GRANDE WILD TURKEYS IN THE EDWARDS PLATEAU  
OF TEXAS**

A Thesis

by

JODY N. SCHAAP

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

May 2005

Major Subject: Wildlife and Fisheries Sciences

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May 2005

Major Subject: Wildlife and Fisheries Sciences

## ABSTRACT

Ranges, Movements, and Spatial Distribution of Radio-tagged Rio Grande Wild Turkeys  
in the Edwards Plateau of Texas.

(May 2005)

Jody N. Schaap, B.S., Texas A&M University

Co-chairs of Advisory Committee: Dr. Nova J. Silvy  
Dr. Markus J. Peterson

To determine possible causes of declining Rio Grande wild turkey (RGWT; *Meleagris gallopavo intermedia*) abundance in the southern Edwards Plateau, research was conducted on 4 sites, 2 with stable (S [SA and SB]; Kerr and Real counties) and 2 with declining (D [DA and DB]; Bandera County) RGWT populations. RGWTs were trapped, radio-tagged, and tracked. Ranges were constructed with 95% kernels. Data on brood survival and invertebrate and predator abundances were combined with range characteristics to assess habitat at a landscape scale.

Annual range sizes did not differ in year 1, but were larger in S than in D in year 2. Range sizes in S increased from year 1 to year 2 while there was no change in range sizes in D. Range overlap was higher in D than S in both years. Movement distances remained consistent in S for both years, but were larger in D during year 1.

During year 1 and year 2, RGWT females exhibited larger reproductive ranges and less range overlap in S. Invertebrate abundance for 4 insect orders was 2.5–15.9 times greater in S than in D while coyote abundance was 2–3 times greater in D than in S.

Results were similar in year 3, with the exception of SB, where reproductive ranges and spatial arrangement were smaller than all other sites.

My results refute the conventional assumption that larger ranges are indicative of poorer habitat quality. Range overlap suggests that useable space may have been limiting in D in the less productive year 2.

In D, multiple broods used the same reproductive range, presumably depleting resources faster than in S. Greater predator abundance in D increased the risk of brood predation. The smaller reproductive spatial arrangement of SB females in year 3 correlates there being >3 times the percentage of females missing in other sites. If SB females moved further in year 3 than the detection distance of the radio telemetry equipment, the results would fit the pattern of greater dispersion distance in SA. RGWT females may attempt to separate themselves from other breeding females, possibly to avoid nest or brood predation and/or potential competition for brood resources.

## ACKNOWLEDGEMENTS

I would like to express my sincere thanks and appreciation first and foremost to my committee co-chairs, Drs. Nova J. Silvy and Markus J. Peterson. Their patience, tenacity, work ethic, and sagacity have inspired me and carried me through some of the most mentally challenging experiences of my life. I also would like to thank Dr. Fred E. Smeins, committee member, for his boundless enthusiasm, sense of humor, and willingness to share the knowledge he has so successfully accumulated over the years. I think I'll never view Wild Mercury in quite the same light after this experience. Working with these 3 scholars and mentors has been one of the most rewarding experiences of my life, and I will always be indebted to them for lessons they've taught me about wildlife, ecology, and life.

My thanks cannot convey my gratitude to turkey project personnel who have made this project run. Dustin Jones, I don't think I could have done all you did to start this project up and get it running. You motivate me. C.J. Randel, I may not have always appreciated you, but I am grateful I got the chance to work with you. You're a sharp guy and I've learned a lot from you. Beau Willsey, thanks for helping me learn how to take things in stride. Your calm efficiency is a model. Shawn Locke, I can't thank you enough for all the little things that you've done that you didn't have to do. You sure don't waste words, but when you speak, it's always worth hearing. Humberto Perotto, you are by far my favorite Bolivian. I can't tell you how much I appreciate all your expertise, guidance, assistance, and your laughter. I also have to thank the technicians who have

endured many long hours of, more often than not, less than exciting work: Dean Marquardt, John Michael Hairston, Todd Phillips, and Curtis Hill. You've all been a pleasure to work with and get to know. I also have to thank the honorary turkey project members that have contributed more than they've been credited with. Fletcher Nelson, thank you for your dedication and effort, and for walking me through the process. You showed me much more patience than I deserved. Dale "The Russian" Kubenka, I can't begin to thank you for everything you've helped me with and done for me. I honestly don't know what I would have done without having you around to fix just about every gizmo I needed help with.

Personnel of the Kerr Wildlife Management Area and Texas Parks and Wildlife Department deserve my sincerest thanks. Donnie Frels, Jr., Bill Armstrong, Gene and Leroy Fuchs, Mark Edinburg, Chad Meadows, Jay Carroll, Pablo Gutierrez, and Ebie Gray, your help, patience, and cooperation have been overwhelming. I'm thankful that I've had the opportunity to work around you all and I've learned a great deal from each of you. Max Traweck, thank you for your help and your support. I also can't thank Ray Aguirre enough for all the work he's done to ensure the success of this project. From trapping to PR work to scouting new places, Ray has done it all and I am grateful that I've had the opportunity to work with him.

Shirley Konecny, Sherry Strickland, Diann Radke, Vicky Buckbee—you ladies are the best and I appreciate you all taking care of me. I know I've been more hassle than I've been worth, but there has never been lack of a smile available. Janice Crenshaw and Ann

Williams, you may be gone from Nagle, but you're not forgotten—you've both also helped me more than I deserved.

Marc Hess, thanks for putting up with me day in and day out. It really was a pleasure having you, Jennifer, and Freddie around. Study breaks with Freddie were always a pleasure. Ben Toole, thanks for not making me go out alone all those times. Ryan Jones, you almost make me wish I were Irish. "We need to get us a goat!"

Last, but certainly not least, I have to thank my parents and my family for their unflagging support. They may not always quite understand my profession (my time spent on the "turkey farm"), but they understand my passion and support my endeavors in every way. From gentle nudging to an emotional shove now and then, my parents have never ceased to fuel the belief that I really can achieve whatever goals I may set for myself. Though I sometimes doubt, they never have and that has made all the difference. Thank you.

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## CHAPTER I

### INTRODUCTION

Rio Grande wild turkey (RGWT; *Meleagris gallopavo intermedia*) abundance declined throughout the range of this subspecies by the early 1900s to the point where the RGWT was in jeopardy of losing its status as a game species in the United States (Blakey 1941, Walker 1951). In Texas, the Texas Game, Fish, and Oyster Commission (TGFOC) estimated there were only about 96,000 RGWTs in 1928 (TGFOC 1929:91), with only 28% of the subspecies' former range being occupied (Taylor 1949). Another estimate (TGFOC 1945:15–33) in 1945 placed that number at 100,000, with approximately 67% located in the Edwards Plateau (EP) ecoregion (Gould 1962) of Texas.

The EP established itself as the heart of RGWT range by maintaining the largest number of wild turkeys amid the declining populations (Kennamer and Kennamer 1995). When efforts were made to repopulate the historic range of the RGWT, and other suitable habitats, most of the birds used for restocking came directly or indirectly from the EP. In fact, M. J. Peterson (Department of Wildlife and Fisheries Sciences, Texas A&M University, unpublished data) noted the world-wide population of RGWTs essentially originated from the EP and South Texas. These restocking efforts were extremely successful and RGWTs now occupy and support huntable populations in 13 states (Kennamer and Kennamer 1995). Since the late 1970s, however, RGWT abundance has

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This thesis follows the style and format of the Journal of Wildlife Management.

declined significantly in the southern region of the EP, particularly in Bandera, Kerr, and Real counties (Fig. 1.1), while numbers remain stable in the other portions of the EP.

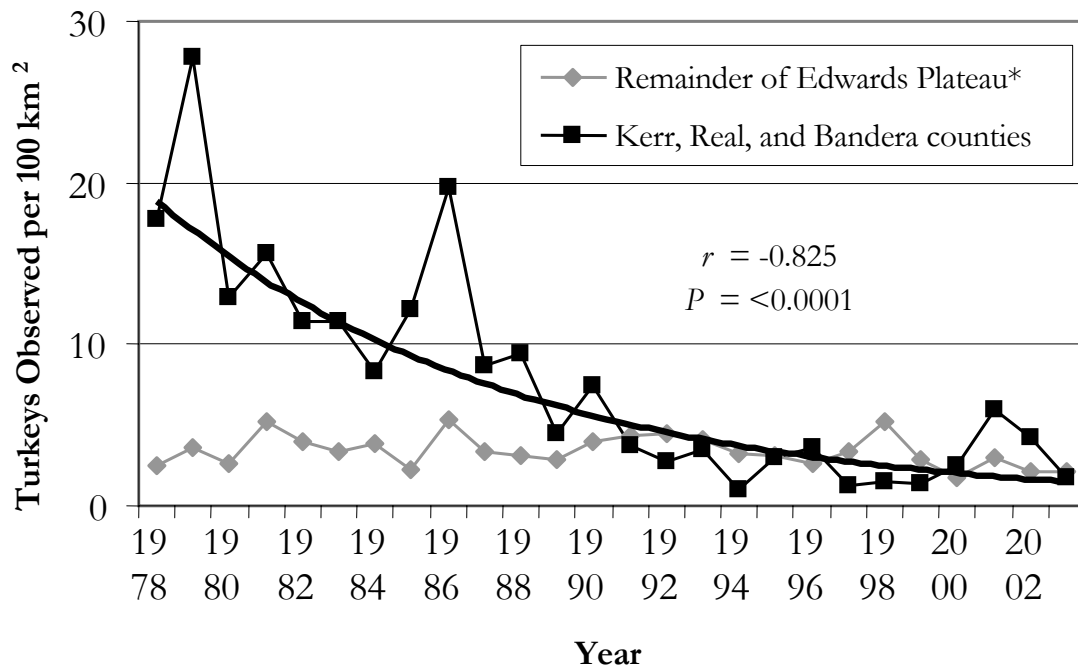


Fig. 1.1. Number of Rio Grande wild turkeys observed per 100 km<sup>2</sup> by Texas Parks and Wildlife Department biologists during summer production surveys for Bandera, Kerr, and Real counties, Texas, and the remainder of the Edwards Plateau (EP), 1975–1999.

\* Excludes counties in the EP with a mean value of less than 1 turkey observed per 100 km<sup>2</sup> including Taylor, Val Verde, Coke, Pecos, Kinney, Medina, Comal, Travis, Coleman, Burnet, Runnels, and Brewster counties.

Unfortunately, few sound management recommendations can be offered based on scientific literature. Peterson (1998) noted little evidence of RGWT research in the past decade, particularly in Texas and specifically in the EP. Because of this lack of research, little is known of the vegetation types used by RGWT and the effects habitat conditions have on the population dynamics of RGWTs.

## OBJECTIVES

The overall objective of my study was to determine the cause of declining RGWT abundance in the southern EP, and once determined, at what spatial scale Texas Parks and Wildlife Department managers, area landowners, and ranch managers should focus upon to mitigate the cause on the decline. Specifically, my thesis is divided into chapters with the following objectives:

1. Quantify the annual ranges, overlap areas, and percent overlap of ranges for RGWT in the EP and compare these measurements between regions of stable and declining RGWT abundance and between years of high and low productivity to determine if habitat quality can accurately predict range size (Chapter II).
2. Determine if invertebrate and predator abundance, incorporated into the spatial context of the actual range used by marked broods during the reproductive season differ between areas of stable and declining RGWT abundance (Chapter III).
3. Determine if a landscape-scale spatial distribution of females during the reproductive season can explain differences in long-range movements of females during the reproductive ranges in regions of stable and declining RGWT abundance (Chapter IV).

I conclude with a summary of key aspects from each chapter and the overall conclusions of the study. I also discuss management and research implications and recommendations (Chapter V).

## CHAPTER II

### CAN SIZE OF RIO GRANDE WILD TURKEY RANGES PREDICT HABITAT QUALITY?

#### INTRODUCTION

Guthery's (1997) analysis of habitat management for northern bobwhites (*Colinus virginianus*) pointed out that management practices designed to increase food abundance and habitat-type interspersed did not necessarily increase bobwhite densities. Instead, he found that providing time saturation of useable space rather than management directed toward some pretense of habitat quality was key to successfully increasing northern bobwhite numbers. For this reason, it seems reasonable that galliform management should shift from increasing habitat quality toward creating more useable space, or habitat quantity. Additionally, it seems the concept of resource-regulation (Emlen 1986) first introduced by Malthus (1798)—as populations increase, food becomes limiting—seems to influence the interpretation of population range fluctuations. For example, conventional wisdom holds that if individuals within a population exhibit large range sizes, it is because 1 or more of their life requisites are limiting, thus requiring them to cover a larger area. Conversely, if individuals have relatively small ranges, it is assumed the habitat is of high quality. Therefore, gallinaceous birds should require a larger range when resources are limited than when they are abundant. This notion results in the hypothesis that range size is a suitable indicator of habitat quality. Unfortunately, the association of range size with

habitat quality is at best ambivalent (Hall et al. 1997), possibly irrelevant (Guthery 1997), and at worst incorrect and misleading.

As with other galliforms, those studying wild turkeys (*Meleagris gallopavo*) generally assume that when resources are limiting, turkeys range over larger areas to satisfy their basic requirements (Taylor 1949, Porter 1977, Exum et al. 1987, Godwin et al. 1996, Thogmartin 2001). Keegan and Crawford (2001), working with Rio Grande wild turkeys (RGWT; *M. g. intermedia*) in Oregon, however, attributed large range sizes to the selective use of ample, albeit scattered, patches of high-quality habitats. Brown (1980) also noted that resource availability was the main factor differentiating wild turkey ranges. Thence it follows that because some life requisite(s) must limit reproduction in poor production years, individual range size should be larger than in more productive years. Similarly, individuals in a declining population should require larger ranges to obtain the life requisites that presumably limit population growth. This idea has not been rigorously tested for wild turkeys, but appears to have gained support primarily through repetition (Romesburg 1981).

Data collected by Texas Parks and Wildlife Department (TPWD) biologists in cooperation with landowners and managers in the Edwards Plateau (EP) ecoregion of Texas (Gould 1962) demonstrated that RGWT abundance has declined since the late 1970s in the southeastern region, particularly in Kerr, Real, and Bandera counties, while remaining stable throughout the remainder of the EP (Fig. 1.1). My objectives were to determine if (1) annual ranges, range overlap areas, and percent overlap of ranges for RGWT in the EP differed between regions of declining and stable wild turkey abundances,



(2) these variables differed between years of high and low productivity for regions of stable and declining abundance, and (3) range size could be used as a predictor of habitat quality based on stable versus declining populations as indicators of habitat suitability.

## **STUDY AREAS**

Study areas were located in the southeastern portion of the EP in Kerr, Real, and Bandera counties, and in the northernmost portion of Medina County, Texas (Fig. 2.1). This area is characterized by rocky limestone outcroppings, flat-to-rolling divides with rocky, but fertile soils, and an average annual precipitation of 38–89 cm (Oakes et al. 1960). The sites were in close proximity to each other, resulting in similar precipitation patterns, vegetation types, and topography. The stable and declining regions were delineated by Texas A&M University (TAMU) and TPWD personnel; sites were selected based on their function as winter roosting sites for populations of RGWTs and the willingness of the landowners and managers to participate.

I selected 2 study sites each from both the stable and declining regions (Fig. 2.1). Stable site A was a 4,880-ha site located in the stable region in northern Kerr County, approximately 20.9 km west of Hunt, Texas. Stable site B was an 845-ha site located in Real County, approximately 9.4 km north of Leakey, Texas. Declining site A was a 4,922-ha site in the declining region of Bandera County, approximately 18.8 km west of Medina, Texas. Declining site B was a 6,100-ha site located in northern Medina County, approximately 17.0 km southwest of Bandera, Texas.

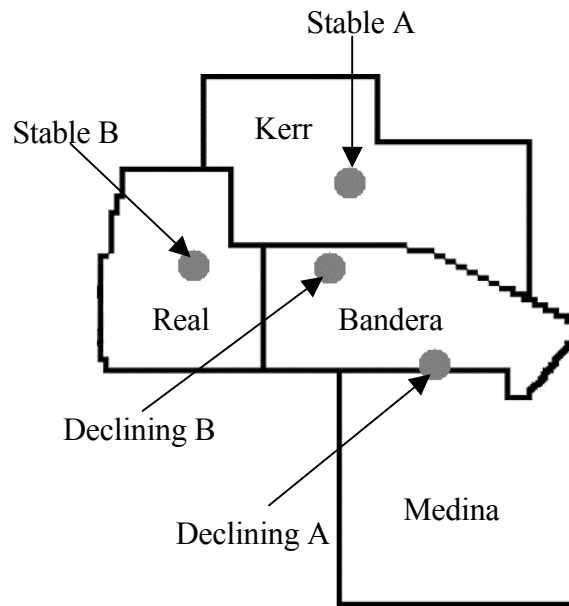


Fig. 2.1 Location of study sites for Rio Grande wild turkey project in the Edwards Plateau, Texas.

## METHODS

Texas A&M University and TPWD personnel trapped RGWTs using modified walk-in traps (Davis 1994, Peterson et al. 2003) during winter when turkeys were gathered in flocks. Birds were equipped with battery-powered mortality-sensitive radio transmitters (64.2–95.0 g; Advanced Telemetry Systems, Isanti, Minnesota) and colored plastic leg bands unique to each of the 4 study sites. Each bird was aged, sexed, weighed, and had blood taken via jugular puncture for related disease and genetic studies. Radioed turkeys were located by homing and triangulation from  $\geq 3$  telemetry stations (Silvy 1975, White and Garrott 1990) at random intervals and  $\geq 3$  times weekly (Swihart and Slade 1985). Locations and error polygons were estimated using LOAS software (Location of a Signal; Ecological Software Solutions, Sacramento, California). Telemetry error was controlled

by eliminating estimated locations with error ellipses greater than 5 ha (Miller 1993) or estimated locations greater than 4,827 m from the farthest telemetry station.

Ranges were calculated in hectares as 95% kernels (Worton 1989) using ArcView Spatial Analyst software, Animal Movement extension (Hooge and Eichenlaub 1997, Lopez 2001). Seasons were defined to coincide with behavioral periods as follows: breeding (16 March–15 August), regression (16 August–15 November), winter (16 November–15 March), and annual (breeding–winter). Sample size was the number of birds that had  $\geq 10$  locations per season for all seasons (Jenrich and Turner 1969, Hoffman 1991, Badyaev et al. 1996). Individual turkey ranges then were overlaid and all areas of an individual turkey range overlapped by ranges of other turkeys (calculated in ha) are hereafter referred to as overlap area (Fig. 2.2). This measure was used as an indicator of population densities. A mean overlap area was calculated by adding overlap areas for all individual turkeys and dividing by the number of turkeys. Percent overlap (Godwin et al. 2001) was calculated as the percentage of each individual turkey's annual range that was overlapped by other telemetered RGWT ranges. Annual ranges, overlap areas, and percent overlap were calculated for each year and for each region (stable and declining) and analyzed using *t*-tests to determine significant ( $P < 0.05$ ) differences between regions and years.

## RESULTS

No significant differences were found between newer (B) sites and the original (A) sites for any category of comparison during the second year within regions. These sites

were subsequently pooled within region for comparisons between stable (S) and declining (D) regions.

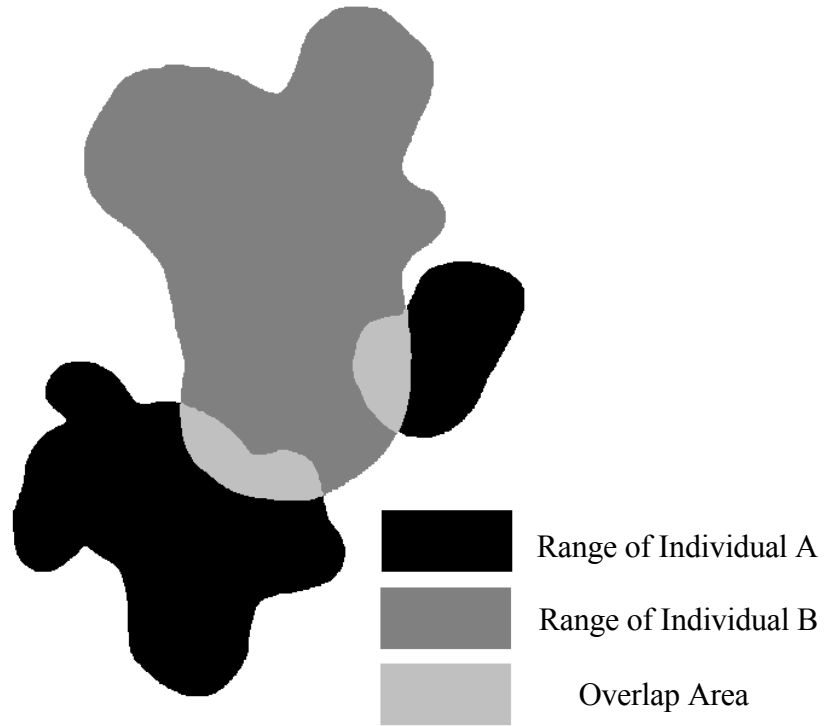


Fig. 2.2 Diagram of the method used for calculating overlap area from 2 individual ranges.

Annual ranges (Table 2.1) were similar between D and S for the first year, but larger ( $t_1 = -2.112$ ,  $P_1 = 0.046$ ) in S than D the second year ( $\bar{x}_{D1} = 1,552.4$ ,  $SD = 635.1$ ;  $\bar{x}_{S1} = 2,526.2$ ,  $SD = 2,923.3$ ;  $\bar{x}_{D2} = 1,535.5$ ,  $SD = 734.8$ ;  $\bar{x}_{S2} = 2,827.6$ ,  $SD = 2,791.4$ ). Within regions, the annual range sizes were not significantly ( $t_D = 0.071$ ,  $P_D = 0.944$ ;  $t_S = -0.345$ ,  $P_S = 0.732$ ) different between years. The mean annual range size, however, decreased in the declining region (-16.9 ha), while it increased (+301.4 ha) in the stable region.

Consecutive movement distances (Table 2.1) were similar between D and S for both years ( $\bar{x}_{DI} = 9,993.7$ , SE = 516.4;  $\bar{x}_{SI} = 9,916.1$ , SE = 1,312.4;  $\bar{x}_{D2} = 9,561.6$ , SE = 538.5;  $\bar{x}_{S2} = 9,914.2$ , SE = 666.4), as well as between years in S. Movement distances were larger ( $t_D = 2.310$ ,  $P_D = 0.032$ ) in D in the first year than in the second.

Mean overlap areas (Table 2.1) were similar in the first year between regions, but larger in the second year ( $t_2 = -8.346$ ,  $P_2 < 0.001$ ) in S than D ( $\bar{x}_{DI} = 754.5$ , SD = 413.3;  $\bar{x}_{SI} = 785.0$ , SD = 685.0;  $\bar{x}_{D2} = 705.7$ , SD = 510.2;  $\bar{x}_{S2} = 1,873.6$ , SD = 1,965.8). There was no difference in mean overlap area in D ( $t_D = 1.042$ ,  $P_D = 0.299$ ) between years. In S, however, mean overlap area was larger ( $t_S = -7.678$ ,  $P_S < 0.001$ ) in the second year than in the first ( $\bar{x}_{SI} = 785.0$ , SD = 685.0;  $\bar{x}_{S2} = 1,873.6$ , SD = 1,965.8).

In both the first and second year, D had greater ( $t_1 = 2.080$ ,  $P_1 = 0.039$ ) mean percent overlap (Table 2.1) than did S ( $\bar{x}_{DI} = 50.0$ , SD = 23.1;  $\bar{x}_{SI} = 35.5$ , SD = 30.0;  $\bar{x}_{D2} = 46.0$ , SD = 27.2;  $\bar{x}_{S2} = 33.7$ , SD = 31.7;  $t_2 = 4.750$ ,  $P_2 < 0.001$ ). There was no difference ( $t_D = -1.948$ ,  $P_D = 0.053$ ;  $t_S = 0.665$ ,  $P_S = 0.507$ ) in mean percent overlap between years for either region.

Table 2.1. Annual range (ha), overlap area (ha), percent overlap, and consecutive movement distance (km) for Rio Grande wild turkeys in an area of stable and declining turkey numbers, Edwards Plateau, Texas, 16 March 2001–15 March 2003.

	Site					
	Declining area			Stable area		
	N	Mean	SD	N	Mean	SD
Year 1						
Annual Range Size	11.0	1,552.4	635.1	21.0	2,526.2 <sup>b</sup>	2,923.3
Overlap Area	110.0	754.5	412.3	406.0	785.0 <sup>b</sup>	685.0
Percent Overlap	110.0	41.0 <sup>a</sup>	23.1	406.0	35.5 <sup>a</sup>	29.7
Movement Distance	11.0	9,993.7	516.4 <sup>*</sup>	21.0	9,916.1	1,312.4
Year 2						
Annual Range Size	27.0	1,535.5 <sup>a</sup>	734.8	22.0	2,827.6 <sup>c</sup>	2,791.4
Overlap Area	410.0	705.7 <sup>a</sup>	510.2	204.0	1,873.6 <sup>b</sup>	1,965.8
Percent Overlap	410.0	46.0 <sup>a</sup>	27.2	204.0	33.7 <sup>b</sup>	31.7
Movement Distance	27.0	9,561.6	538.5 <sup>*</sup>	22.0	9,914.2	666.4

<sup>a</sup> Significant ( $P < 0.05$ ) difference between regions only

<sup>b</sup> Significant ( $P < 0.05$ ) difference between years only

<sup>c</sup> Significant ( $P < 0.05$ ) difference between regions and between years

<sup>\*</sup> Standard Error

## DISCUSSION

Range sizes for RGWTs in the EP of Texas were comparable to those seen for RGWTs in studies conducted elsewhere (Thomas et al. 1966, Schmutz and Braun 1989, Keegan and Crawford 2001). The range sizes in my study support Keegan and Crawford's (2001) findings that RGWTs have a pattern of long movements and associated large annual and seasonal ranges. Whether due to environmental necessity or biological programming, RGWTs seem to require a relatively large land area to fulfill their life requisites.

Although I expected to see larger range sizes in the declining region than in the stable region based on conventional wisdom (Taylor 1949, Porter 1977, Exum et al. 1987, Godwin et al. 1996, Thogmartin 2001), this was not the case. Individual range sizes did not differ the first year, but were larger in the stable than in the declining region during the second year. Thus, the region of my study showing stable population trends over time demonstrated characteristics traditionally thought to indicate poor habitat quality.

There was no change in range size from year to year in the declining region, even though turkey productivity decreased substantially during the second year (Randel 2003). However, range sizes in the stable region increased during this period, consistent with the hypothesis that individual range sizes should be larger during years characterized by poor reproductive success. Further, percent overlap of ranges was higher in the declining than in the stable region during both years. Also, though movement distances remained consistent in the stable region for both years, they were significantly larger in the declining

region during the more productive first year. This suggested that during the less productive second year, individuals were confined to a smaller area.

The use of the same range by multiple individuals in the declining region may be explained by a restriction in the availability of useable space (Guthery 1997) compared to ample useable space in the stable region. This restriction could be due to habitat fragmentation and changing land-use practices in the landscape surrounding the declining region. Future research regarding landscape use by RGWTs at larger scales is required to address this question. It is clear, however, that quantifying resource availability at a site-specific scale is not sufficient to estimate habitat requirements for broad-ranging galiform such as the RGWT. Lastly, without factoring in potential habitat fragmentation and other landscape characteristics, habitat quality cannot be accurately estimated from range sizes.

## **MANAGEMENT IMPLICATIONS**

It appears that fine-scale, site-specific resources are not limiting Rio Grande wild turkeys (RGWTs) in the portion of the Edwards Plateau (EP) characterized by declining RGWT abundance; the limiting resource appears to be the quantity of useable space available throughout the year. Management for such a population would require creating more annual usable space so that RGWTs in the population are able to resume normal migratory patterns between winter roosting areas and brood-rearing sites.

This might be accomplished by building on the cooperatives among landowners and managers already in place in many areas. These cooperatives were established to alleviate the full brunt of expenses associated with land-management practices by spreading the cost among several owners and managers in an area. This same premise



could be used to design a comprehensive management plan relevant at broad spatial scales. Instead of giving management recommendations for RGWT management on an individual property, a subscriber to a RGWT cooperative may only be given a piece of the management strategy for a cooperative that covers 50,000–75,000 ha. In this way, management for RGWTs could be accomplished inexpensively (writing one management plan for RGWT management and using that as a guide for a large area), efficiently (one set of rules and guidelines covering a large tract of land), and without excessive manpower (large tracts of land can easily cover several territories, allowing what little added work there is to be distributed among several regulatory biologists already employed).

## CHAPTER III

# INSECT AND PREDATOR ABUNDANCE IN DIFFERING POPULATION CONCENTRATIONS AND SPATIAL SCALES OF RIO GRANDE WILD TURKEYS

## INTRODUCTION

Resource usage and availability studies have long been a part of descriptive habitat studies for many wild species, including Rio Grande wild turkeys (*Meleagris gallopavo intermedia*; RGWTs). Brown (1980) wrote that resource availability was the primary factor differentiating wild turkey ranges from uninhabited areas and numerous researchers over time have developed the idea that when resources are limiting, turkeys range over larger areas to satisfy their basic requirements (Taylor 1949, Porter 1977, Exum et al. 1987, Godwin et al. 1996, Thogmartin 2001). While large ranges are widely acknowledged, few studies have incorporated this scale into their study design. Almost since the inception of using Geographic Information Systems (GIS) in the biological field, researchers and modelers have noted the need to input ecological parameters at appropriate spatial and temporal scales to increase accuracy and predictive abilities of their models and to reduce bias (Allen and Starr 1982, Addicott et al. 1987, Morris 1987, Urban et al. 1987, Turner 1990). For nearly 20 years, modelers have understood that certain habitat parameters that are important to an individual of the species of interest may not be as important to an entire population (Henderson-Sellers et al. 1985, Meentemeyer and Box

1987, Turner 1990). Thus, wildlife research should include analyses that coincide with the spatial and temporal scale of the proposed question. All too often, however, habitat differences between regions are defined simply as summaries of parameter values collected at site-specific scales; for this reason they cannot be expected to necessarily represent values of regional parameters. It is possible that regions having no apparent difference in invertebrate or predator abundance might differ when analyzed in terms of the density of individuals those resources support or use. For example, if per capita resource usage is higher in an area because several individual turkeys are using the area at the same time, then resources in that area must be greater during the period in question for the assumption of no differences in habitat quality between regions to be supported by data.

Data collected by Texas Parks and Wildlife Department (TPWD) biologists in cooperation with landowners and managers in the Edwards Plateau (EP) ecoregion of Texas (Gould 1962) illustrated that RGWT abundance has declined significantly since the late 1970s in the southeastern portion of the region, particularly in Bandera, Kerr, and Real counties (Fig. 1.1), while remaining stable throughout the remainder of the EP.

Preliminary results on brood survival in these regions conducted by D. A. Jones (Texas A&M University, unpublished data) demonstrated that brood survival was significantly greater ( $P < 0.05$ ) in the stable region than in the declining region.

My objective was to compare turkey poult production during the reproductive season with the per capita area available for broods to determine whether differences in invertebrate (Randel 2003) and predator abundance (Willsey 2003) could explain

differences in brood survival based on concurrent usage by multiple broods. I focused on marked females with broods during the reproductive season as the most important demographic factor contributing to changes in abundance at the population level, in light of Jones's (Texas A&M University, unpublished data) data that showed brood survival to be roughly twice as high in the stable region as in the declining region. Although broods associated with unmarked hens undoubtedly were simultaneously present in the area, I assumed that marked hens were a random and representative sample of the breeding female population, and subsequent brood populations, at the time of trapping.

## **STUDY AREAS**

Study areas were located in the southeastern portion of the EP in Kerr, Real, and Bandera counties, and in the northernmost portion of Medina County, Texas (Fig. 2.1). This area is characterized by rocky limestone outcroppings, flat-to-rolling divides with rocky, but fertile soils, and an average annual precipitation of 38–89 cm (Oakes et al. 1960). The sites were in close proximity to each other, resulting in similar precipitation patterns, vegetation types, and topography. The stable and declining regions were delineated by Texas A&M University (TAMU) and TPWD personnel; sites were selected based on their function as winter roosting sites for populations of RGWTs and the willingness of the landowners and managers to participate.

I selected 2 study sites each from both the stable and declining regions (Fig. 2.1). Stable site A was a 4,880-ha site located in the stable region in northern Kerr County, approximately 20.9 km west of Hunt, Texas. Stable site B was an 845-ha site located in Real County, approximately 9.4 km north of Leakey, Texas. Declining site A was a

4,922-ha site in the declining region of Bandera County, approximately 18.8 km west of Medina, Texas. Declining site B was a 6,100-ha site located in northern Medina County, approximately 17.0 km southwest of Bandera, Texas.

## **METHODS**

Texas A&M University and TPWD personnel trapped RGWTs using modified walk-in traps (Davis 1994, Peterson et al. 2003) during winter when turkeys were gathered in flocks. Birds were equipped with battery-powered mortality-sensitive radio transmitters (64.2–95.0 g; Advanced Telemetry Systems, Isanti, Minnesota) and colored plastic leg bands unique to each of the 4 study sites. Each bird was aged, sexed, weighed, and had blood taken via jugular puncture for related disease and genetic studies. Radioed turkeys were located by homing and triangulation from  $\geq 3$  telemetry stations (Silvy 1975, White and Garrott 1990) at random intervals and  $\geq 3$  times weekly (Swihart and Slade 1985). Locations and error polygons were estimated using LOAS software (Location of a Signal; Ecological Software Solutions, Sacramento, California). Telemetry error was controlled by eliminating estimated locations with error ellipses greater than 5 ha (Miller 1993) or estimated locations greater than 4,827 m from the farthest telemetry station.

For purposes of this study, the reproductive season (16 March–15 August) began with the dispersion of females away from winter roost sites and ended when individuals began returning to these winter roost sites. Reproductive season ranges were calculated in hectares using 95% kernels (Worton 1989) with ArcView Spatial Analyst software and Animal Movement Extension (Hooze and Eichenlaub 1997, Lopez 2001). Sample size

consisted of the number of females with broods that had at least 10 locations through the reproductive season (Jenrich and Turner 1969, Hoffman 1991, Badyaev et al. 1996).

Individual brood ranges then were overlaid and total areas were calculated in hectares at levels of increasing concurrent usage, hereafter called density levels. For all subsequent calculations, the number of marked broods in each region was divided by the density level to account for concurrent usage. This value was then divided by the number of marked broods in each region to determine the percentage of unshared resources available per brood ( $p$ ). To determine the per capita area, the total area in each density level was multiplied by  $p$  and divided by the number of marked broods in each region (stable and declining).

Invertebrate abundance, thought to be a potential difference between the stable and declining regions, was determined by Randel (2003). I converted the 2-year average dry weight of invertebrates collected by region to a density estimate by dividing the mean values by transect-area. I concentrated on the 4 invertebrate orders (Coleoptera, Hemiptera, Orthoptera, and Homoptera) shown to be among the highest percentage of turkey poult diets during the first few weeks of life (Hurst and Stringer 1975).

Predator abundance for both regions was analyzed by Willsey (2003), and concentrated on bobcats (*Lynx rufus*), coyotes (*Canis latrans*), and raccoons (*Procyon lotor*) as predators of both nests and all age classes of turkeys (Glazener 1967, Cook 1972, Miller and Leopold 1992). Willsey (2003) maintained that coyote abundance was a possible cause of the population decline in the declining region and was the focal brood-predator species.

I analyzed coyote abundance for my study from the relative mean abundance (RMA) values (Willsey 2003) for the same time period as from Randel's (2003) invertebrate study. The resulting density estimates were used as baselines for constructing per capita invertebrate and predator abundance estimates based on the area and number of marked broods present in each density level. Invertebrate abundance by order was calculated by multiplying the density estimate for each order (kg/ha) by the per capita area under each density level while predator abundance was calculated by multiplying the RMA for each species by the per capita area under each density level.

Small sample sizes of broods in both the stable or declining regions during the last 2 years of the study precluded reliable statistical testing for these periods. Data collected during these years were calculated as a baseline of the resources available in these regions. Comparisons of per capita area and the related resource and predator abundance calculations are based on marked broods in the first year.

Thus, I made the assumption that, because no broad-scale practices aimed at increasing or decreasing invertebrate or coyote abundance were implemented during this time period, the abundance of each of these resources remained relatively constant. Further, using 2 years of data helps to control for a shift either high or low in abundance for 1 year in either resource.

## **RESULTS**

The per capita area (ha) was greater in the stable ( $S_1 = 854.1$ ) than in the declining region ( $D_1 = 529.0$ ) for the non-overlapping areas (Fig. 3.1). The same held true for every density category the regions had in common ( $S_2 = 65.9$ ,  $D_2 = 53.1$ ;  $S_3 = 15.5$ ,  $D_3 = 9.4$ ;

Fig. 3.2). The declining region also had a higher density level category, with 4 broods occupying the same area ( $D_4 = 6.8$ ).

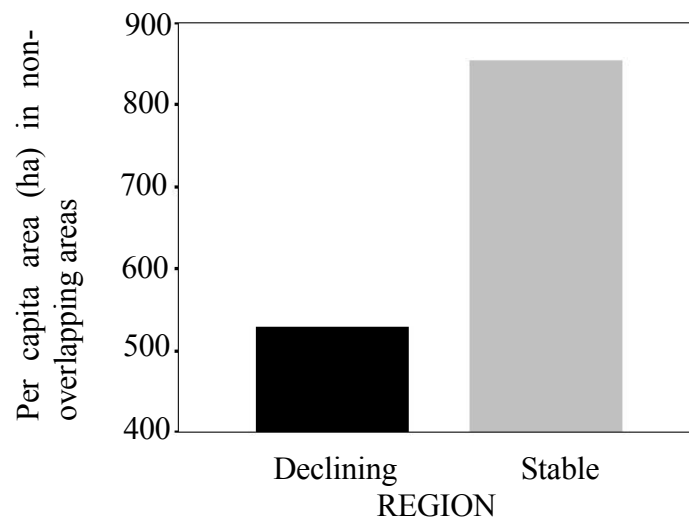


Fig. 3.1. Area available per brood (ha) in non-overlapping areas (density level  $d_1$ ) in declining (Bandera County) and stable (Kerr County) regions of the Edwards Plateau, Texas, 2001.



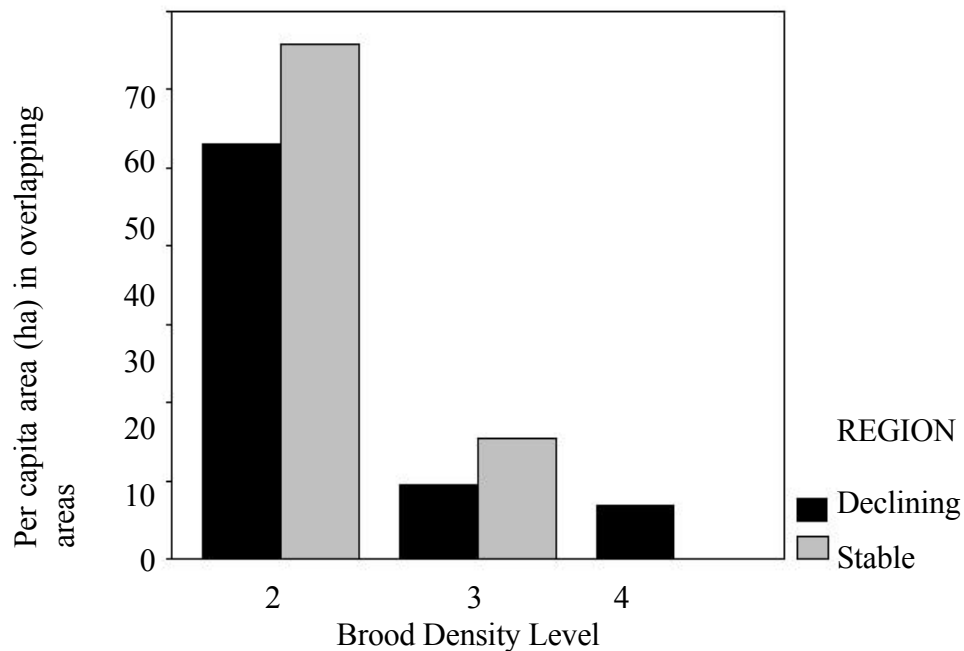


Fig. 3.2. Area available per brood (ha) by density level in overlapping areas in declining (Bandera County) and stable (Kerr County) regions of the Edwards Plateau, Texas, 2001.

Invertebrate abundance by region (Table 3.1) showed a greater mass (kg/ha) of invertebrates in the stable region for every invertebrate order found. In the stable region, invertebrate mass of Coleopterans averaged 5.4 times greater than in the declining region across all 3 density levels (Coleoptera<sub>s</sub> = 2.3–125.0, Coleoptera<sub>d</sub> = 0.4–21.5).

Hemipteran masses averaged 15.8 times greater in the stable region than in the declining region across all 3 density levels (Hemiptera<sub>s</sub> = 3.3–182.5, Hemiptera<sub>d</sub> = 0.2–10.7).

Orthopteran masses across all 3 density levels averaged 2.5 times greater in the stable region than in the declining region (Orthoptera<sub>s</sub> = 42.0–2,321.4, Orthoptera<sub>d</sub> = 15.4–870.9). The largest average difference was in the order Homoptera with the stable region averaging 15.9 times greater than the declining region across all 3 density levels (Homoptera<sub>s</sub> = 1.7–94.6, Homoptera<sub>d</sub> = 0.1–5.5). Coyote abundance was 2–3 times

greater in the declining region than in the stable region at all density levels ( $C_{d1} = 12.38$ ,

$C_{s1} = 5.72$ ;  $C_{d2} = 1.24$ ,  $C_{s2} = 0.44$ ;  $C_{d3} = 0.22$ ,  $C_{s3} = 0.10$ ).

Table 3.1. Invertebrate abundance per capita (kg/ha) by order for Rio Grande wild turkeys in an area of stable and declining turkey numbers, Edwards Plateau, Texas, 16 March 2001–15 March 2003.

Invertebrate Order	Region					
	Stable area			Declining area		
	d <sub>1</sub>	d <sub>2</sub>	d <sub>3</sub>	d <sub>1</sub>	d <sub>2</sub>	d <sub>3</sub>
Coleoptera	125.0	9.7	2.3	21.5	2.2	0.4
Hemiptera	182.5	14.1	3.3	10.7	1.1	0.2
Orthoptera	2,321.4	179.1	42.0	870.9	87.4	15.4
Homoptera	94.6	7.3	1.7	5.5	0.6	0.1

dn density level (number of broods sharing the specified area)

## DISCUSSION

In the declining region, multiple broods used the same range during the reproductive season. The higher degree of concurrent usage by marked females with broods in the declining region would be expected to deplete available resources at a faster rate than in the stable region. Because of this disproportionate resource usage, it stands to reason the declining region would require a greater abundance of resources and fewer predators for the same usage area if brood survival were to be equal. Previous research has not included population dynamics and has subsequently bypassed this disparity in resources at different population concentrations (Peterson 1998). In view of Brown's (1980) contention that resource availability was the main factor differentiating ranges, one might conclude from a comparison of the range sizes alone that the declining region was the area of more abundant invertebrates as more broods used less space in the declining region. This was not the case.

Invertebrate abundance for all 4 insect orders shown to be of greatest importance to turkey poults in the first few weeks of life were orders of magnitude greater in the stable than in the declining region at every density level. Though the differences between individual sites might not seem sufficiently large to account for a decreased brood survival in the declining region, per capita invertebrate abundance demonstrated a marked disparity in available resources. If the stable region was indicative of the resource level required to support a RGWT population during the reproductive season, then the declining region falls well short of this mark.

Coyote abundance also was greater in the declining than in the stable region during the reproductive season. Although coyote range size has been reported to range from 430 ha in South Texas (Andelt 1985) to 1,850 ha in Nebraska (Althoff 1978, Andelt and Gipson 1979), it is more likely that multiple broods would be found within a coyote's range in the declining than in the stable region due to greater overlap in brood-use areas in the declining region. Further, Andelt (1985) reported that a high percentage (> 75%) of radiomarked coyote observations during April for 2 consecutive years on the Welder Wildlife Refuge in South Texas was of multiple individuals, either pairs or groups. For these reasons, it seems likely that the predatory threat of coyotes to broods in the declining region would be greater even if coyote RMA were the same in each region, and even more so with the higher reported coyote RMA in the declining region (Willsey 2003).

## **MANAGEMENT IMPLICATIONS**

Site-specific quantification of habitat parameters is and has been an important component of wildlife research; however, when dealing with hypotheses for entire

populations, it is imperative to maintain an appropriate spatial scale. For example, in this study, even though resources may appear somewhat similar at a site-specific level, animal densities and per capita use illustrate potentially significant causative factors for the population decline in the declining region. The scope and scale of the study must match the scope and scale of the problem so that possibly crucial components of the problem are not discarded too hastily.

Superficially, it would appear that the most likely management recommendation to come from this research would be to control predator or use disking to increase invertebrate abundance. However, both of these options address symptoms of the problem, not the cause. The following bulleted list outlines a common-sense methodology in increasing the effectiveness of RGWT management at a population level:

- Attempt to determine correlations between habitat characteristics and population ranges. If a strong correlation between habitat characteristics that are readily identifiable through GIS interpretation and population range characteristics, a more appropriate scale may be developed for future research.
- Analyze these habitat characteristics at a population scale ( $\geq 50,000$  ha) to understand how these characteristics affect the entire population of RGWTs as opposed to just a portion of their range.
- Develop cooperatives among landowners dedicated to increasing the suitability of habitat throughout RGWT range, thereby increasing the effectiveness of any individual's contribution.

It appears that managing RGWT populations at fine spatial scales, such as predator control by an individual ranch owner or manager, may not be sufficient to ensure population viability. Establishing cooperative relationships among landowners would be necessary to allow increased efficiency and awareness, as well as a decreased cost for individual ranches.

## CHAPTER IV

### SPATIAL-SCALE DISTRIBUTION OF RIO GRANDE WILD TURKEY

#### FEMALES DURING THE REPRODUCTIVE SEASON

##### INTRODUCTION

Movements of Rio Grande wild turkey (*Meleagris gallopavo intermedia*; RGWT) females from winter ranges to their reproductive ranges comprise the largest portion of movements during the year for RGWTs and are generally larger than other subspecies of wild turkey (Thomas et al. 1966, Schmutz and Braun 1989, Keegan and Crawford 2001). As with other galliforms, those studying RGWTs generally assume that limited resources induce larger ranges and longer distance movements (Taylor 1949, Porter 1977, Exum et al. 1987, Godwin et al. 1996, Thogmartin 2001). Brown (1980) also noted that resource availability was the main factor differentiating wild turkey ranges.

Badyaev et al. (1996) proposed that selection of suitable nesting habitat was the catalyst for these long-distance movements. Indeed, research has shown that there does seem to be a proclivity by RGWT females to return to a given area to nest (Ellis and Lewis 1967, Hayden 1980, Keegan and Crawford 2001). If this is true, it could add credence to the argument that RGWT females return to an area where they find suitable nesting habitat. However, this fact alone is inadequate to explain an individual's initial long-distance movement because, although suitable nesting habitat may be recognizable, it is unknown what drives the nest-selection process. For this reason, availability of suitable nesting sites cannot easily be quantified and a subsequent preference/avoidance cannot be

easily calculated. Consequently, while the premise that long-distance movements to breeding areas seems plausible, it also seems to be grounded in the tautology that because RGWT females nest after long-distance movements, that they must move a long distance to find a suitable nest site. This idea has not been rigorously tested for wild turkeys, but appears to have gained support primarily through repetition (Romesburg 1981).

Assuming that the search for suitable nesting habitat is indeed the catalyst for long-distance movements by RGWT females to their breeding ranges, there are some logical conclusions that can be drawn. One is that in an area with abundant ,suitable nesting habitat, RGWT females should not move as far as in areas with a lesser abundance of suitable nesting habitat. Another conclusion is that, if an area has more suitable nesting habitat, that region should show an increased stability in turkey numbers while regions with less suitable nesting habitat should show less stable populations. Data collected by Texas Parks and Wildlife Department (TPWD) biologists in cooperation with landowners and managers in the Edwards Plateau (EP) ecoregion of Texas (Gould 1962) demonstrated that RGWT abundance has declined since the late 1970s in the southeastern region, particularly in Bandera, Kerr, and Real counties, while remaining stable throughout the remainder of the EP (Fig. 1.1). In recent research on RGWTs in the EP, D. A. Jones (Texas A&M University, unpublished data) demonstrated that brood survival was significantly ( $P < 0.05$ ) greater in a stable than in a declining study area while nest success was not different ( $P > 0.05$ ). Given this information, it follows that RGWT females in the region characterized by declining RGWTs should be expected to disperse a greater

distance across the landscape in search of suitable nesting habitat than females in the stable region, which in turn should have lesser movements.

The objective of my study was to test the hypothesis that RGWT females in the declining region disperse further during the breeding season than those in the stable region. I also address an alternative hypothesis for these long-distance movements based on a population dynamics perspective. I present the hypothesis that spatial distribution of females across the landscape during the reproductive season may be an important component of population stability. I contend that RGWT hens may not only seek out a nest site meeting their requirements, but also attempt to separate themselves somewhat from other breeding females, possibly as an adaptation to avoid predation and possible competition for brood resources. Specifically, I determined if distances between reproductive-range centers for RGWT females in the EP differed between regions of declining and stable wild turkey abundances.

## **STUDY AREAS**

Study areas were located in the southeastern portion of the EP in Kerr, Real, and Bandera counties, and in the northernmost portion of Medina County, Texas (Fig. 2.1). This area is characterized by rocky limestone outcroppings, flat-to-rolling divides with rocky, but fertile soils, and an average annual precipitation of 38–89 cm (Oakes et al. 1960). The sites were in close proximity to each other, resulting in similar precipitation patterns, vegetation types, and topography. The stable and declining regions were delineated by Texas A&M University (TAMU) and TPWD personnel; sites were selected



based on their function as winter roosting sites for populations of RGWTs and the willingness of the landowners and managers to participate.

I selected 2 study sites each from both the stable and declining regions (Fig. 2.1). Stable site A (SA) was a 4,880-ha site located in the stable region in northern Kerr County, approximately 20.9 km west of Hunt, Texas. Stable site B (SB) was an 845-ha site located in Real County, approximately 9.4 km north of Leakey, Texas. Declining site A (DA) was a 4,922-ha site in the declining region of Bandera County, approximately 18.8 km west of Medina, Texas. Declining site B (DB) was a 6,100-ha site located in northern Medina County, approximately 17.0 km southwest of Bandera, Texas.

## **METHODS**

Texas A&M University and TPWD personnel trapped RGWTs using modified walk-in traps (Davis 1994, Peterson et al. 2003) during winter when turkeys were gathered in flocks. Birds were equipped with battery-powered mortality-sensitive radio transmitters (64.2–95.0 g; Advanced Telemetry Systems, Isanti, Minnesota) and colored plastic leg bands unique to each of the 4 study sites. Each bird was aged, sexed, weighed, and had blood taken via jugular puncture for related disease and genetic studies. Radioed turkeys were located by homing and triangulation from  $\geq 3$  telemetry stations (Silvy 1975, White and Garrott 1990) at random intervals and  $\geq 3$  times weekly (Swihart and Slade 1985). Locations and error polygons were estimated using LOAS software (Location of a Signal; Ecological Software Solutions, Sacramento, California). Telemetry error was controlled by eliminating estimated locations with error ellipses greater than 5 ha (Miller 1993) or estimated locations greater than 4,827 m from the farthest telemetry station.

I focused on females during the reproductive season (16 March–15 August) to test my hypothesis. Sample size was the number of females that had  $\geq 10$  locations for the season (Jenrich and Turner 1969, Hoffman 1991, Badyaev et al. 1996). Ranges were calculated in hectares as 95% kernels (Worton 1989) and the arithmetic mean center of each individual turkey range was found using ArcView Spatial Analyst software and Animal Movement Extension (Hooge and Eichenlaub 1997, Lopez 2001). The distances between these arithmetic centers of all radioed females in each population were calculated to find spatial distribution distances. Spatial distribution distances for each year and for each region (stable and declining) were analyzed using *t*-tests (first year) and ANOVA and LSD tests (subsequent years) to determine if there were significant ( $P < 0.05$ ) differences between regions and years.

## RESULTS

In the first year of the study (2001), spatial distribution (km) in SA was significantly ( $P < 0.001$ ) larger than in DA ( $\bar{x}_{SA1} = 7.49$ , SD = 5.62;  $\bar{x}_{DA1} = 3.85$ , SD = 2.04; Table 4.1). The second year of the study (2002) showed a similar ( $P < 0.001$ ) pattern, with stable-site spatial distribution distances being roughly twice as large as those in the declining sites ( $\bar{x}_{SA2} = 8.47$ , SD = 4.68;  $\bar{x}_{DA2} = 3.40$ , SD = 2.07;  $\bar{x}_{SB2} = 8.01$ , SD = 6.55;  $\bar{x}_{DB2} = 4.11$ , SD = 2.65). There were no significant differences ( $p_D = 0.08$ ,  $p_S = 0.18$ ) between sites within the same region, but both DA and DB had significantly ( $P < 0.001$ ) smaller spatial distribution distances than the stable sites. During the third year of the study (2003), SA ( $\bar{x}_{SA3} = 5.23$ , SD = 4.08) was once again significantly ( $P < 0.001$ ) larger than the declining sites ( $\bar{x}_{DA3} = 3.73$ , SD = 2.30;  $\bar{x}_{DB3} = 4.15$ , SD = 2.09), but also

significantly ( $P < 0.001$ ) larger than SB ( $\bar{x}_{SB3} = 3.48$ ,  $SD = 2.25$ ). There was no significant ( $P = 0.112$ ) difference between the 2 declining study areas. Also, there was no significant ( $P = 0.373$ ) difference between DA and SB in year 3 and DB was significantly ( $P = 0.043$ ) larger than SB in that year.

Table 4.1. Mean distance (km) between arithmetic mean centers of breeding ranges for Rio Grande wild turkeys in areas of stable and declining turkey abundance, Edwards Plateau, Texas, 16 March 2001-15 March 2003.

Region												
Declining area							Stable area					
DA				DB			SA			SB		
Year	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD
2001	21	3.85	2.04	—			23	7.49	5.62	—		
2002	26	3.40	2.07	9	4.11	2.65	28	8.47	4.68	10	8.01	6.55
2003	22	3.73	2.30	11	4.15	2.09	26	5.23	4.09	10	3.48	2.25

## DISCUSSION

The larger distribution distances found in both study sites in the stable region during the first and second years and in SA during the third year contradict the hypothesis that RGWT females in area characterized by declining abundance disperse further than those in areas characterized by no trends in abundance. D.A. Jones (TAMU unpublished data) established that nest success was not significantly different ( $P > 0.05$ ) between region while brood rearing success was significantly ( $P < 0.05$ ) greater in the stable region than in the declining region. Combined with Jones' findings, the findings in this study support the alternative hypothesis that there may be some degree of spatial distribution necessary regardless of resource availability for a stable RGWT population during the reproductive season.

The smaller spatial arrangement of females during the reproductive season in SB appears counter to the findings in the first 2 years. It is important to note, however, the existence of confounding factors associated with SB during the third year. This reproductive season was characterized by poor production (Randel 2003) with few females leaving hen flocks to even attempt nesting. There is reason to believe that this was not common across all study sites and could have influenced the statistical analysis of distribution distances in SB.

Moreover, Keonig et al. (2000) argued, based on a study of acorn woodpeckers (*Melanerpes formicivorus*), that the combination of a strong bias toward the detection of short-distance dispersal and the impossibility of detection of dispersal events outside the study area precluded the detection of long-distance dispersal distances that could alter statistical analyses. In light of this information, the anomaly in year 3 for SB prompted a retrospective analysis of the sample sizes for all study sites in year 3. I divided the sample size (N) by the difference between the total number of females and the number of females that died during the breeding season for all study sites. This value was subtracted from 100 to determine the percentage of females from each site for which no breeding range could be created. For DA, DB, and SA in year 3, a female breeding range could not be calculated for 4.35, 21.43, and 7.14%, respectively. For SB in year 3, the result was 65.52%, >3 times the percentage missing in DB, the next largest number. It appears that the phenomena Keonig et al. (2000) refers to also occurred in this study. Thus it seems likely that if females in SB during year 3 moved further than the detection distance of the

radio-telemetry equipment, the results would fit the pattern of greater dispersion distance in regions of stable RGWT populations.

My research suggests that the driving force behind dispersion during the breeding season is not simply the availability of suitable nest sites (Badyaev et al. 1996). I contend that spatial distribution of females across the landscape during the reproductive season may also be an important component of population stability. Specifically, RGWT hens may not only seek out a nest site meeting their requirements, but also attempt to separate themselves from other breeding females, possibly as an adaptation to avoid nest or brood predation and/or avoid potential competition for brood resources.

Further research at a landscape level should be conducted to compare habitat characteristics between breeding ranges used by females in both regions characterized by stable and declining RGWT numbers. If these habitat characteristics are found similar, it would lend further support to the spacing hypothesis. Further, ranges that were unused by reproductive females could be analyzed for these same habitat characteristics, thereby creating a baseline habitat suitability index that could be used in future management practices.

## **MANAGEMENT IMPLICATIONS**

Research to date suggests that RGWTs range much further than other subspecies of wild turkey (Taylor 1949, Thomas et al. 1966, Porter 1977, Schmutz and Braun 1989, Keegan and Crawford 2001). For this reason, the traditional approach that directs management recommendations to individual landowners and managers may be misguided, at least for RGWTs. To make management recommendations relevant to landowner

cooperatives operating at a landscape level, wildlife managers must better understand the habitat characteristics consistently associated with RGWT females during the reproductive season. Currently, much more accurate, reliable, and efficient geospatial analyses are available, enabling these habitat characteristics to be accurately analyzed at a landscape scale. Unoccupied areas not possessing these characteristics could be manipulated to create them, thereby increasing the area females could use during the reproductive season. The framework required to complete this task can be laid now by establishing landowner cooperatives where habitat management can be completed at a scale relevant to RGWTs.

## CHAPTER V

### CONCLUSIONS

My results confirm that Rio Grande wild turkeys (RGWTs; *Meleagris gallopavo intermedia*) have a pattern of long movements and associated large annual and seasonal ranges. In the first year of my study, annual ranges were similar ( $P > 0.05$ ) between regions of declining (D) and stable (S) RGWT abundance, but larger ( $P = 0.046$ ) in S than in D for the second year. Even though ranges were larger in S, consecutive movement distances were larger ( $P = 0.032$ ) in D in the second year than in the first year.

My results do not support the conventional assumption that larger ranges are indicative of relatively poor habitat quality. The region of stable RGWT abundance over time demonstrated characteristics traditionally thought to be indicative of poor habitat quality. While individuals in the stable region increased their range sizes in the poorer production year, presumably in search of resources to fulfill their life requisites, individuals in the declining region maintained consistency in their range sizes and locations.

Further, in both the first and second years of the study, D had greater ( $P_1 = 0.039$ ,  $P_2 < 0.001$ ) percent overlap than in S. Interpretation of these results suggests that, although individuals in D seem to have attempted to move more in the less productive second year (D. A. Jones, TAMU, unpublished data), they may have been confined to a smaller area of useable space (Guthery 1997).

The negative ramifications of this range restriction became more apparent when I examined per capita insect and predator abundance associated with marked broods during

the reproductive season. In the declining region, multiple broods used the same range during the reproductive season, which would presumably deplete available resources at a faster rate than in the stable region. Because of this disproportionate resource usage, it stands to reason the declining region would require a greater abundance of resources and fewer predators for the same area for the per capita results to be equal between regions of stable and declining abundance.

Invertebrate abundance for all 4 insect orders shown to be of greatest importance to turkey poults in the first few weeks of life were orders of magnitude greater (2.5–15.9 times) in the stable than in the declining region at every density level. Coyote abundance in the declining region also was greater (2–3) times in the declining than in the stable region during the reproductive season. Combined with the fact that multiple broods in the declining region used the same areas, this greater predator abundance greatly increases the risk of brood predation in the declining region.

Conventional wisdom once again was used as a guide in attempting to understand the behavioral differences of female RGWTs between regions. It is a common assumption that RGWT females travel long distances in search of suitable nest sites. While this certainly seems plausible, I examined the possibility that there is also a degree of spatial distribution across the landscape that, above which females in the population are more likely to raise a successful brood.

In the first year of the study (2001), spatial distribution (km) in SA was significantly ( $P < 0.001$ ) larger than in DA. The second year of the study (2002) showed a similar ( $P < 0.001$ ) pattern of stable-site spatial distribution distances being roughly twice



as large as those in the declining sites. Again in the third year, spatial distribution (km) in SA was significantly ( $P < 0.001$ ) larger than in the declining region. Only SB contradicted these results in the third year, being significantly ( $P = 0.043$ ) smaller than in DB.

The smaller spatial arrangement of females during the reproductive season in SB seems to contradict the findings in the first 2 years; however, there were confounding factors associated with SB during the third year of the study. This was a poor production year (Randel 2003) with few females leaving hen flocks to even attempt nesting during the reproductive season. There is reason to believe that this was not common across all sites and may have had a significant impact on the statistical analysis of distribution distances in SB.

Moreover, Keonig et al. (2000) argued, in a study of acorn woodpeckers (*Melanerpes formicivorus*), that the combination of a strong bias toward the detection of short-distance dispersal and the impossibility of detection of dispersal events outside the study area precluded the detection of long-distance dispersal distances that could alter statistical analyses. In light of this information, the anomaly in year 3 for SB prompted a retrospective analysis of the sample sizes for all study sites in year 3. I divided the sample size (N) by the difference between the total number of females and the number of females that died during the breeding season for all study sites. This value was subtracted from 100 to determine the percentage of females from each site for which no breeding range could be created. For DA, DB, and SA in year 3, the results were 4.35%, 21.43%, and 7.14%, respectively. For SB in year 3, the result was 65.52%, >3 times the percentage missing in DB, the next largest number. It appears that the phenomena Keonig et al.

(2000) refers to also may be observed in this study. Thus it seems likely that if females in SB during year 3 moved further than the detection distance of the radio telemetry equipment, the results would fit the pattern of greater dispersion distance in regions of stable RGWT populations.

My research suggests that the driving force behind dispersion during the breeding season is not simply the availability of suitable nest sites (Badyaev et al. 1996). I contend that spatial distribution of females across the landscape during the reproductive season may also be an important component of population stability. Specifically, RGWT hens may not only seek out a nest site meeting their requirements, but also attempt to separate themselves from other breeding females, possibly as an adaptation to avoid nest or brood predation and/or avoid potential competition for brood resources.

## **MANAGEMENT IMPLICATIONS**

Conducting and analyzing this research at a broad landscape scale allows the results to be easily adapted into broad management practices that could be employed by regulatory agencies such as TPWD. Some general recommendations are as follows:

1. Determine correlations between habitat characteristics and population ranges. If a strong correlation between habitat characteristics that are readily identifiable through GIS interpretation and population range characteristics exists, a more appropriate scale may be developed for future research.

2. Analyze these habitat characteristics at a population scale ( $\geq 50,000$  ha) to understand how these characteristics affect the entire population of RGWTs as opposed to just a portion of their range.
3. Develop land-management practices designed to be effective at the population scale for RGWT and create a population-management plan emphasizing practices and measures to be taken to increase the useable space and resources available to the population.
4. Build on the cooperatives associations among landowners and managers already in place in many areas established to alleviate the full brunt of expenses associated with land-management practices by spreading the cost among several owners and managers in an area. Instead of providing management recommendations for RGWT management on an individual property, a subscriber to a RGWT cooperative may only be given a piece of the management strategy for a cooperative that covers 50,000–75,000 ha. In this way, management for RGWTs can be accomplished inexpensively (writing one management plan for RGWT management and using that as a guide for a large area), efficiently (one set of rules and guidelines covering a large tract of land), and without excessive manpower (large tracts of land can easily cover several territories, allowing what little added work there is to be distributed among several regulatory biologists already employed).

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