THE EFFECTS OF RED IMPORTED FIRE ANTS ON NORTHERN BOBWHITE AND EASTERN COTTONTAIL IN THE GULF PRAIRIES AND MARSHES OF TEXAS

A Thesis

by

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ABSTRACT

Northern bobwhites (*Colinus virginianus*) have been declining throughout their range since the 1960s. The decline in the Gulf Prairies and Marshes Ecoregion (GPM) has primarily been the result of habitat loss and fragmentation. With the population already reduced, additional causes of quail decline become important issues. In 1957, red imported fire ants (RIFA, *Solenopsis invicta*) began to invade the GPM. RIFA can potentially affect bobwhites by direct predation of pipping chicks, reduced survival of young chicks, and competition for food. Eastern cottontails are another important species that could be impacted by RIFA. Previous work has documented RIFA predation of altricial young born in pen-raised cottontail nests.

The Attwater Prairie Chicken National Wildlife Refuge in Colorado County, Texas received large-scale aerial treatment of RIFA with *Extinguish Plus*™ insecticide as a management action for the endangered Attwater's prairie-chicken (*Tympanuchus cupido attwateri*). This presented me with an opportunity to evaluate the effects of RIFA treatment on: (1) bobwhite nest success and brood survival, (2) bobwhite abundance and density, (3) bobwhite movements and ranges, and (4) cottontail numbers. An additional objective was to (5) contribute reference data for bobwhite in the GPM to address this region's lack of data. To investigate these objectives bobwhites were radio-collared and tracked, RIFA were sampled, and cottontails were surveyed in both the treated and non-treated areas.

Treatment with *Extinguish Plus*™ successfully reduced the abundance of RIFA in

the treated area from 2014–2017. However, I found that flooding can negate the effectiveness of the treatment when the treated area is surrounded by adjacent non-treated areas. Bobwhite densities were 76.6% higher ($P = 0.042$) in the treated area compared to the non-treated area. There was no difference between bobwhite consecutive movements ($P = 0.275$) or seasonal ranges ($P = 0.783$) in the treated and non-treated area. However, there was a difference ($P = <0.001$) by category. Nesting season females without a brood had larger movements ($P = <0.001$) than nesting season females with a brood and larger movements ($P = 0.002$) than pre-nesting females. Cottontail numbers were higher ($P = 0.003$) in the non-treated than the treated area.

DEDICATION

I dedicate this thesis to those people that have been by my side throughout my education. To my parents, thank you for supporting me financially and for encouraging me to approach my education at a high level with a dedication to hard work. Thank you, dad, for always pushing me to take the hard road to reap the later benefits and for raising me to be a sportsman with a passion for wildlife and conservation. Thank you, mom, for your constant encouragement and for helping make it through high school English classes. Thank you, Grandma and Grandpa Mahanay, for helping finance my Master's degree and for all your help critiquing my writing. Thank you, Kristen, for supporting me through graduate school and for coming to Texas A&M University with me. I look forward to a married life full of pride in our accomplishments. Thank everyone for being a part of the journey with me. Additionally, I dedicate this thesis to the northern bobwhite. Your economic and social importance and future success paid for my Master's degree, and that contribution is much appreciated.

ACKNOWLEDGEMENTS

I would like to thank Bernice Fujinaka for a conversation that she likely does not remember. That conversation helped me to decide that my goal was to go to graduate school.

Thank you, Dr. Nova J. Silvy, for giving me the opportunity to study under you. It has truly been an honor. I appreciate all the hard work you put into my field work, writing, and overall education.

This study also could not be possible without the hard work of those who helped me in the field Trey Johnson, Corey Pursell, and Oscar Perez. Thank you all for your contributions.

Thank you to my committee members, Dr. Roel Lopez, Dr. Richard Conner, and Dr. Michael Morrow for your contributions and critiques. Also, thank you to all the Attwater Prairie Chicken National Wildlife Refuge staff for your help and for the use of your facilities and refuge to complete this study.

CONTRIBUTORS AND FUNDING SOURCES

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CHAPTER I

INTRODUCTION

Northern bobwhite (*Colinus virginianus*) population declines have been acknowledged since the 1930s, and widespread declines across their historic range have been documented since the 1960s (Williams et al. 2004). The decline in Texas has primarily been the result of habitat loss and fragmentation (Brennan et al. 2005, Hernández and Peterson 2007). Northern bobwhites become isolated in fragmented populations, and these populations become vulnerable to local extinction with the occurrence of a catastrophic event (Brennan et al. 2005, Perez 2007). Additional causes of quail mortality are related to red imported fire ants (*Solenopsis invicta*, hereafter RIFA), predation, and disease (Hernández and Guthery 2012). However, these secondary causes become primary concerns when a quail population is at a record low with continuing downward trend.

A moderate number of northern bobwhites inhabit the Gulf Coast Prairies and Marshes Ecoregion of Texas (Lehmann 1984, Perez 2007). This region has experienced a northern bobwhite population decline (Fig 1.1) of 3.2%/year between 1966 and 2002 with an accelerated decline of 3.7% per year between 1980 and 2002 according to the North American Breeding Bird Survey (Sauer et al. 2007). However, the Texas Parks and Wildlife Department's quail production survey route results showed a slower decline of 2.3% per year between 1978 and 2002 (Perez 2007). This ecoregion is similar to much of the bobwhite range in that declining populations can mostly be associated with urbanization and land use changes that reduce usable space and fragment suitable habitat for quail populations. Fragmentation of the Gulf Prairies bobwhite habitat is predominately due to the large urban human population (25% of the state population) and agricultural lands that are unsuitable for quail such as rice farms and dryland crops (Wilkins et al. 2003, Perez 2007).

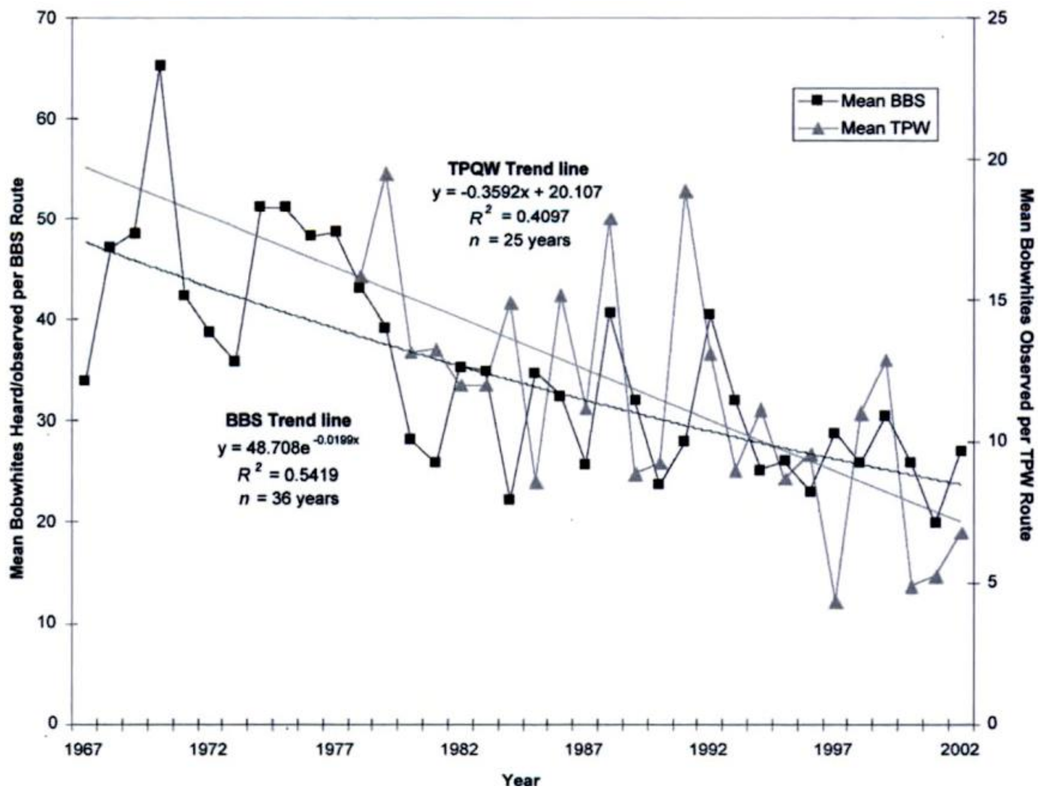

Figure 1.1. Mean number of northern bobwhites observed per North American Breeding Bird Survey (BBS) and Texas Parks and Wildlife Department (TPW, TPQW) quail production survey routes in the Gulf Prairies and Marshes (Reprinted from Perez 2007).

As stated previously, these declining and fragmented bobwhite populations are vulnerable to local extinction as the result of catastrophic events and exacerbated effects of secondary causes of decline. Considering land use and urbanization issues in this region, bobwhites populations are unlikely to improve drastically. It is important to investigate additional potential limiting issues such as RIFA infestation. RIFA began its establishment in the Gulf Prairies in 1957 (Fig. 1.2) then spread through the region at a rate of approximately 30 to 50 km per year (Vinson and Sorensen 1986). Correlation analysis indicates that bobwhite populations are decreasing in areas infested with RIFA, while un-infested areas remain stable or are increasing (Allen et al. 1995). Allen et al. (1995) suggested 3 likely processes by which RIFA negatively impact bobwhite survival and subsequently bobwhite populations. There processes are: (1) direct predation of pipping eggs in the nest, (2) adverse effects on chick survival associated with RIFA stings, and (3) indirect impact of competition over invertebrates as a food source.

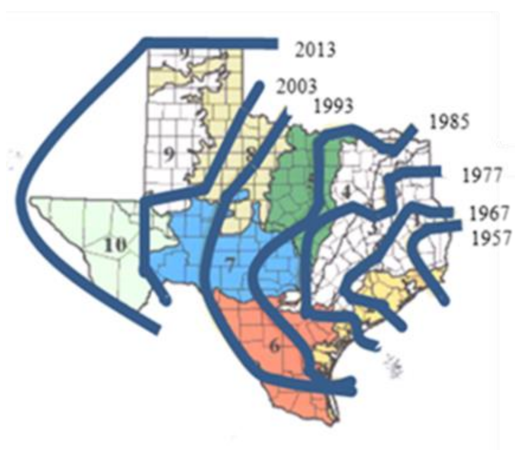

Figure 1.2. The spread of red imported fire ants across Texas ecoregions between 1957 and 2013 (Reprinted from Drees and Vinson 1993, Caldwell 2015).

It is important to determine if and how much RIFA affect bobwhites. The presence of invasive RIFA translates to a $1.2 billion impact on the economy, environment, and quality of life in Texas (Drees and Lard 2006). Bobwhites contribute to all three of those factors. If RIFA are negatively impacting an already declining bobwhite population a solution that minimizes or eliminates these negative impacts would be a valuable tool to ensure the survival of bobwhites in RIFA-infested portions of their range.

It also has been suggested that RIFA pose a threat to the success of eastern cottontails (*Sylvilagus floridanus*). Cottontails give birth to altricial young which makes them susceptible to negative interaction with RIFA during the nesting season (Johnson 1961, Hill 1972, Allen et al. 2004). Hill (1972) documented many occasions of RIFA predation on domesticated cottontail nests, thus it is important to understand the effects that RIFA could have on wild cottontail populations.

RESEARCH OBJECTIVES

The objectives of my study were to evaluate the effects of: (1) RIFA treatment on northern bobwhite nest success and brood survival, (2) RIFA treatment on northern bobwhite abundance and density, (3) RIFA treatment on northern bobwhite movements and range, and (4) RIFA treatment on eastern cottontail numbers. An additional objective was to (5) contribute reference data for northern bobwhite in the Gulf Prairies and Marshes Ecoregion to address this region's lack of data. The objectives are addressed in the following chapters: (II) effects of RIFA on northern bobwhite nest success, brood survival, abundance, and density, (III) effects of RIFA northern bobwhite movements and ranges, (IV) effects of RIFA on eastern cottontail numbers, and (V) Conclusions and management implications. These chapters were created as mostly independent products and contain some overlapping and redundant material.

STUDY AREA

My study was conducted on the Attwater Prairie Chicken National Wildlife Refuge (hereafter APCNWR) in the Gulf Coast Prairies and Marshes Ecoregion of Texas (hereafter GPM), approximately 97 km west of Houston, Texas (Fig. 1.3). Northern bobwhite trapping was limited to the approximately 3,790-ha unit of the refuge that is in Colorado County. The primary management goal of this refuge is to restore and maintain native prairie habitat for the endangered Attwater's prairie chicken (*Tympanuchus cupido attwateri*, hereafter APC). Common soil types on APCNWR include loamy prairie, claypan prairie, and coarse sand (Caldwell 2015). Habitat management practices include control of brush, invasive plants, and predators with prescribed burning, cattle grazing, and herbicide spraying (Lockwood 1998).

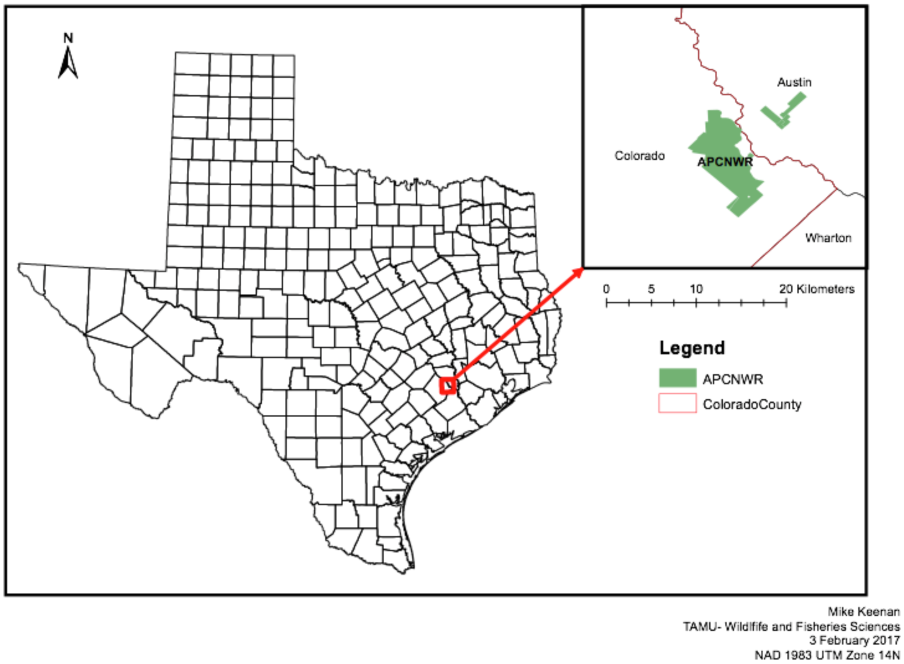

Figure 1.3. APCNWR located in Colorado County, Texas (97 km west of Houston, Texas).

The portion of the GPM where the APCNWR is located was historically flat grassland plains divided by streams (Gould 1962, Perez 2007). The APCNWR is bordered to the east by the San Bernard River and divided into upper north and lower south portions by the Coushatta Creek. The primary land use surrounding the APCNWR is irrigated rice and other cropland fields and rangelands for cattle grazing. The soils in this portion of the GPM are characterized by clay and clay loams that are dark and are neutral to slightly acidic and produce slow surface drainage (Smeins et al. 1991; Perez 2007).

The GPM have an annual average rainfall of between 64 and 150 cm and periodically experience hurricanes and tropical storms (Smeins et al. 1991; Perez 2007). A National Weather Service station is in Columbus, Texas (17 km west of APCNWR), showed 106.1 cm in 2014 and 127.9 cm in 2015 and well above the maximum average at 169.7 cm in 2016 (www.weather.gov/climate). Extreme rainfall events were common in April and May between 2014 and 2016 (Fig. 1.4). Over 40% of the rainfall in 2016 occurred during those 2 months. Extreme concentrated rainfall events resulted in water levels above flood stage in the San Bernard River and Coushatta Creek resulting in flooding of large portions of the refuge (Fig. 1.5). Flooding was especially severe in the lower southern portions of the refuge

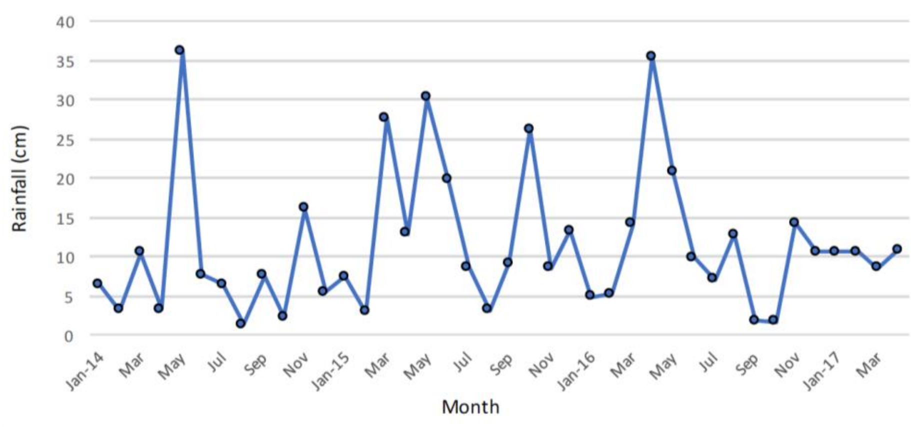

Figure 1.4. Rainfall for Columbus, Texas (17 km west of APCNWR) January 2014 to April 2017 with highly concentrated rainfall events during the months of April and May in 2014 to 2016.

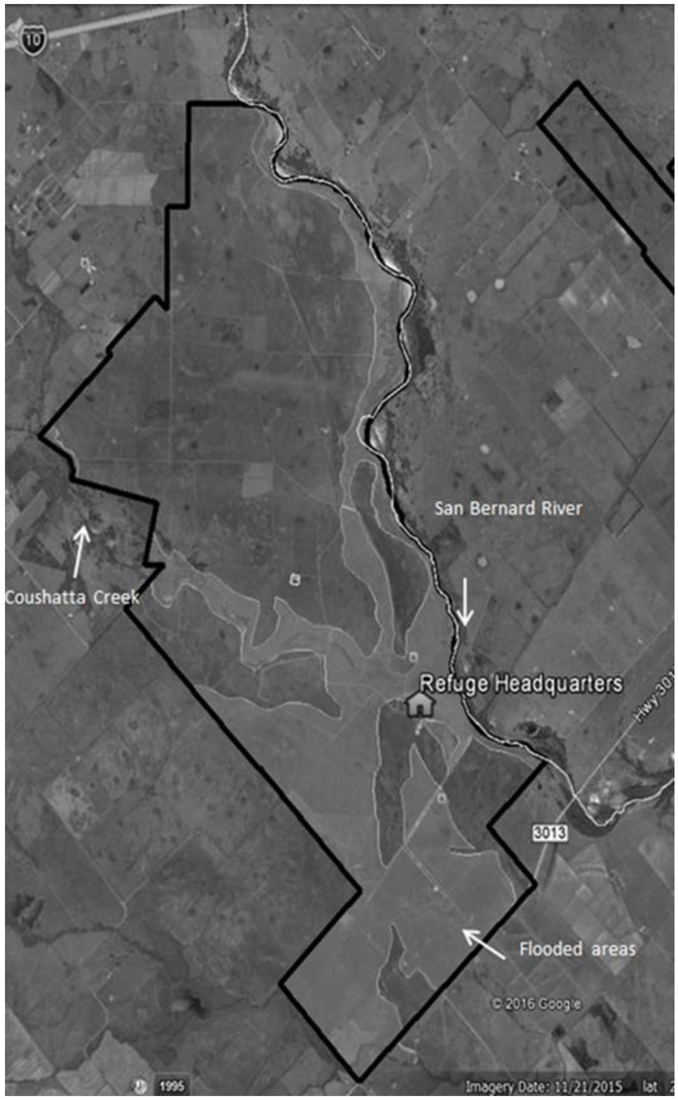

Figure 1.5. Areas of APCNWR, Colorado County, Texas, flooded by heavy rains on 18 April 2016 (Map generated by John Magera, Attwater Prairie Chicken National Wildlife Refuge, based on his personal observations of the flooding).

The APCNWR first received a 308-ha pilot treatment of 1.7 kg/ha of *Extinguish Plus*^{TM} (Wellmark International, Schaumburg, Illinois), fire ant insecticide in April and November of 2009 (Morrow et al. 2015). *Extinguish Plus*^{TM} is a RIFA insecticide that combines an adulticide and an insect growth regulator to kill worker ants immediately then make the queen ant infertile, effectively exterminating the entire colony (Extinguish Plus 2009). This product is a small granule, similar in appearance and size to yellow corn meal. The *Extinguish Plus*™ was applied aerially to my study site with a crop dusting plane except for treatments before 2013 which were applied by helicopter. During November 2010 and September 2011, 527 ha of the APCNWR were treated, with an additional treatment in September 2012 (Morrow et al. 2015). In October 2013 (Fig. 1.6), 1,491 ha and in October 2014 (Fig. 1.7), 2,383 ha of the refuge were treated with 1.7 kg/ha of *Extinguish Plus*™ (Caldwell 2015). The treatment was the same in 2015 as it was in 2014. In November 2016, 997 ha were treated and then in March 2017, an additional 1,054 ha were treated (M. Morrow, APCNWR, personal communication). This combined 2,051 ha treatment for the 2016–2017 treatment was the same as for the 2014–2015 treatments, but it excluded 2 of the northeastern formally treated areas (Fig. 1.8). For my study, pastures treated with *Extinguish Plus*™ were considered treated areas and areas not receiving *Extinguish Plus*™ were considered control areas. These 2 areas contain some ecological biases because treated areas were selected based on the areas most used by APC (Caldwell 2015). Non-treated areas consisted of areas of former wetlands and former rice fields currently under restoration to prairie grasslands. As such, non-treated areas were more prone to flooding and occupied lower successional stages compared to treated areas.

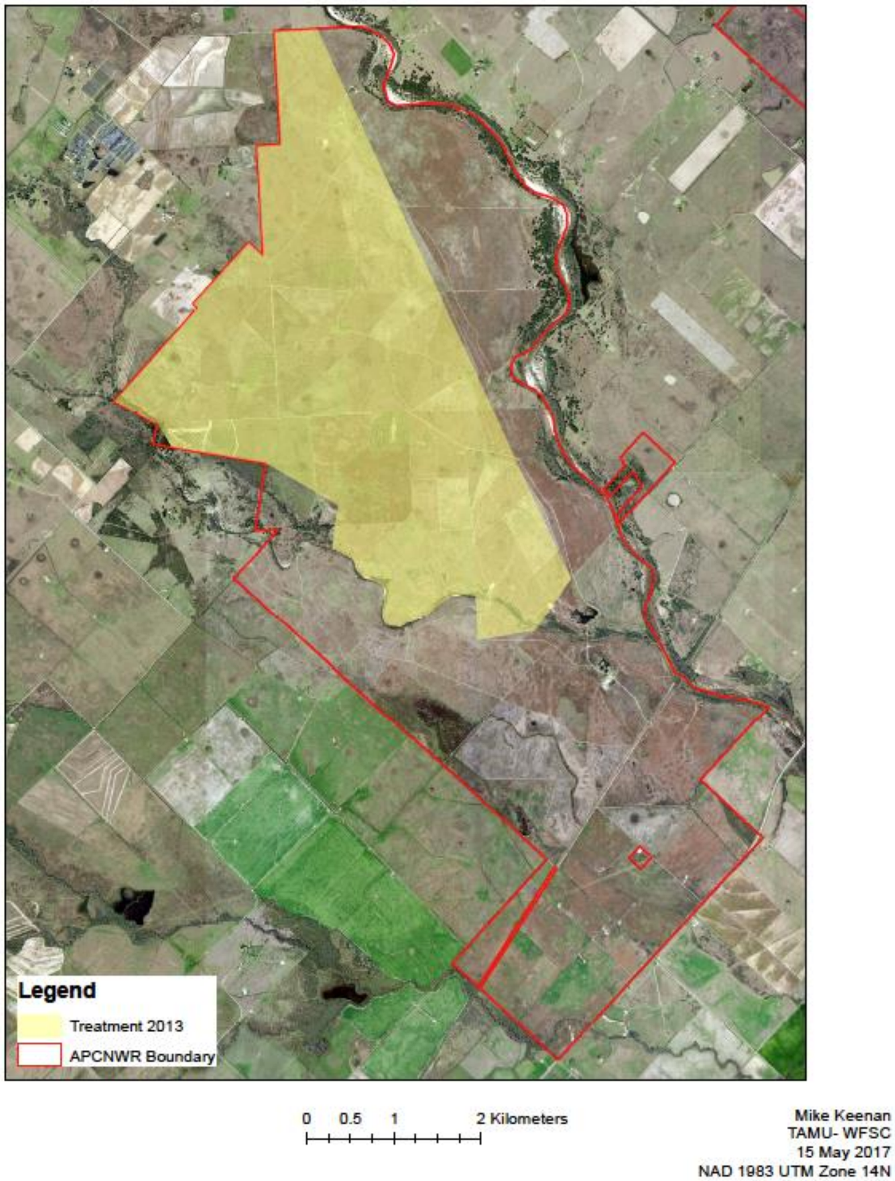

Figure 1.6. *Extinguish Plus*^{TM} treatment on APCNWR in Colorado County, Texas during 2013 to control RIFA (data from Rebecca Chester, APCNWR, Eagle Lake, Texas, October 2014).

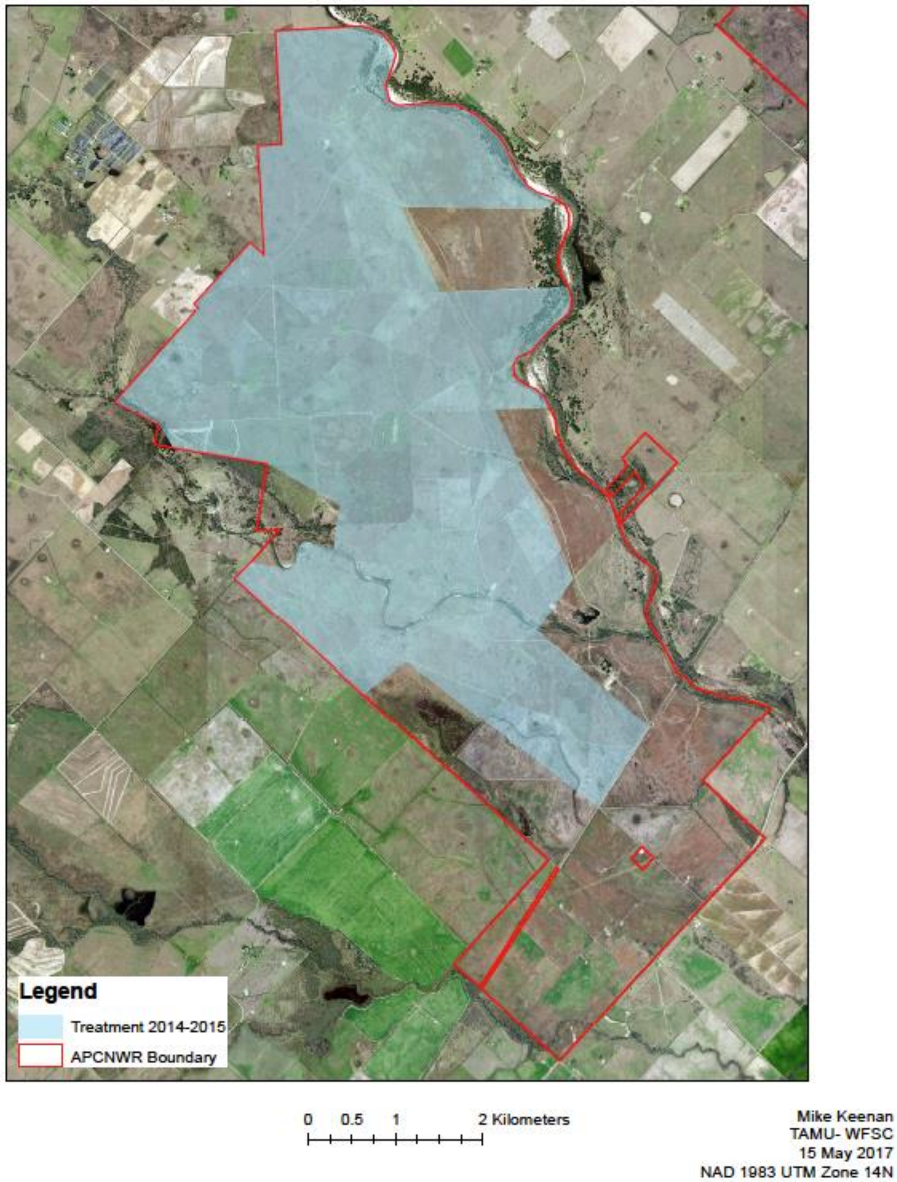

Figure 1.7. *Extinguish Plus*^{TM} treatment on APCNWR in Colorado County, Texas from 2014–2015 to control RIFA (data from Rebecca Chester, APCNWR, Eagle Lake, Texas, October 2014).

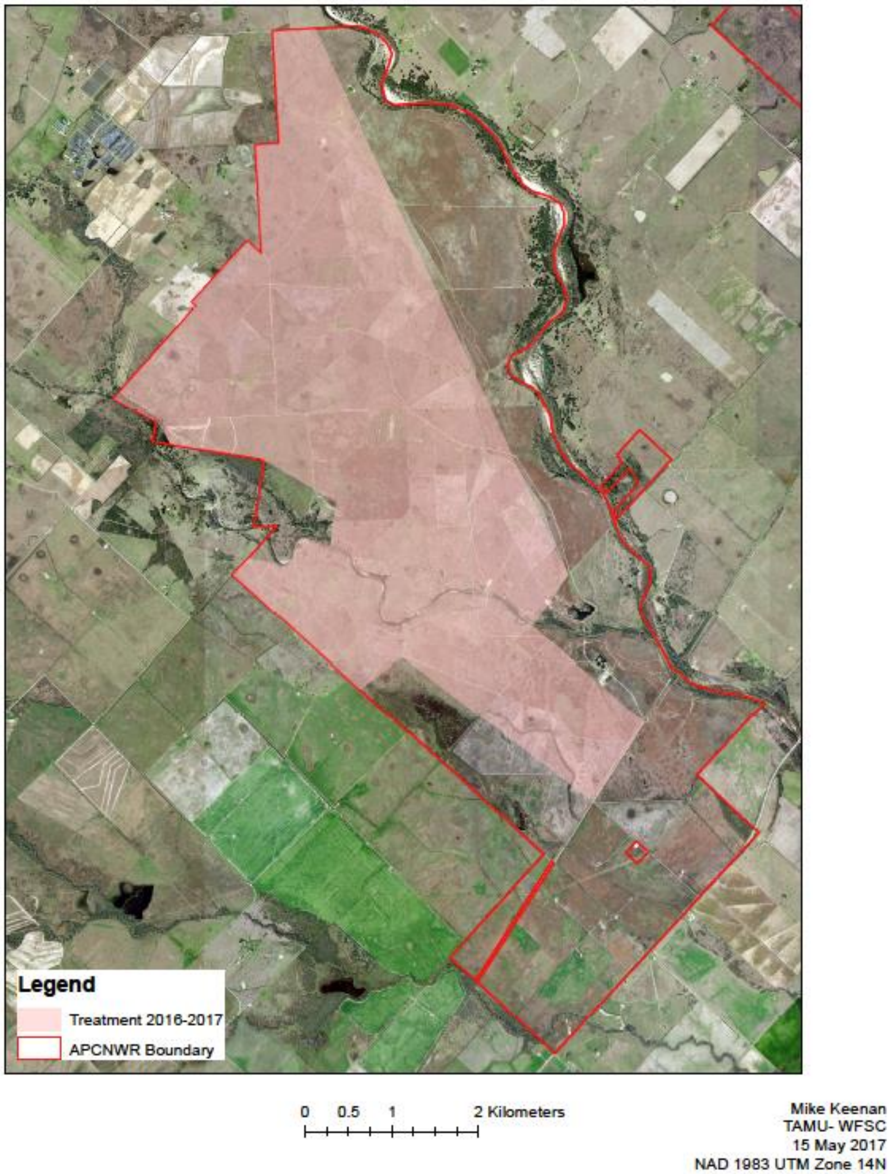

Figure 1.8. *Extinguish Plus*^{TM} treatment on APCNWR in Colorado County, Texas during 2016–2017 to control RIFA (data from Rebecca Chester, APCNWR, Eagle Lake, Texas, January 2017).

METHODS

Northern Bobwhite Trapping

Trap sites were selected by presumed northern bobwhite abundance based on observed breeding calls, but were modified as needed to accommodate broods, pairs, or individuals that were frequently observed while conducting research on the refuge (Fig. 1.9). New sites with potential for trapping success replaced unproductive sites that showed little to no bait utilization between trapping days. Trap sites were pre-baited regularly between trapping seasons (March–August) so when trapping commenced, quail were already using these areas with readily available food. Each trap location received approximately 0.5 kg of mixed grains including cracked corn, millet, milo, and sunflower seed once a week leading up to trapping season (March–October). The use of a variety of grains for bait rather than using milo or another grain exclusively allowed bobwhites to selectively eat preferred grains then slowly consume less preferable grains resulting in consistent access to a food source, even when the bait had been heavily utilized.

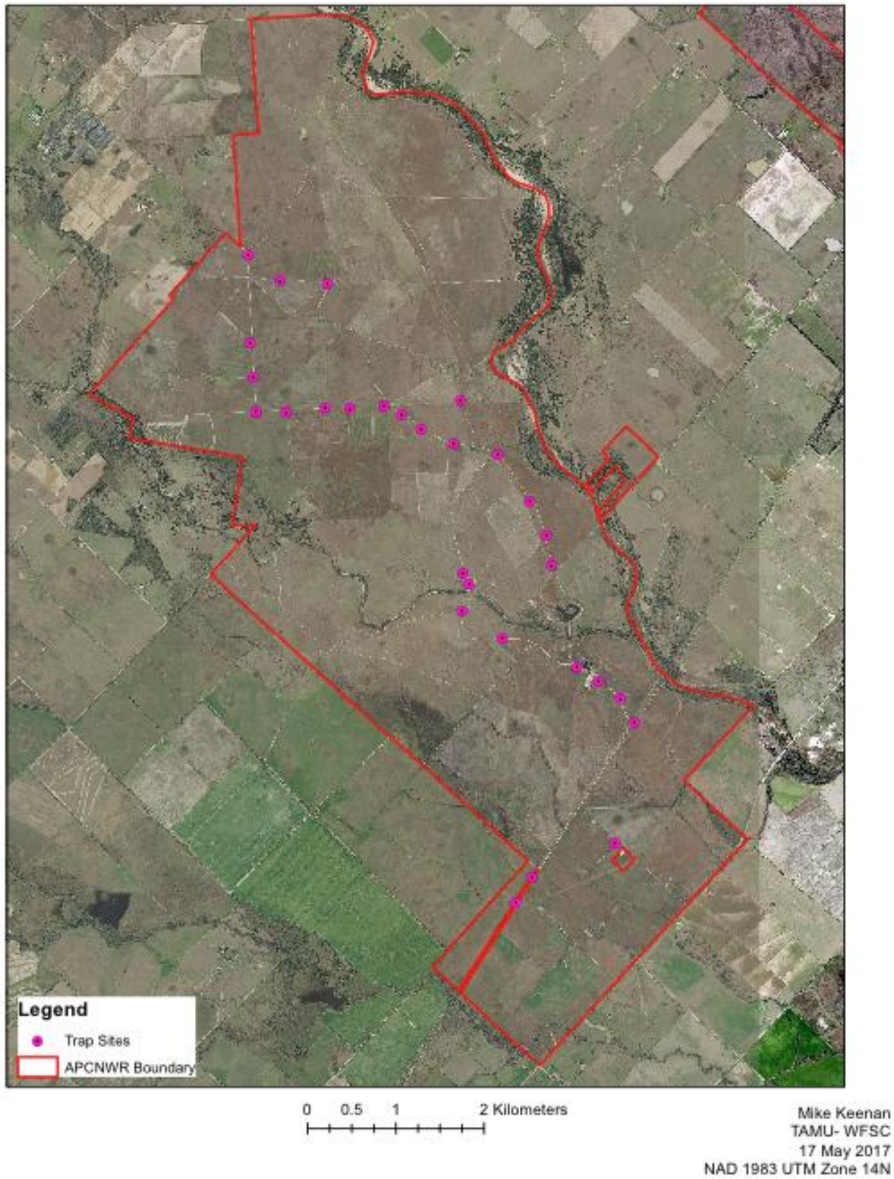

Figure 1.9. Northern bobwhite trap-site locations on APCNWR in Colorado County, Texas, 2017.

Trapping season was based on the bobwhite breeding season and the battery longevity of the radio-transmitter collars. All female bobwhites were fitted with an 8.8 g (approximately 4% body weight) radio transmitter (150 MHz; Wildlife Materials, Carbondale, Illinois). These units are designed to last 248 days (Wildlife Material Inc.

2007). However, previous experience has shown they will only reliably hold a charge for 150–180 days. Trapping began in April 2014 and continued through December 2014 and resumed in March 2015 and continued through July 2015 and started again at the end of March 2016 and continued through October 2016, although I only collared new females through the end of August. Trapping resumed April 2017 and continued through June 2017. This start date ensured that radio-transmitter collar batteries lasted through the nesting season. Quail were trapped using Kniffin modified funnel traps (Reeves et al. 1968), a walk-in style trap similar to that originally described by Stoddard (1946) for trapping quail. To avoid capture and unintended ill effects to the endangered APC, traps in 2017 were staked down with a single 46 cm tent stake driven in and latched in the middle of the trap, between the offset funnel entrances (Fig. 1.10). These traps were placed at the pre-baited sites and baited with approximated 0.5 kg of mixed grains. Traps were checked no less than once an hour to process captured animals. Captured quail were sexed, aged, weighed, banded with a blue aluminum band on the right leg, and collared with a radio-transmitter (adult females only). All northern bobwhites trapped were aged by primary covert color, sexed by head color (Lyons et al. 2012), weighed, banded with a size 7 blue colored band (National Band and Tag Company, Newport, Kentucky) on the right leg. These data, as well as the trap name and any additional notes, were recorded on a data sheet. Non-target species captured were released and a tally was kept each trap day by species.

Figure 1.10. Tent stake used to secure funnel taps and avoid unintended capture of endangered Attwater's prairie chicken.

RIFA Sampling

RIFA sampling was conducted May–August 2014 and April–May 2015 (Caldwell 2015) and again in May–August 2016 and April–May 2017. Sampling took place on the Colorado County unit of the APCNWR. Sampling sites were randomly selected each month and were evenly distributed with 13 sites in the treated area and 13 sites in the non-treated control area for a total of 26 sampling sites/month. Each location contained dual samples with 2 Petri dishes placed 3 m apart. One dish contained sliced hot dogs, which is a standard attractant used for RIFA (Morrow et al. 2015, Caldwell 2015) and the other contained cat food (Meow Mix Tender Centers® dry pelleted cat food [Big Heart Pet Brands, San Francisco, CA]), which Caldwell found to be an effective RIFA bait. Dishes were placed on a dry section of bare ground at each random site. Samples were picked up after 20 minutes of exposure. Ants within the sample were identified by species (Cook et al. 2014). Total RIFA abundance was compared between treated and non-treated sites with a Chi-square test (Ott and Longnecker 2016) performed in JMP 12.0.1 (SAS Institute, Cary, NC).

CHAPTER II

EFFECTS OF RIFA ON NORTHERN BOBWHITE NEST SUCCESS, BROOD SURVIVAL, ABUNDANCE, AND DENSITY

Allen et al. (1995) suggested 3 likely processes by which red imported fire ants (*Solenopsis invicta*, hereafter RIFA) negatively impact northern bobwhite (*Colinus virginianus*) survival and, in a greater sense, widespread population. The processes noted were: (1) direct predation of pipping eggs in the nest, (2) adverse effects on chick survival associated with RIFA stings, and (3) competition for invertebrates as a food source. These suggested impacts of RIFA warrant further investigation.

Pederson et al. (1996) found bobwhite chicks stung by RIFA often exhibited significant behavioral reactions as well as physiological reactions such as swollen-closed eyes, if stung on the eyelid, and impaired movement of some chicks when stung on the feet or legs. These adverse effects could be capable of reducing the fitness of the chicks. Giuliano (1996) found captive northern bobwhite chicks exhibited reduced survival rates when exposed to RIFA for 15 to 60 seconds with 50 to 200 RIFA, respectively. Porter and Savignano (1990) indicated RIFA decreased arthropod species richness by 40%. Morrow et al. (2015) found a greater number of invertebrate individuals and invertebrate biomass in areas treated for RIFA while Caldwell (2015) found no significant difference.

Mueller et al. (1999) conducted a study in the Gulf Prairies and Marshes Ecoregion (GPM) that monitored the nest success and brood survival of bobwhites in areas infested with RIFA and treated with insecticide. This study found no difference in nesting success between the treated and non-treated areas, but did conclude that broods in the treated area had nearly a 300% increase in survival to 21 days. Survival to 21 days for treated and non-treated areas was 60% and 22%, respectively. Similarly, Morrow et al. (2015) observed that the probability of an APC brood surviving to 2 weeks post-hatch was more than doubled in RIFA-treated areas on APCNWR.

With non-treated areas and areas treated for RIFA with *Extinguish Plus^TM^* on the Attwater Prairie Chicken National Wildlife Refuge (APCNWR), the objectives of this part of my study were to determine: (1) the effect of RIFA treatment on northern bobwhite nest success and brood survival, (2) the effect of RIFA treatment on northern bobwhite abundance and density, and (3) to contribute reference data for northern bobwhite in the Gulf Prairies and Marshes Ecoregion.

METHODS

Northern Bobwhite Nest Success and Brood Survival

From June 2016 to August 2016, radio-collared females were tracked by radio telemetry ≥4 times per week with the use of a large roof-mounted and a handheld Yagi antenna. I walked in on females once they had been found in the same location for 3–4 times, consecutive tracking sessions to determine if the hen was on a nest and flushing was avoided if possible. If a nest was found, it was marked on a Garmin handheld GPS, and flagging tape was tied to nearby, tall vegetation and a record was kept of how many meters (≥10 m) the tape was from the nest and a compass direction. Marking was done so that a nest could be relocated once it hatched or was destroyed. Nesting females were tracked once or twice daily ≥4 times per week. Once a female was located off the nest for 3–4 consecutive tracking sessions, the nest was checked to determine if the brood had hatched or failed. For successful nests, notes were taken on the location of the nest, the number of hatched eggs, the number of unhatched eggs, and the date of hatch. For unsuccessful nests, notes were taken on location of the nest, the reason for failure, the number of unhatched or destroyed eggs if possible to determine, and the date it was destroyed. Once it was determined that a nest was successful, the female and brood was tracked twice daily ≥4 times per week and the number of chicks surviving in the brood was recorded if the female and brood were sighted along a road or captured at a trap site. Radio telemetry location data was logged with Google Earth 7.1 (Google Inc., Mountain View, California), and pertinent information was added to the notes section of the Placemark (time, date, brood information, location description). Any transmitter that emitted a mortality signal was checked immediately. If the collar was recovered, the site was examined for probable cause of mortality and the female was listed as deceased. Because all females killed with broods were within 1 week of hatching, I also considered the brood to be dead. Nest success and brood survival were compared between the treated and non-treated areas (areas were mapped on ArcMap 10.4.1; Figs. 1.6, 1.7, 1.8) with a Student's *t*-test Ott and Longnecker 2016). Nest success was determined by nests hatched divided by total nests. A brood was considered to have survived if at least 1 chick remained at 3 weeks of age. Brood survival was thus, surviving broods divided by total broods.

Northern Bobwhite Abundance and Density

Relative bobwhite abundance was calculated each June from mark and recapture data with a Lincoln-Petersen Estimator (Pierce et al. 2012). Recaptured northern bobwhites were identified by their leg band and released back into the same area. I assumed that captured birds were not trap-happy or trap-shy as determined by frequency of recaptures. Abundance was estimated for the area affected by the traps in both treated and non-treated areas. Density was calculated by estimating the effective range of the trap sites. Maximum width of minimum convex polygon (MCP) range (see Chapter III) was measured for each nesting season female (regardless of treatment) without a brood in 2016, and the mean maximum width (365 m) was considered to be the estimated diameter of a trap's effective range. Trap sites were mapped in ArcMap 10.4.1 (ESRI, Redlands, California) as treated sites and non-treated sites and the buffer tool was used to create a circular buffer around each trap with a diameter of the mean maximum MCP. Trap buffers were dissolved together with the dissolve tool to eliminated overlapping areas (Fig. 2.1, 2.2). Total effective trapping range was calculated by using the calculate geometry tool on the dissolved buffers. To calculate the estimated northern bobwhite density in the treated and non-treated areas, I divided each area's relative abundance by the total effective trapping range of the traps in that area.

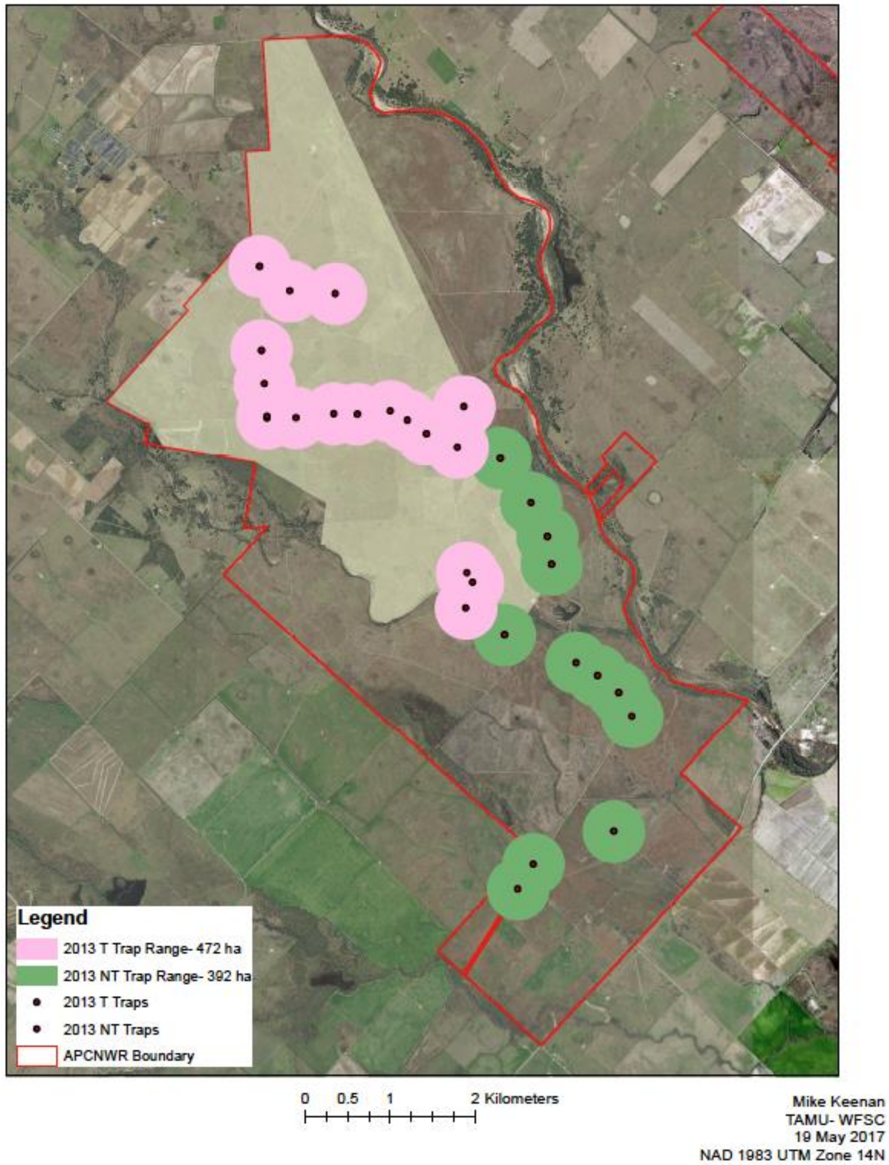

Figure 2.1. Effective trapping range for treated (472 ha) and non-treated (392 ha) areas on the APCNWR in Colorado County, Texas, 2013.

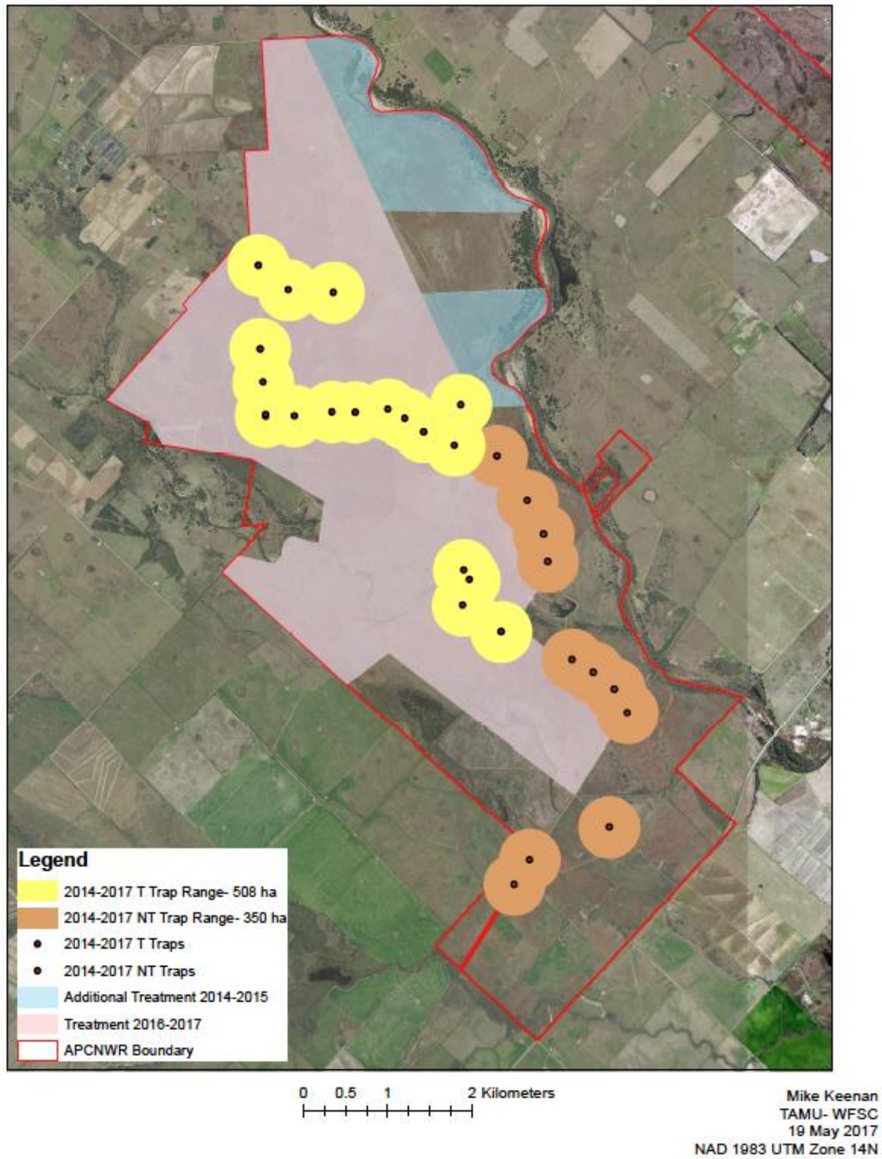

Figure 2.2. Effective trapping range for treated (508 ha) and non-treated (350 ha) areas on the APCNWR in Colorado County, Texas, 2014–2017.

RESULTS

RIFA Abundance and Treatment

The first year that RIFA were sampled on the APCNWR, 2014, the *Extinguish Plus*^{TM} treatment seemed to work as advertised (Caldwell 2015; Table 2.1).

RIFA/sample (pooled for both baits; however, in most cases, RIFA were found in 1 bait only) was 79.7% lower in the treated area than the non-treated area which is even higher than the 75% reduction advertised (Extinguish Plus 2009). The following year, 2015, the treated area had a 61.7% reduction in RIFA/sample as compared to that year's control. However, in 2016 the treated area had a higher RIFA abundance than the non-treated area. RIFA/sample indicated an 83.5% increase of RIFA in the treated as compared to the non-treated area. In 2017, RIFA abundance was at a record low in both areas with a 94.6% reduction of RIFA in the treated area compared with the control, though this year's sampling only included April and May data.

Table 2.1. RIFA abundance (both baits [hot dog and cat food] pooled) on APCNWR Colorado County, Texas, 2014–2017.

Year	Treatment	RIFA abundance	Samples	RIFA/ sample	Treatment RIFA reduction (%)	RIFA reduction compared to previous year's treated area (%)	RIFA reduction compared to 2014 non-treated (%)
2014	Treated	1,315	125	10.5	79.8	N/A	N/A
	Non-treated	5,956	115	51.8			
2015	Treated	620	144	4.3	61.8	59.1	91.7
	Non-treated	1,303	116	11.2			
2016	Treated	3,068	130	23.6	-83.6	-448.1	54.4
	Non-treated	1,672	130	12.9			
2017	Treated	10	52	0.2	94.7	99.2	99.6
	Non-treated	184	52	3.5			

For the long-term, RIFA abundance has decreased in both areas (Table 2.1). Compared to 2014, non-treated RIFA abundance has decreased every year. The 2014 treated area had a 79.7% reduction, 2015 had a 91.7% reduction, 2016 RIFA abundance increased, but was still a 54.4% reduction compared to 2014, and 2017 was a 99.6% cumulative reduction since 2014. In addition to a reduction in the treated area RIFA abundance, larger areas were treated prior to 2015–2017 RIFA sampling compared to 2014 (Fig. 2.3). Therefore there was a greater rate of reduction on a larger number of hectares, meaning the refuge as a whole (3,790 ha) experienced an even greater reduction in RIFA abundance compared to previous years with smaller treatment areas.

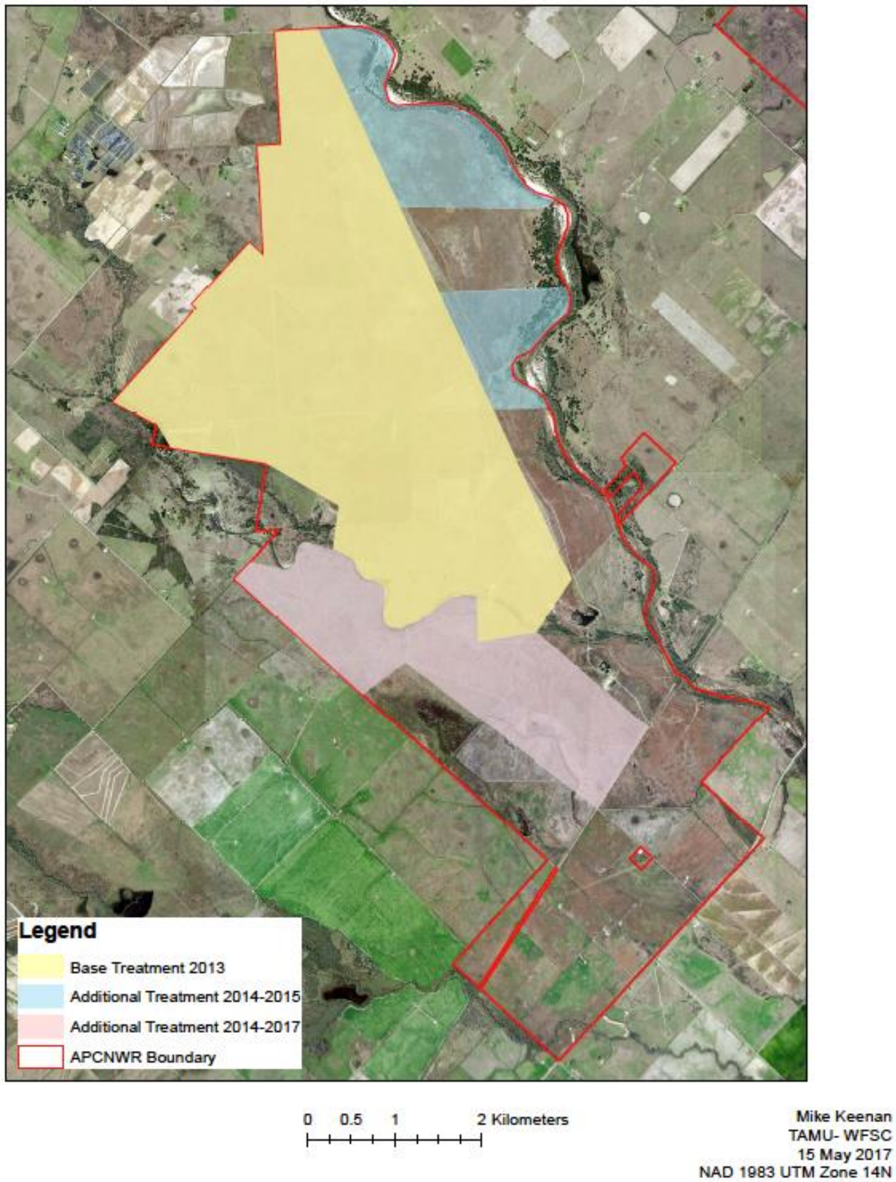

Figure 2.3. Map of all *Extinguish Plus*™ treatments from 2013–2017: 2013 treatment is yellow; 2014–2015 is yellow, red, and blue; and 2016–2017 is yellow and red.

Northern Bobwhite Nest Success and Brood Survival

During the 2016 nesting season, 12 nests were located and monitored (Table 2.2). Of these nests, 9 were in the treated and 3 were in the non-treated area. The treated had a higher nest success (66.7%) than the non-treated area (33.3%). The treated area nests produced 106 eggs of which 61 (57.6%) hatched, 12 (11.3%) were unhatched, and 33 (31.1%) were destroyed (nest predation, flooding, or predation of hen). The hatchability of the treated area eggs that were not destroyed was 83.6%. The non-treated area produced 21 eggs plus 1 nest in which eggs were not counted before it was destroyed by a predator. Excluding the nest that was destroyed before eggs could be counted, the non-treated area produced 21 eggs of which 9 (42.9%) hatched, 0 were unhatched, and 12 (57.1%) were destroyed or the female was killed off the nest. Egg hatchability, excluding the uncounted nest, was 100%. Average clutch size on the APCNWR in both areas was 11.6 eggs with the largest nest containing 18 eggs.

Table 2.2. Nesting data for northern bobwhites on APCNWR in Colorado County, Texas, 2016.

Treatment	*n*	Hatched nests	Failed nests	Total eggs	Eggs hatched	Eggs not hatched	Eggs destroyed/ female killed off nest	Egg hatchability (%)
Treated	9	6 (66.7%)	3 (33.3%)	106	61	12	33	83.6%
Non-Treated	3	1 (33.3%)	2 (66.7%)	21[a]	9	0	12[a]	100%
Total	12	7 (58.3%)	5 (41.7%)	127[a]	70	12	45[a]	85.4%

[a]One non-treated nest was destroyed before nest size was observed.

During the 2016 nesting season, 8 broods were monitored (Table 2.3). These broods were from the 7 successful nests (Table 2.1) and from 1 additional brood that had hatched from a non-located nest (collared female was located with a >1-week-old brood the day following her capture and tagging). Of the 8 broods monitored, 7 were in the treated and 1 was in the non-treated area. In the treated area, 4 (57.1%) broods survived to 7 days, 4 (57.1%) broods survived to 14 days, and 3 (50%) broods survived to 21+ days. One of the 4 broods to survive 14 days was not tracked long enough because the study ended before it could be determined if it had survived to 21+ days. Thus, it was excluded from the percentage surviving to 21+ days. In the non-treated area, only 1 female with a collar hatched a brood. This brood was killed before it reached 7 days of age. Thus, the non-treated area had 0 broods survive to 7, 14, or 21+ days.

Table 2.3. Brood survival data for northern bobwhites on APCNWR in Colorado County, Texas, 2016.

Treatment	*n*	Survival to 7 days	Survival to 14 days	Survival to 21+ days
Treated	7	4 (57.1%)	4 (57.1%)	3 (50.0%)[a]
Non-treated	1	0 (0.0%)	0 (0.0%)	0 (0.0%)
Total	8	4 (50.0%)	4 (50.0%)	3 (42.9%)[a]

[a]One treated area brood was not tracked lone enough to determine survival to 21+ days.

Northern Bobwhite Abundance and Density

June 2014 had an estimated bobwhite relative abundance of 83 (95% CI = 71–95) individuals (54 [95% CI = 48–60] treated and 29 [23–35] non-treated); June 2015 had an estimated relative abundance of 82 (95% CI = 64–100) bobwhites (49 [95% CI = 35–63] treated and 33 [95% CI = 17–49] non-treated); June 2016 had an estimated relative abundance of 87 (95% CI = 47–108) bobwhites (60 [95% CI = 32– 88] treated and 27

[95% CI = 15–42] non-treated); and May 2017 had an estimated relative abundance of 53 (95% CI = 36–70) bobwhites (43 [95% CI = 30–56] treated and 10 [95% CI = 8–12] non-treated) in the areas influenced by my traps (Table 2.4). Total abundance in May 2017 was lower than June 2014, the preliminary abundance calculation for the study. No banded or radio-tagged bobwhites captured in the treated areas were recaptured in or observed to spend significant time in a non-treated area, although 3 females trapped on roads between treated and non-treated areas were found once, once, and twice, respectively in the treated area. No banded or radio-tagged bobwhites captured in the non-treated areas were recaptured in or observed to move into a treated area.

Table 2.4. Abundance and density estimates for northern bobwhites on APCNWR in Colorado County, Texas, 2014–2017.

Year	Location	June[a] abundance	95% CI	Trap sampling area (ha)	Density (quail/ha)	Total area (ha)	Estimated total abundance
2014	Treated	54	48–60	472	0.11	1,491	171
	Non-treated	29	23–35	392	0.07	2,299	170
	Total	83	71–95	864	0.10	3,790	341
2015	Treated	49	35–63	508	0.10	2,383	230
	Non-treated	33	17–49	350	0.09	1,407	133
	Total	82	64–100	858	0.10	3,790	363
2016	Treated	60	32–88	508	0.12	2,383	281
	Non-treated	27	15–42	350	0.08	1,407	109
	Total	87	47–108	858	0.10	3,790	390
2017	Treated	43	30–56	508	0.09	2,051	174
	Non-treated	10	8–12	350	0.03	1,739	50
	Total	53	36–70	858	0.06	3,790	223

[a]May abundance used for 2017.

The treated area had a statistically (*P* = 0.042) higher bobwhite density than the non-treated area. On average, the treated area density estimate was 76.6% higher than the non-treated area for the 4-year period (2014–2017; Table 2.4). When density estimations were extrapolated to estimate total abundance in the treated and the non-treated, the treated area contained more bobwhites every year (2014 was nearly equal). My total quail abundance estimation assumed that all areas of the refuge were of equal habitat quality to the area that was trapped.

DISCUSSION

RIFA Abundance and Treatment

Extinguish Plus^{TM} was largely effective at reducing RIFA abundance. There was a 91.7% reduction of RIFA numbers in the treated area after 2 years of treatment. However, the flood that occurred in April 2016 appeared to have an effect on the treatment. In 2016, RIFA abundance was at its highest in the treated area and also was higher than it was in the non-treated area. RIFA are known to raft up and float to survive flooding events (Adams et al. 2011). It also is likely that RIFA from non-treated areas north of the treated area rafted south to the treated area during the flood. Once the water receded, RIFA abundance increased in the treated area. This catastrophic flooding event followed by a freezing event (7.8 C) during winter of 2016 also may explain why the RIFA population crashed as shown by extremely low abundance (99.6% and 93.2% reduction for treated and non-treated areas, respectively from 2014 to 2017) during the 2017 sampling season.

One issue that effective RIFA treatment faces is scale of treatment. During the past 3 years, ≥2,051 ha have been treated on the APCNWR. However, the treated area is surrounded on all side by non-treated areas. With adjacent RIFA populations, there is always an opportunity for RIFA to reestablish between treatments. Flooding represents an additional issue for RIFA treatment. Flood waters force RIFA to reestablish in higher ground, which in this case was the treated area. These adjacent RIFA populations create a serious challenge to RIFA reduction or eradication from an area as shown after the heavy rainfall in April 2016.

Northern Bobwhite Nest Success and Brood Survival

Although nest success on the treatment area (67%) was higher than the non-treated area (33%), sample size, especially in the non-treated area, was too small to make any significant statements about the effect of treatment on nest success. Egg hatchability, 83.6% (no confidence interval because this was only 1 season of data) in my treated area was lower than found by Scott et al. (2013) in non-treated Brooks County, 91.1% (95% CI 86.2–93.9%). My treated area egg hatchability also was lower than treated nests (91.7%) reported by Mueller at al. (1999) in Refugio County. Egg hatchability in my treated and non-treated areas combined was slightly higher (85.3%), but still below Scott et al.’s (2013) confidence interval. This may have been influenced by the extremely wet conditions experienced during my study. Reduced hatchability of APC eggs has also been observed during unusually wet conditions (M. Morrow, APCNWR, personal communication). Average clutch size (11.6 eggs) on the APCNWR was consistent (12, 95% CI 11.5–12.4) with that observed by Scott et al. (2013). Nest success (58.3%) on the APCNWR, was toward the upper confidence limit of Scott et al.’s (2013) findings, 50.9% (95% CI 43.4–58.4%).

Mueller et al.’s (1999) study differed from my study in that nests were spot treated while in my study area, entire pastures were treated aerially. Once a chick left a treated nest, it was in the non-treated area, though Mueller et al. (1999) still considered them to be treated area chicks. Unlike Mueller et al. (1999) study, I never observed RIFA in the treated and non-treated areas on any of the 5 failed nests or the 12 unhatched eggs in successful nests. The low number of females nesting in the non-treated area was possibly influenced by the following observed issues: (1) lower bobwhite density in the non-treated area, (2) smaller area of the non-treated area, and (3) greater issue with flooding in the non-treated. The nesting success on the refuge as a whole is relatively consistent with the observation of Scott et al. (2013) in non-treated Brooks County and Mueller et al. (1999) in Refugio County.

The sample size of the non-treated broods also was too small to make any statement about a difference between treatment and the control. Brood survival in my treated area to 3 weeks was 50.0%. The only successful brood in the non-treated area was killed before 1 week. Survival (50.0%) of broods in my treated area to 3 weeks was lower than the treated area broods reported by Mueller et al. (1999), where only 22.0% of broods experienced the death of all chicks. Mueller et al. (1999) attributed 48.8% chick mortality to RIFA; however, I did not flush females with broods and therefore have no data on chick mortality.

Northern Bobwhite Abundance and Density

The lower bobwhite density and abundance observed in the non-treated area after April 2016 was likely due to the catastrophic event-related mortality (flooding) and lower elevation of the non-treated (Fig. 1.5). Bobwhite density between treated and non-treated areas had the largest discrepancy in 2016 when catastrophic flooding likely killed northern bobwhites (1 female was drowned in this area) and forced the survivors to immigrate to higher ground in areas off the refuge (Table 2.4). In 2017, bobwhite populations were lower than they were when the study began in 2014. The low 2017 abundances and density seem to indicate that extreme rainfall during April 2016 affected both quail abundance and density. The abundance estimation was lower in 2017 than 2014, and the 2017 estimation was calculated during May rather than June, thus including bobwhites that will die during June 2017. June 2017 abundance estimation would likely be lower than the May 2017 abundance that I calculated. The significantly higher density of bobwhites for the 4 years of study could possibly be due to RIFA treatment and/or differences in habitat between the treated and non-treated areas.

CHAPTER III

EFFECTS OF RIFA ON NORTHERN BOBWHITE MOVEMENTS AND RANGE

Few data are available for northern bobwhite (*Colinus virginianus*) movements and ranges in the Gulf Prairies and Marshes Ecoregion (GPM). Perez (2007) indicated that Lehmann (1984) working in Colorado County between 1938 and 1940 banded 249 northern bobwhites. Sixteen quail had moved 0.48–17 km with an average movement from the banding site of 1.9 km (Lehmann 1984, Perez 2007). Perez (2007) confirmed these movements were consistent with reports from other regions with annual ranges of 4–32 ha. However, the modern-day fragmentation of habitat in the GPM may force northern bobwhites to range further to find required resources (Puckett et al. 2000, Oakley et al. 2002, Perez 2007). Lehmann (1984) also described spring to fall movements in an unspecified portion of the Rio Grande Plain (Table 3.1). The mean movement from banding site to recovery site in 1942 was 201 m (sample size = 20) and 559 m in 1943 (sample size = 131). In 1943, Lehmann (1984) recorded a maximum movement of 12.1 km. This gap in the data for the GPM ecoregion provides the opportunity to create reference data for this region and to compare ranges and movements on this highly fragmented landscape to those in other portions of the northern bobwhite range. Thus, the objectives of this part of my study were to: (1) evaluate the effects of red imported fire ants (RIFA, *Solenopsis invicta*) treatment on northern bobwhite movements and range and (2) contribute additional bobwhite movement and range data for the GPM.

Table 3.1. Northern bobwhite spring to fall movements in Rio Grande Plain of Texas, 1942–1943 (Adapted from Lehmann 1983).

Year	*n*	Mean distance (m)	Longest distance (m)
1942	6	0	
	4	78–114	
	6	220–373	
	4	≥402	
Total	20	201	N/A
1943	8	0	
	26	≤183	
	32	402	
	51	402–805	
	5	≥1,609	
Total	131	559	12,070

METHODS

Northern Bobwhite Movements and Range

During June 2016 to August 2016 and April 2017 to June 2017, radio-collared females on the Attwater Prairie Chicken National Wildlife Refuge (APCNWR) were tracked by radio telemetry ≥4 times per week with the use of a large roof-mounted and a handheld Yagi antenna. I walked in on females once they had been found in the same location for 3–4 consecutive tracking sessions either to determine if they were nesting or if they had been killed. If a nest was found, it was marked on a Garmin handheld GPS, and flagging tape was tied to nearby, tall vegetation and a record was kept of how many meters (≥10 m) the tape was from the nest and a compass direction. Marking was done so that a nest could be relocated once it hatched or was destroyed. Nesting females were tracked once or twice daily ≥4 times per week. Nesting females were monitored, and if they were located off the nest for 3–4 consecutive tracking sessions, then the nest was checked to determine if the brood had hatched or failed. Once it was determined that a nest was successful, the female with the brood was tracked twice daily ≥4 times per week and the number of chicks surviving in the brood was recorded if the opportunity presented itself. Radio telemetry location data was logged with Google Earth 7.1 (Google Inc., Mountain View, CA), and pertinent information was added to the notes section of the Placemark (time, date, brood information, location description).

Northern bobwhite consecutive movements were calculated to better understand the detailed movements between observed locations (Millsphaugh et al. 2012). These were not consecutive daily movements, but were distances between consecutive observed locations. The distance between consecutive radio telemetry locations and the distance from banding trap site to furthest location from the trap site were measured in ArcMap 10.4.1 (ESRI, Redlands, Califorina). Mean consecutive movement was calculated for each radio-tagged female. These data were pooled and compared across treatment and non-treatment for pre-nesting (April through May 2017) females, nesting season (mid-May to August 2016) females with a brood, and nesting season females without a brood.

The minimum convex polygon (MCP) method was used to determine the range of the females, with and without a brood (Silvy et al. 1979, Millsphaugh et al. 2012). This method was selected because it is comparable between studies (Harris et al. 1990), which is useful when the goal is to create reference, baseline data. This method also is more robust than other methods with a lower number of locations, as we have in this study. Northern bobwhite ranges were calculated in ArcMap 10.4.1 (ESRI, Redlands, CA) using the Minimum Bounding Geometry tool with the convex hull option to create an MCP range. Females with >15 locations were included in the range analysis. I determined the number (15 locations) of locations needed to describe a range by graphing range area by the number of relocations (Chavarria et al. 2017). Treated and non-treated area data were mapped on ArcMap 10.4.1 (Figs. 1.6, 1.7, 1.8) to compare movements and range in the 2 areas. A Student's *t*-test was used to determine if there was a difference between the mean consecutive movement, maximum movement from trap, and seasonal range in the treated and non-treated areas (Ott and Longnecker 2016). An ANOVA with the Tukey-Kramer procedure was used to compare pre-nesting season females, nesting season females with a brood, and nesting season females without a brood. These tests were run in the software program JMP 12.0.1 (SAS Institute, Cary, NC).

RESULTS

Northern Bobwhite Movements and Range

The mean consecutive movement for all females observed from 2016–2017 (Table. 3.2) was 189.1 m (SD = 183.5 m). I found no difference ($P = 0.275$) in consecutive movements between the treated ($\bar{X}$ = 167.5 m, SD = 129.3 m) and non-treated areas ($\bar{X}$ = 191.3 m, SD = 188.8 m). However, there was a difference (P = <0.001) by category. Nesting season females without a brood ($\bar{X}$ = 224.5 m, SD = 227.0

m) had larger movements (*P* = <0.001) than nesting season females with a brood ($\bar{X}$ = 129.1 m, *SD* = 109.2 m) and larger movements (*P* = 0.002) than pre-nesting females ($\bar{X}$ = 168.0 m, *SD* = 184.2 m).

Table 3.2. Consecutive movements for northern bobwhites on APCNWR, 2016–2017.

Classification	Treatment	*n* Quail	*n* Consecutive locations	Mean consecutive movement (m)	*SD*
Pre-Nesting	Treated	13	133	170.3	109.6
	Non-treated	3	44	161.1	109.9
	Total	16	177	168.0	109.5
Nesting Season with brood	Treated	4	126	127.1	107.9
	Non-treated	1	2	260.3	157.3
	Total	5	128	129.1	109.3
Nesting Season without brood	Treated	18	271	231.3	233.9
	Non-treated	3	34	170.2	153.2
	Total	21	305	224.5	227.0
All	Treated	35	530	167.5	129.3
	Non-treated	7	80	191.3	188.8
	Total	42	610	189.1	183.5

The mean maximum movement form the trap site during 2016–2017 (Table 3.3) was 594.8 m (*SD* 372.7). Longest maximum movement from trap sites was 1,491 m, made by a nesting season female without a brood in the treated area. I found no difference (*P* = 0.179) in maximum movement from trap site between the treated ($\bar{X}$ =

623.8 m, *SD* = 388.4 m) and non-treated ($\bar{X}$ = 459.8 m, *SD* = 252.3 m) areas. There was a difference (*P* = 0.004) of maximum movement between classification. Nesting season females without a brood ($\bar{X}$ = 772.1 m, *SD* = 418.9 m) had a larger (*P* = 0.001) mean maximum movement than pre-nesting females ($\bar{X}$ = 385.7 m, *SD* = 182.0 m).

Table 3.3. Maximum movement from trap site for northern bobwhites on APCNWR, 2016–2017.

Classification	Treatment	*n* Quail	Mean longest movement from Trap (m)	*SD*	Longest movement from trap (m)
Pre-Nesting	Treated	13	368.7	149.7	629
	Non-treated	3	459.3	322.5	805
	Total	16	385.7	182.0	805
Nesting Season with brood	Treated	4	557.9	301.0	950
	Non-treated	1	365.0	N/A	365
	Total	5	532.2	266.9	950
Nesting Season without brood	Treated	18	822.7	421.1	1491
	Non-treated	3	468.5	294.1	710
	Total	21	772.1	418.9	1491
All	Treated	21	623.8	388.4	1491
	Non-treated	5	459.0	252.3	805
	Total	42	594.8	372.7	1491

The mean seasonal MCP range for all females observed from 2016–2017 (Fig. 3.4) was 23.7 ha (*SD* = 20.6 ha). I found no difference (*P* = 0.783) in seasonal range between the treated ($\bar{X}$ = 23.2 ha, *SD* = 21.2 ha) and non-treated areas ($\bar{X}$ = 26.4 ha and *SD* = 19.2). However, there was a difference (*P* = 0.008) by category. Nesting season females without a brood ($\bar{X}$ = 38.7 ha, *SD* = 21.7 ha; Fig. 3.1) had larger ranges (*P* = 0.042) than nesting season females with a brood ($\bar{X}$ = 11.9 ha, *SD* = 5.3 ha; Fig. 3.2) and larger ranges (*P* = 0.013) than pre-nesting females ($\bar{X}$ = 15.7 ha, *SD* = 16.0 ha; Fig. 3.3). The mean range of females from all classifications was 23.7 ha (*SD* = 20.6). Then smallest range (3.9 ha) belonged to a pre-nesting season female and the largest range (75.1 ha) belonged to a nesting season female without a brood.

Table 3.4. Seasonal MCP ranges (ha) of northern bobwhites on APCNWR, 2016–2017.

Classification	Treatment	*n* Quail	Mean *n* locations	Max. range	Min. range	Mean range	*SD*
Pre-Nesting	Treated	10	16.0	46	3.9	12.1	12.6
	Non-treated	3	18.7	54.2	10.5	27.8	23.3
	Total	13	16.6	54.2	3.9	16	23.7
Nesting Season with brood	Treated	4	33.5	17.6	7.3	11.9	5.3
	Non-treated	0	N/A	N/A	N/A	N/A	N/A
	Total	4	33.5	17.6	7.3	11.9	5.3
Nesting Season without brood	Treated	9	23.2	75.1	19.5	40.6	22.2
	Non-treated	1	21.0	22.0	22.0	22.0	N/A
	Total	10	23.0	75.1	19.5	38.7	21.7
All	Treated	23	21.9	75.1	3.9	23.2	21.2
	Non-treated	4	19.3	54.2	10.5	26.4	19.2
	Total	27	21.5	75.1	3.9	23.7	20.6

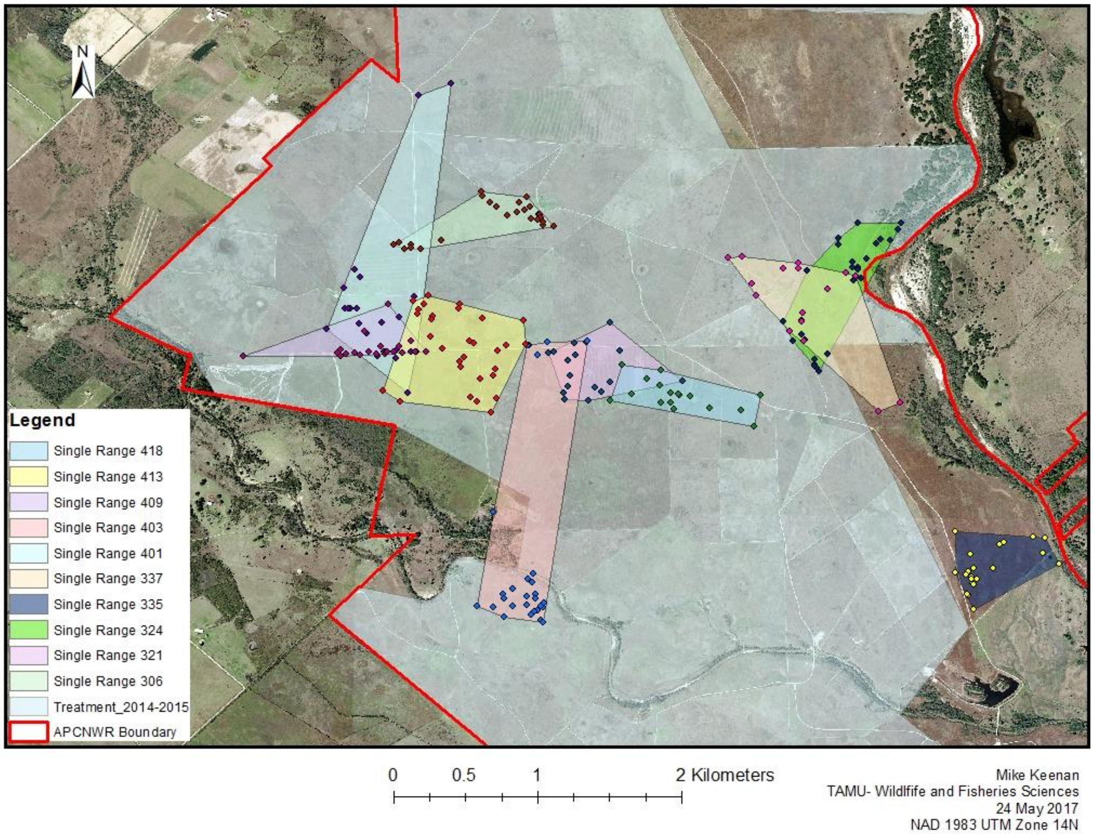

Figure 3.1. MCP ranges of nesting season females without a brood on APCNWR Colorado County, Texas, 2016.

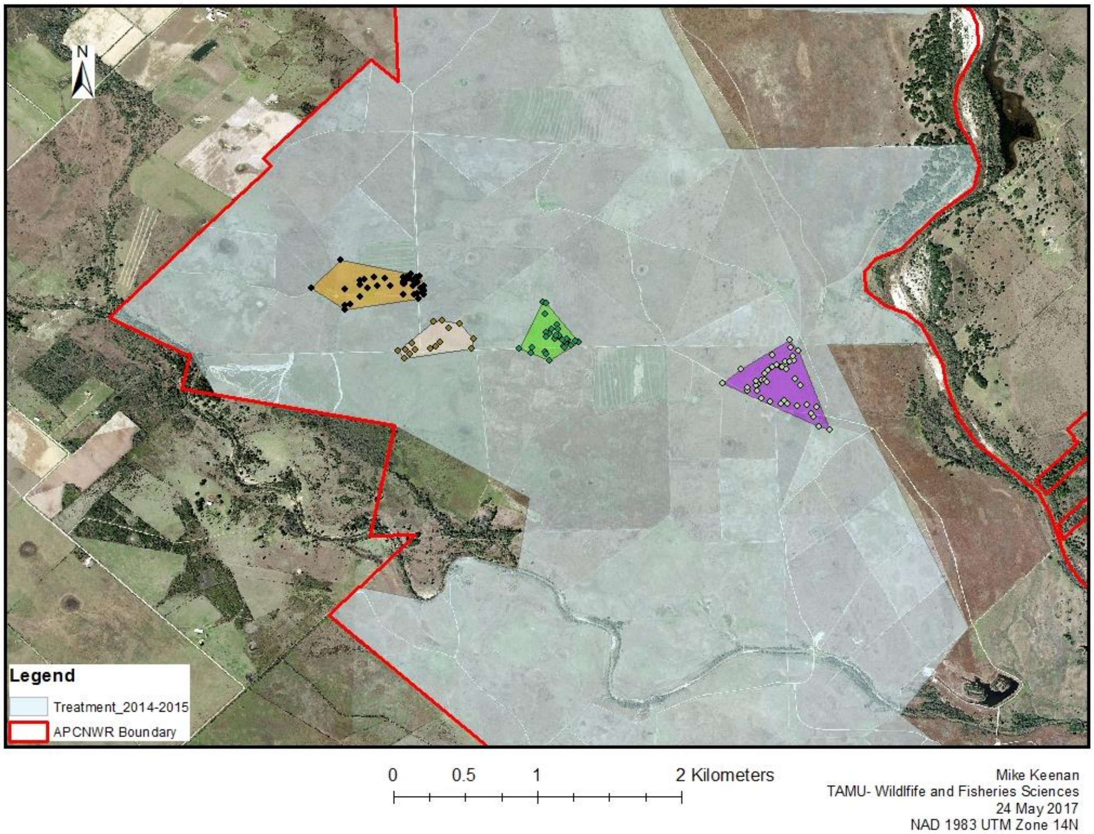

Figure 3.2. MCP ranges of nesting season females with a brood on APCNWR Colorado County, Texas, 2016.

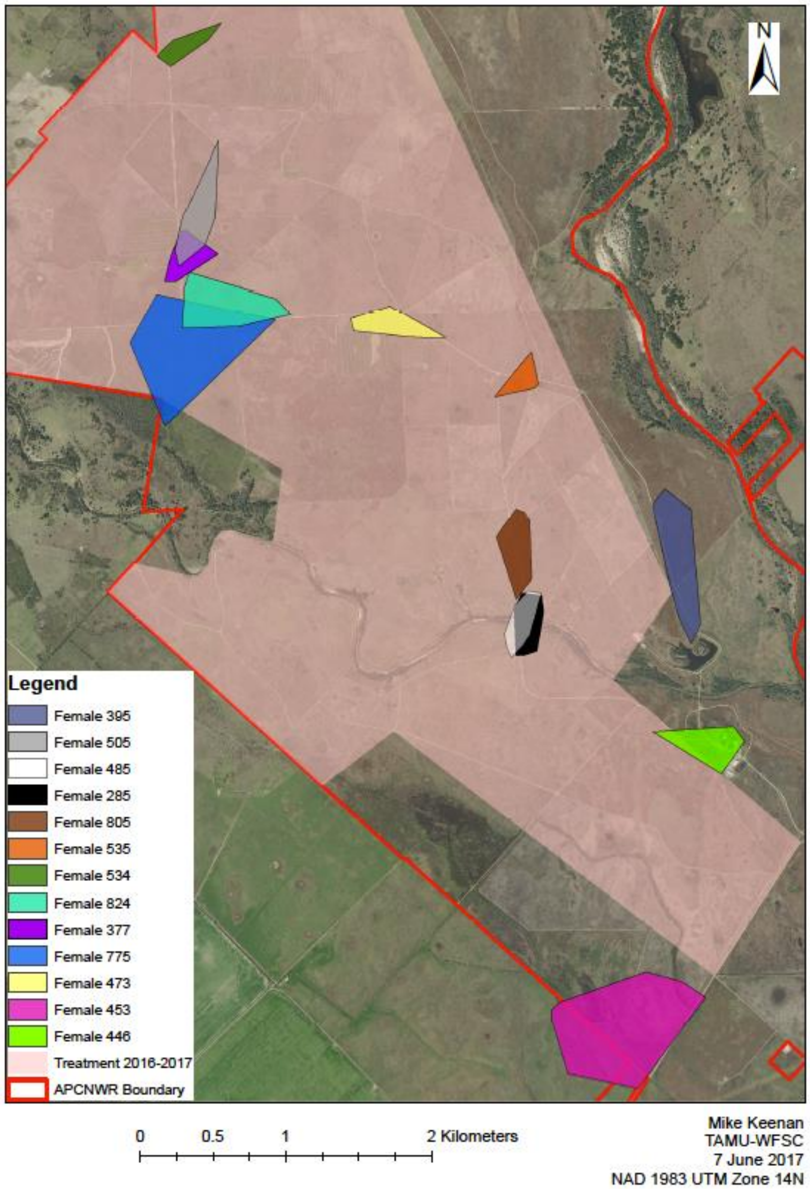

Figure 3.3. MCP ranges of pre-nesting females on APCNWR Colorado County, Texas, 2017. Individual locations are not shown due to overlap of ranges.

DISCUSSION

Northern Bobwhite Movements and Range

Females had equal consecutive movements in the treated area to the non-treated area. This indicates that the RIFA do not affect how the bobwhites are moving around and using their habitat. Nesting season females without a brood had larger movements than females with broods and females during the pre-nesting season. The nesting season females without broods are no longer tied to nests or broods and can move freely looking for resources and avoiding predators. Females with broods are likely making smaller movements to minimize the brood's exposure to predators and because of the limited movement of small chicks. Pre-nesting females are building nutrient supplies, building nests, and preparing to lay eggs and therefore are tied closely to the areas of their nests.

Maximum movements were consistent with consecutive movements; there was no difference between treated and non-treated and the nesting season females without a brood had a larger movement. These results can be explained by the same reasoning as the consecutive movements. The mean maximum movement I observed (594.8 m) was comparable to Lehmann's (1983) 558.7 m. My furthest recorded movement from the banding site (1,491 m) was considerably smaller than Lehmann (1983) who recorded a movement of 12,070 m (Table 3.1), 8.1 times larger than mine.

With larger movements, the nesting season females without a brood also moved within larger seasonal ranges. Broods and pre-nesting females remained in a small, more localized area to protect the broods and to prepare for nesting, respectively. I observed 7 females with season ranges >32 ha, the high end of observed northern bobwhite ranges Perez (2007). Also, the mean range of nesting females without a brood, a value that is likely more representative of the annual range, was 20.9% larger than 32 ha found for females with broods and pre-nesting females. The largest seasonal range I recorded was 75.1 ha. My data indicate that ranges are larger in the GPM than previously observed for other areas of Texas.

CHAPTER IV

EFFECTS OF RIFA ON EASTERN COTTONTAIL NUMBERS

Another important wildlife species that resides in the Gulf Prairies and Marshes Ecoregion (GPM) is the eastern cottontail (*Sylvilagus floridanus*). Studies have shown that RIFA have greater effects on mammals giving birth to altricial young (such as the eastern cottontail) and a lesser effect on mammals giving birth to precocial young (Johnson 1961, Hill 1972, Allen et al. 2004). Negative effects of red imported fire ants (RIFA, *Solenopsis invicta*) on eastern cottontails have been documented in multiple regions infested by RIFA (Hill 1972, Allen 1993, Drees 2013). Hill (1972) studied pen-raised eastern cottontails in Alabama for 5 years between 1963 and 1967. During his study, RIFA destroyed 16 full and 2 partial litters of 101 litters in 232.3 m^2 pens, destroyed 41 full and 1 partial litter of 81 litters in 3,716.1 m^2 pens, and destroyed 10 full litters of 43 in large enclosures (2.43 to 16.12 ha). Nestling eastern cottontails were found dead in the nest with numerous bite pustules on their skin and were being fed on by RIFA.

With documented negative effects such as these stated above, one would expect RIFA treatment would be beneficial to eastern cottontails and their numbers would be greater in treated areas than in non-treated areas, assuming no other differences between the areas. Thus, the object of this portion of my study was to evaluate the effect of RIFA treatment on eastern cottontail numbers.

METHODS

Eastern Cottontail Numbers

A record was kept of eastern cottontail sightings year around while research was performed on the Attwater Prairie Chicken National Wildlife Refuge (APCNWR) from 2015–2017. Cottontail surveys are often done in conjunction with upland game bird surveys and research (Kline 1965 and Rees 2015). Cottontails have been surveyed at bobwhite whistle count stops on a roadside survey (Rees 2015), and they have been surveyed along roadside ring-necked pheasant (*Phasianus colchicus*) survey routes (Kline 1965). For my study, individuals were tallied by their location (treated or non-treated) along roads within the refuge. Surveys were conducted while the team was on the refuge to pre-bait northern bobwhite traps (a single round), trap northern bobwhites (hourly rounds), track northern bobwhites (twice daily rounds), and survey invertebrates and RIFA (single round). It is important to note the same individuals may have been tallied on multiple rounds, but cottontails in treated and non-treated areas each had an equal probability of being re-sighted.

The survey road was mapped in ArcMap 10.4.1 (ESRI, Redlands, CA) along with the RIFA treatment (Fig. 4.1). A road on the boundary between treated and non-treated areas was considered to be non-treated because the treatment application ended at the road (example: southeastern portion of survey road; Fig. 4.1) . Lengths of treated and non-treated roads were calculated for each year using the intersection tool to calculate the intersection of the treated area and the survey road. Eastern cottontail numbers were totaled by month and year. To avoid psedoreplication and determine if there was a significant difference in the number of cottontails sighted is the treated and non-treated areas and to be as conservative as possible, I picked a day in June 2015, 2016, and 2017 where I observed the most cottontails in the treated area. I then used the corresponding number of cottontails observed on that day in the non-treated area to run a Chi-square goodness-of-fit test (Ott and Longnecker 2016) performed in JMP 12.0.1 (SAS Institute, Cary, NC). I used June as the month to conduct the test because it is the month when cottontail sightings were observed to peak each year in both the treated and non-treated areas (Fig. 4.2). Also, to compare treatments evenly, I calculated cottontails seen per hour per kilometer of road survey in each treatment. This value (cottontails/hr/km) was then compared to mean number of RIFA per sample by month to determine if there was a correlation between RIFA per sample and eastern cottontail per hour per kilometer.

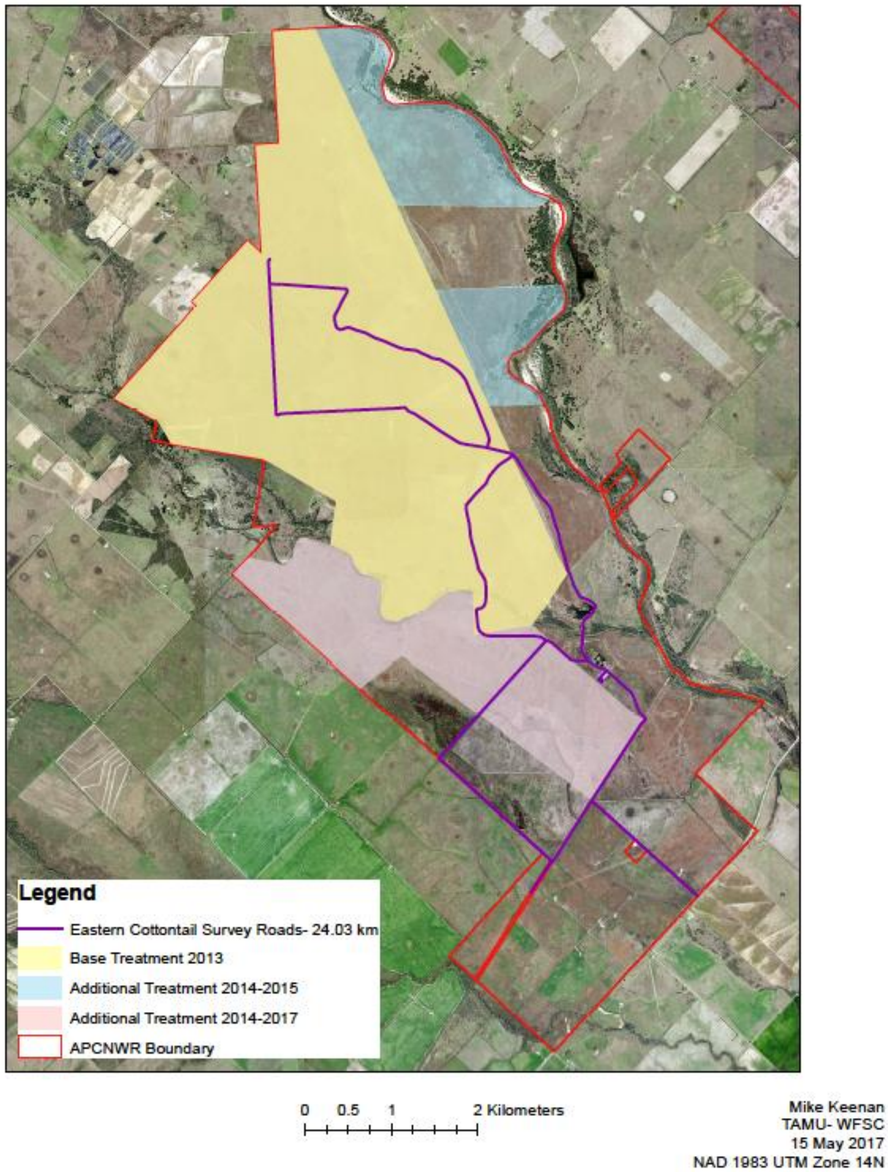

Figure. 4.1. Eastern cottontail survey road (24.03 km) with RIFA treatments on the APCNWR in Colorado County, Texas.

RESULTS

Eastern Cottontail Numbers

Eastern cottontails were sighted in much greater numbers in the non-treated than the treated area (Table 4.1). A Chi-square test confirmed there were significantly (*P* =

0.003) more cottontails in the non-treated than the treated areas from 2015–2017. In 2016, the only year when cottontails were surveyed during all 12 months, cottontails were observed 16.3 times more often in the non-treated than the treated area. During the 21 months (2015–2017) when cottontails were surveyed on the APCNWR, cottontails observations in the non-treated area accounted for 93.2% of the total. When observed numbers were adjusted to make the treated and non-treated areas proportionally equal (cottontails/hr/km), cottontail numbers in the non-treated areas were consistently higher than in the treated area (Fig. 4.2). Cottontail numbers were highest in both areas between May and June. The largest recorded cottontails/hr/km occurred during June 2016 in the non-treated area with a value of 0.515. A cottontails/hr/km value of ≥0.1 was never recorded (greatest was 0.04 in June 2016) in the treated area, while the non-treated area had a value of ≥0.1 a total of 6 times.

Table 4.1. Eastern cottontail numbers on APCNWR Colorado County, Texas, 2015–2017

		2015	2016	2017	
Treatment	Category	Jun–Dec	Jan–Dec	Jan–May	Total
Treated	Cottontails	19	36	2	57 (6.8%)
	Road Length (km)	13.1	13.1	13.1	
Non-treated	Cottontails	142	588	69	799 (93.2%)
	Road Length (km)	11.0	11.0	11.0	
Total	Cottontails	161	624	71	856(100%)
	Road Length (km)	24.1	24.1	24.1	

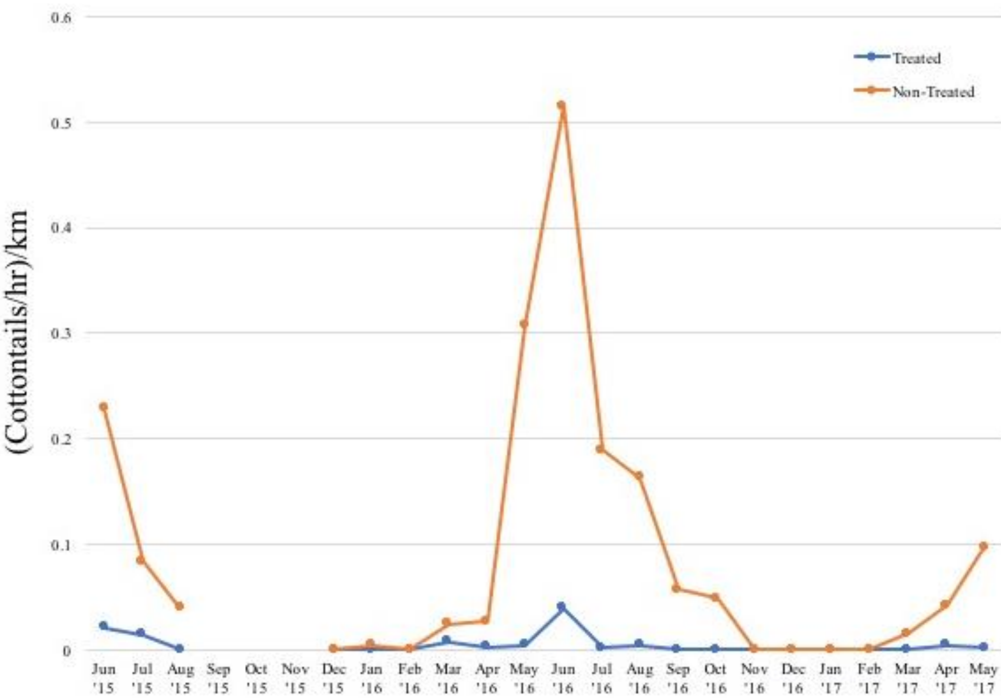

Figure 4.2. Adjusted cottontail numbers in the treated and non-treated areas of the APCNWR Colorado County, Texas, 2015–2017.

Cottontail numbers (cottontails/hr/km) were compared to RIFA per sample for the months when both were sampled (Table 4.2). There was a slight negative correlation between RIFA and eastern cottontail numbers in both the treated (R = -0.15, P = <0.001) and the non-treated (R = -0.12, P = <0.001) areas.

Table 4.2. Cottontail and RIFA numbers in treated and non-treated area of APCNWR Colorado County, Texas, 2015–2017.

	2015			2016					2017	
	Jun	Jul	Aug	Apr	May	Jun	Jul	Aug	Apr	May
Treated										
Cottontails/hr/km	0.02	0.01	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.02
RIFA/Sample	9.2	3.7	4.0	11.5	2.5	10.8	6.5	86.8	0.2	0.2
Non-treated										
Cottontails/hr/km	0.23	0.08	0.04	0.03	0.31	0.52	0.19	0.16	0.04	0.10
RIFA/Sample	3.6	8.9	7.0	6.1	11.0	2.5	0.5	44.3	1.7	5.4

DISCUSSION

Eastern Cottontail Numbers

An increase in cottontail numbers in both the treated and non-treated areas occurred during the months of May and June and the unintended capture of young cottontails in bobwhite traps during this same period, indicating there was reproduction taking place during that time. Kline (1965) also observed an increase in cottontail abundance on roadside surveys during this time frame. I observed a higher number of cottontails (0.515 cottontail/hr/km) during the summertime peak than Kline (1965) did (0.228 cottontails/km), however, this could be the result of methodology differences or simply the difference between east-central Iowa and GPM of Texas. RIFA numbers were typically highest during July and August. If RIFA had a large negative effect on newborn cottontails, then I would expect to see a strong correlation between RIFA and cottontail numbers. However, reproduction appears to successfully take place during May and June contrary to observations by Hill (1972). In fact, cottontails were found in greater numbers in the non-treated area, having higher numbers than the treated area every month they were sampled (even though the treated area roads accounted for more than 50% of the sampling area) indicating the non-treated area is a more favorable habitat for cottontails. It also was evident that cottontails were selecting habitat based on some other environmental factors such as brush cover (Davis and Schmidly 1994) which has been controlled in the treated area more than in the non-treated area. The non-treated area also contains a higher proportion of edge and early successional habitats than the treated area. The slight negative correlation between RIFA and cottontail numbers indicates there might be a negative interaction between the 2 species. More research is necessary to fully elucidate the relative contributions of habitat and RIFA on cottontail population dynamics.

CHAPTER V

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

NORTHERN BOBWHITE

The northern bobwhite (*Colinus virginianus*) is an iconic species in Texas; contributing cultural, economic, and ecological value. This species has experienced widespread decline throughout its range which threatens lifestyle and livelihood of people that depend on them. Aerial *Extinguish Plus*^{TM} treatment of red imported fire ants (RIFA, *Solenopsis invicta*) on the Attwater Prairie Chicken National Wildlife Refuge (APCNWR) for Attwater's prairie-chicken (APC; *Tympanuchus cupido attwateri*) management provided an opportunity to study the effects of RIFA and the potential use of large-scale RIFA treatment for quail management.

The following conclusions were drawn from my study on the APCNWR:

1. Treatment with *Extinguish Plus*^{TM} reduced the abundance of RIFA from 2014–2017.
2. Flooding is capable of negating RIFA treatment effect when there are adjacent non-treated areas.
3. Because of limited data in the non-treated area, I cannot conclude whether or not the treatment improved northern bobwhite brood survival or nesting success.
4. Quail density estimates for the treatment area were higher in each of the years 2014–2017, with an average annual treatment effect of 80%.

5. Northern bobwhite consecutive movements and maximum movement from trap site did not differ between treated and non-treated areas in 2016–2017, but did by female classification (pre-nesting, with brood, and without brood).
6. Northern bobwhite seasonal range did not differ between treated and non-treated areas in 2016-2017, but did by female classification.
7. Pre-nesting northern bobwhite females and nesting season females with a brood had smaller movements and seasonal ranges than nesting season females without a brood.
8. Ranges were larger than typically reported for northern bobwhite ranges in other regions of Texas.

Reference data created for the Gulf Prairies and Marshes Ecoregion:

1. *Extinguish Plus*^{TM} RIFA treatment efficacy
2. Northern bobwhite density
3. Northern bobwhite brood survival to 7, 14, and 21+ days
4. Northern bobwhite nesting data: nest success, clutch size, and egg hatchability
5. Northern bobwhite range and movements of pre-nesting and nesting season females with and without broods

With data available to me, I cannot make a conclusion about how treatment for RIFA with *Extinguish Plus*^{TM} affects brood survival, nesting success, or abundance.

Treatment does not appear to have an effect on movements or range size. However, treatment may have a positive effect on bobwhite density.

Additional research with a larger control area and more replicates would be able to increase non-treated sample size and draw conclusions about brood survival, nesting success, and abundance. A longer-term study focused on range and movements that could calculate an annual range for northern bobwhites in the GPM and at replicate locations would be a beneficial addition to this region's reference data. A better understanding of RIFA treatment effectiveness and the dynamics of this ecoregion would better equip wildlife managers with the tools to reverse the decline of quail.

EASTERN COTTONTAIL

The eastern cottontail (*Sylvilagus floridanus*) is another important wildlife species in the GPM. The large-scale RIFA treatment also afforded me the opportunity to investigate the effect of RIFA and RIFA treatment on cottontail numbers.

The following conclusions were drawn from my study on the APCNWR:

1. Eastern cottontail numbers were higher in the non-treated than the treated area from 2015–2017.
2. Eastern cottontail numbers peaked May–June for both the treated and non-treated sites.

3. While I could not determine if interaction with RIFA influenced habitat selection and abundance of eastern cottontail, my data suggests that other environmental factors affect cottontail habitat quality more than RIFA.

Eastern cottontails appeared to be more successful in areas not treated for RIFA with *Extinguish Plus™*, but it is possible the difference I observed has less to do with RIFA and treatment and more to do with other factors such as grazing pressure, prescribed burning, successional stage (much of the non-treated area was former marsh and rice agriculture under restoration to native warm season grasses) and other habitat differences. Replication of this study in areas with different types of cottontail habitat would be useful to better understand the relationship between RIFA and cottontails. It also would be beneficial to study cottontail nests in the wild to understand nest success and potential RIFA predation issues.

Replication of this study in different habitat types and in conjunction with research on eastern cottontail habitat requirements on those study sites would help to bolster or challenge my results. If RIFA are having an impact on cottontails, it is important for wildlife managers to identify the issue and work to create management strategies to combat the issue.

LITERATURE CITED

Adams, B. J., L. M. Hooper-Bùi, R. M. Strecker, and D. M. O'Brien. 2011. Raft formation by the red imported fire ant, *Solenopsis invicta*. Journal of Insect Science 11:1–14.

Allen, C. R. 1993. Response of wildlife to red imported fire ant population reductions in the south Texas coastal prairie. Thesis, Texas Tech University, Lubbock, Texas, USA.

Allen, C. R., D. M. Epperson, and A. S. Garmestani. 2004. Red imported fire ant impacts on wildlife: a decade of research. American Midland Naturalist 152:88–103.

Allen, C. R., R. S. Lutz, and S. Demarais. 1995. Red imported fire ant impacts on northern bobwhite populations. Ecological Applications 5:632–638.

Brennan, L., S. DeMaso, F. Guthery, J. Hardin, C. Kowaleski, S. Lerich, R. Perez, M. Porter, D. Rollins, M. Sams, T. Trail, and D. Wilhelm. 2005. Where have all the quail gone?. Texas Parks and Wildlife Department, Austin, USA.

Caldwell, J. W. 2015. Use of Extinguish Plus™ to reduce red imported fire ants and increase northern bobwhite abundance. Thesis, Texas A&M University, College Station, Texas, USA.

Chavarria, P. M., N. J. Silvy, R. R. Lopez, D. S. Davis, and A. Montoya. 2017. Ranges and movements of Montezuma quail in southeast Arizona. National Quail Symposium Proceedings 8:In Press.

Cook, J. L., S. T. O'Keefe, S. B. Vinson, B. M. Drees. 2014. Texas pest ant identification: an illustrated key to common pest ants and fire ant species. Publication ENTO-01, Texas A&M AgriLife Extension, College Station, USA.

Davis, W. B., and D. J. Schmidly. 1994. The mammals of Texas. Texas Parks and Wildlife Department Nongame and Urban Program, Austin, USA.

Drees, B. M. 2013. Diagnosing and treating animals for red imported fire ant injury. Publication ENTO-004, Texas A&M AgriLife Extension, College Station, USA.

Drees, B. M. and S. B. Vinson. 1993. Fire ants and their management. Publication B-1536. Texas Agricultural Extension Service, Texas A&M University, College Station, USA.

Drees, B. M., and C. F. Lard. 2006. Imported fire ant: economic impacts justifying integrated pest management programs. Proceedings of the Congress International Union for the Study of Social Insects 15:114–115.

Extinguish Plus. 2009. Extinguish Plus. <http://www.centralantcontrol.com/media/files/centralantcontrol-na/us/resources/extinguish%20brochure%20300502190%20final%20pdf.pdf?la=en>. Accessed 3 Mar 2017.

Giuliano, W. M., C. R. Allen, R. S. Lutz, and S. Demarais. 1996. Effects of red imported fire ants on northern bobwhite chicks. Journal of Wildlife Management 60:309–313.

Gould, F. W. 1962. Texas plants—a checklist and ecological summary. Publication MP-585, TexasAgricultural Experiment Station, The Agriculture and Mechanical College of Texas, College Station, USA.

Harris, S., W. J. Cresswell, P. G. Forde, W. J. Trewhella, T. Woollard, and S. Wray. 1990. Home-range analysis using radio-tracking data–a review of problems and techniques particularly as applied to the study of mammals. Mammal Review 20:97–123.

Hernández, F., and F. S. Guthery. 2012. Beef, brush, and bobwhites: quail management in cattle country. Texas A&M University Press, College Station, USA.

Hernández, F., and M. J. Peterson. 2007. Northern bobwhite ecology and life history. Pages 40–64 *in* L. A. Brennan, editor. Texas quails: ecology and management. Texas A&M University Press, College Station, USA.

Hill, E. P. 1972. The cottontail rabbit in Alabama. Bulletin 440. Agriculture Experiment Station, Auburn University, Auburn, Alabama, USA.

Johnson, A. S. 1961. Antagonistic relationships between ants and wildlife with special reference to imported fire ants and bobwhite quail in the Southeast. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 15:88–107.

Kline, P. D. 1965. Factors influencing roadside counts of cottontails. Journal of Wildlife Management 29:665–671.

Lehmann, V. W. 1984. Bobwhites in the Rio Grande Plain of Texas. Texas A&M University Press, College Station, USA.

Lockwood, M. A. 1998. Survival, reproduction, and habitat use of captive-reared Attwater's prairie chicken. Thesis, Texas A&M University, College Station, Texas, USA

Lyons, E. K., M. A. Schroeder, and L. A. Robb. 2012. Criteria for determining sex and age of birds and mammals. Pages 207–229 *in* N. J. Silvy, editor. The wildlife techniques manual, Volume 1: Research. Seventh Edition, Johns Hopkins University Press, Baltimore, Maryland, USA.

Millsphaugh, J. J., R. A. Gitzen, J. L. Belant, R. W. Kays, B. J. Keller, C. T. Rota, J. H. Schulz, and C. M. Bodinof. 2012. Analysis of radiotelemetry data. Pages 480–501 *in* N. J. Silvy, editor. The wildlife techniques manual, Volume 1, Research. John Hopkins University Press, Baltimore, Maryland, USA.

Morrow, M. E., R. E. Chester, S. E. Lehnen, B. M. Drees, and J. E. Toepfer. 2015. Indirect effects of red imported fire ants on Attwater's prairie-chicken brood survival. Journal of Wildlife Management 79:898–906.

Mueller, J. M., C. B. Dabbert, S. Demarais, and A. R. Forbes. 1999. Northern bobwhite chick mortality caused by red imported fire ants. Journal of Wildlife Management 63:1291–1298.

Oakley, M. J., D. L. Bounds, T. A. Mollett, and E. C. Soutiere. 2002. Survival and home range estimates of pen-raised northern bobwhites in buffer strip and non-buffer strip habitats. Proceedings of the National Quail Symposium 5:74–80.

Ott, R. L., and M. Longnecker. 2016. An introduction to statistical methods and data analysis. Seventh edition. Cengage Learning, Boston, Massachusetts, USA.

Pedersen, E. K., W. E. Grant, and M. T. Longnecker. 1996. Effects of red imported fire ants on newly-hatched northern bobwhite. Journal of Wildlife Management 60:16–169.

Perez, R. M. 2007. Bobwhites on the Gulf Coast Prairies. Pages 260–272 *in* L. A. Brennan, editor. Texas quails: ecology and management. Texas A&M University Press, College Station, USA.

Pierce, B. L., R. R. Lopez, and N. J. Silvy. 2012. Estimating animal abundance. Pages 284–310 *in* N. J. Silvy, editor. The wildlife techniques manual, Volume 1, Research. John Hopkins University Press, Baltimore, Maryland, USA.

Porter, S. D., and D. A. Savignano. 1990. Invasion of polygyne fire ants decimates native ants and disrupts arthropod community. Ecology 71:2095–2106.

Puckett, K. M., W. E. Palmer, P. T. Bromley, J. R. Anderson, and T. L. Sharpe. 2000. Effects of filter strops on habitat use and home range of northern bobwhites on Alligator River National Wildlife Refuge. Proceedings of the National Quail Symposium 4:26–31.

Rees, J. 2015. Regional bobwhite quail and cottontail rabbit survey. Wisconsin Department of Natural Resources, Madison, Wisconsin, USA.

Reeves, H. M., A. D. Geis, and F. C. Kniffen. 1968. Mourning dove capture and banding. Special scientific report: wildlife 117, U.S. Fish and Wildlife Service, Washington, D.C., USA.

Scott, J. L., F. Hernández, L. A. Brennan, B. M. Ballard, M. Janis, and N. D. Forrester. 2013. Population demographics of translocated northern bobwhites on fragmented habitat. Wildlife Society Bulletin 37:168–176.

Silvy, N. J., J. L. Roseberry, and R. A. Lancia. 1979. A computer algorithm for determining home range size using Mohr's minimum home range method. Proceedings of the International Wildlife Biotelemetry Conference 2:170–177.

Smeins, F. E., D. D. Diamond, and C. W. Hanselka. 1991. Coastal prairie. Pages 269–290 *in* R. T. Coupland, editor. Natural grassland: introduction and western hemisphere. Elsevier, Amsterdam, Netherlands.

Stoddard, H. L. 1946. The bobwhite quail: its habits, preservation and increase. Charles Scribner's Sons, New York, New York, USA.

Vinson, S. B., and A. A. Sorensen. 1986. Imported fire ants: life history and impact. Texas Department of Agriculture, Austin, Texas, USA.

Vinson, S. B., and A. A. Sorenson. 1988. Imported fire ants: life history and impact. Texas Department of Agriculture, Austin, USA.

Wildlife Material Inc. 2007. Small bird transmitters. <http://wildlifematerials.com/downloads/datasheet_sm_birds.pdf>. Accessed 3 Mar 2017.

Wilkins, N, A. Hays, D. Kubenka, D. Steinbach, W. Grant, E. Gonzalez, M. Kjelland, and J. Shackelford. 2003. Texas rural lands: trends and conservation implications for the 21st century. Publication number B-6134, Texas Cooperative Extension, Texas A&M University System, College Station, USA.

Williams, C. K., F. S. Guthery, R. D. Applegate, and M. J. Peterson. 2004. The northern bobwhite decline: scaling our management for the twenty-first century. Wildlife Society Bulletin 32:861–869.