BEHAVIORAL ECOLOGY OF STRIPED SKUNK: FACTORS INFLUENCING URBAN RABIES MANAGEMENT

A Dissertation

by

DENISE MARIE RUFFINO

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

DOCTOR OF PHILOSOPHY

December 2008

Major Subject: Wildlife and Fisheries Sciences

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Approved by:

Co-Chairs of Committee,	Scott E. Henke
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ABSTRACT

Behavioral Ecology of Striped Skunk: Factors Influencing Urban Rabies Management.

(December 2008)

Denise Marie Ruffino, B.S., Texas A&M University;

M.S., Sam Houston State University

Co-Chairs of the Advisory Committee, Dr. Scott E. Henke
Dr. Nova J. Silvy

Striped skunks (*Mephitis mephitis*) are a rabies vector in Texas and efforts are underway to develop an oral rabies vaccination program for skunks. To better understand some of the components necessary, I studied the habitat preferences and home range of skunks, an alternative skunk capture method, and surveyed the knowledge base of medical providers practicing across the state. I radiocollared 99 skunks from the Houston, Texas metropolitan area and monitored skunk movements from March 2004–June 2006. To accelerate progress of this study, I captured 93 of 99 skunks using a dip net. Dip netting allowed for an effective collection alternative to cage trapping. Movement data indicated a strong preference for short grass areas (82%), however, habitat use changed to remote, brushy areas when temperatures were ≤7C. Habitat use during the year was different (P = 0.001), with December 2004, January 2005, and February 2005 significantly (P = 0.001) different from one another. Additionally, habitat use during December 2005, February 2006, and March 2006 were significantly different (P = 0.045, P =0.098, and P =0.003, respectively). Data from 20 skunks, covering multiple seasons, were analyzed for home range use. I found male home range use averaged 255 ha (217–345), while females averaged 126 ha (60–218). Male range use was significantly larger than females ($P = 0.005$). No significant seasonal movements were observed. Lastly, I conducted a survey of 297 Texas primary care medical providers to assess their knowledge of rabies vaccine procedures and their experience with rabies vaccines. Small town providers within the oral rabies vaccination baiting zone were more aware of rabies prophylaxis ($P < 0.03$), however, most providers (>95% of 297) rarely saw patients for rabies prophylaxis. Survey data indicated providers have minimal, if any, experience with acquiring and administering rabies prophylaxis. My data suggests that an effective oral rabies vaccination program could be established within urban areas by using short grass area baiting strategies during the fall season, using dip net capturing for faster surveillance collection, and by initiating a rabies education program targeted at Texas' primary care physicians and their staff.

DEDICATION

To Mr. Gary Nunley
State Director - Texas Wildlife Services Program (Retired)

With deep appreciation for all your support of me, my education, and my WS career.

ACKNOWLEDGEMENTS

The funding for this project was provided by the US Department of Agriculture-Animal and Plant Health Inspection Service-Wildlife Services (USDA-APHIS-WS), through its National Wildlife Research Center (NRWC), and USDA-APHIS-WS Texas Program. Also, special recognition goes to the Caesar Kleberg Wildlife Research Institute, Texas A&M University - Kingsville for their sponsorship of this project. The central theme of this research came from Dr. Thomas DeLiberto (NWRC), Dr. Robert McLean (NWRC), Dr. Dennis Slate (USDA-APHIS-WS-National Rabies Program) Dr. Chuck Rupprecht (Centers for Disease Control and Prevention) and Mr. Gary Nunley (State Director, USDA-APHIS-WS Texas Program, retired). My deepest appreciation goes to these men for their insight, determination, and resolve in attempting to eliminate skunk rabies, a task some feel is unachievable. I thank you for your funding and support on this project throughout the years. Also, I wish to recognize and thank Dr. Scott Henke for helping to take this idea from the chalk board to the field. Scott served as my committee's Kingsville Co-chair, research advisor, constant source of support, and as a wonderful friend throughout the years it has taken to get this degree finished. I am heavily indebted to you for your patience and for showing me the true meaning of investing in your students.

I would like to thank my graduate committee for all their support, patience, and friendship throughout this adventure. I've always heard the importance of having a committee that you can depend on and that actually cares. Along with Scott, I was blessed to have Dr. Nova Silvy serve as my committee's College Station Co-chair. Nova has been the embodiment of calm in the storm and has always made sure I knew his door was always open. In these latter stages, you have taken the lead to get this work completed and I can not tell you how much your support and wisdom has meant to me. To Dr. Don Davis, you have always been there to tell it to me straight, whether I wanted to hear it or not, but always with a touch of humor and with the intent of making me a better biologist. We have been friends for 20 years now and I can't tell you how much I appreciate your willingness to serve on my committee. Your sense of realism, enveloped in humor, has been a wonderful counter balance to the rhetoric of agency politics and I appreciate that more than I can express. Lastly, I would like to thank Dr. Jim Cathey, one of the busiest agency biologists that I know. Your attention to detail has been outstanding and I am very grateful for your making time for me in the middle of your very busy, travel-filled work schedule. Throughout this period of my life, I was very lucky to have such a great committee.

When one takes the full 10 years to finish a degree, others come through your world, adding their gifts to your basket. I would like to recognize and thank Dr. Marcus Peterson, Dr. Tarla Peterson, Dr. Clark Adams, and Dr. Neal Wilkins for sharing their time and talent with me during the time they served on my committee. Their contributions were invaluable to the project and to me. I would also like to recognize and thank Lee Rindlisbacher for his dedication to gathering data for this study and Anthony Lipscomb for assisting on this project.

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CHAPTER I

INTRODUCTION

Background

Habitat destruction has been targeted as one of the most serious threats to biological diversity (Wilcove et al. 1998) and accounts for numerous news headlines today. As the human population nears 7 billion, concern over how humans share the earth with all species, and whether many resources currently present will still be present for future generations, has long been common fodder for political debates and social forums, especially since the environmental movement of the 1960s. Major cities continue to expand, encroaching into areas not previously settled, and leaving some wildlife species struggling for survival. Crooks (2002) found that in areas with increasing urbanization, loss and fragmentation of habitat is virtually inevitable. Because growing urban/suburban areas have habitat features constantly in a state of flux, possibly stressing some species unable to quickly adapt, Gehrt (2005) found that identifying those factors that are limiting to populations are fundamental to understanding wildlife population dynamics. However, for species able to adapt, this human expansion has provided a new frontier for wildlife to populate, navigate, and/or successfully exploit for the betterment of their species' ecological health.

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

Since the 1960s, the amount of urbanized land in the United States (US) has more than doubled, with over 400,000 ha of land per year lost to urban and suburban development from 1960–1990 (Heimlich and Anderson 2001). The Houston metropolitan area is among the nation's most dynamic and rapidly growing metropolitan areas. Oguz et al. (2008) found urban growth in Houston has epitomized the term urban sprawl over the past 30 years, quadrupling from 941 to 3,724 km^2 from 1974–2002. From 1900–2000, the region's population more than doubled growing from to approximately 4,600,000, with projected growth of an additional 2,800,000 by the year 2030. Because Houston's spatial growth over the past 30 years has been a prime example of urban sprawl, there is no reason to assume this growth mode will not continue in the future (Oguz et al. 2008).

Rapid urbanization, often resulting in loss of agricultural and natural areas, has raised concerns regarding detrimental effects on individual species, as well as natural communities. Additionally, frequent interaction with humans and domestic pets has posed serious problems for some species. However, some species, termed generalists, exhibit a positive response to urbanization by possessing broad dietary and habitat requirements (McKinney 2002). While many species thrive in the human/wildlife interface, Prange and Gehrt (2004) found that, among mammals, the striped skunk (*Mephitis mephitis*) best exemplifies a generalist.

Striped skunks are among the most recognizable and ubiquitous animals in North America. Although skunks, striped skunks in particular, have been the subject of numerous biological investigations, Baldwin et al. (2004) found that most previous studies related to habitat (Verts 1967, Rosatte 1987, Bixler and Gittleman 2000, and Lariviere and Messier 2000), while Hansen et al. (2004) found that most skunk research focused on their role as nest predators (Greenwood 1986, Lariviere and Messier 1998*b*, Vander Lee et al. 1999) or rabies vectors (Sargeant et al. 1982, Rosatte et al. 1986, Pybus 1988). Because striped skunks are one of the most common mammals reported with rabies each year (Krebs et al. 2005, Hass and Dragoo 2006), a focus on rabies research is an extremely important topic within the urban/suburban environment.

Rabies is one of the oldest recorded infectious diseases and, although now preventable, still has the ability to instill fear in many. It is an acute, fatal encephalitis caused by a bullet shaped virus (genus *Lyssavirus*) that is almost always transmitted by the bite of a rabid animal. Globally, between 50,000 to 100,000 humans are estimated to die from rabies annually, with many deaths occurring in children (Rupprecht et al. 2006). During the early 1960s, wild mammals emerged as the most frequently reported animals infected with rabies in the US, replacing the domestic dog as the dominant virus reservoir (Krebs et al. 2001, Rupprecht et al. 2006). Further, the striped skunk has been the terrestrial species most often reported as rabid (Parker 1975, Heidt et al. 1982, Pool and Hacker 1982, Macdonald and Voigt 1985). Within the urban/suburban environment, this finding is problematic. While habitat modification, a useful site-specific management approach capable of reducing potential interactions between human beings and potential rabies vectors (Hanlon et al. 1999), can reduce the chance of disease transmission to people and pets, it is important to note the reverse is true as well. Within urban/suburban environments, habitat modification can actually increase the potential for interactions if care is not taken to identify the factors that, when manipulated, will encourage vector species, such as skunks, to move elsewhere. In addition, supplemental food and the absence of mortality factors, common in rural areas, may serve to increase urban skunk survival rates (Riley et al. 1998), while also increasing the threat of disease transmission (Prange et al. 2003). In a comparison study conducted by Gehrt (2005), disease was one of the greatest causes of mortality at his urban study site throughout the year, whereas it was the most common mortality factor at his rural site only during winter and spring, possibly as a result to winter stress and reduced food resources. Thus, while disease is a very important and necessary factor to limit population size of certain species, especially in the absence of larger predators, it also produces a serious vulnerability to an increasing, unknowing urban/suburban public.

In contrast to other countries (e.g., China), Krebs et al. (1995) stated that cases of human rabies in developed nations have become increasingly rare. While the numbers of human-rabies cases in the US exceeded 100/year during the early 1900s, an annual average of >1 indigenously acquired cases of human rabies has been reported over the past 20 years. However, control of rabies requires a complex and expensive system of operations at local, state, and federal levels. Management of wildlife rabies is complicated by the ecologic and biologic factors associated with wildlife reservoirs, the multiagency approach needed to manage an important public health problem originating in wildlife, the limitations of available control methods, and the broad range of public attitudes toward wildlife. The complexity of controlling rabies has increased dramatically in the US since wildlife began to replace domestic dogs as the principal disease vector >40 years ago (Hanlon et al. 1999). One of the most exciting developments in recent decades is the demonstration that wildlife can be vaccinated against rabies, primarily using oral rabies vaccination (ORV). Successful use of ORV delivered in edible baits is changing the geographic distribution of rabies (Krebs et al. 1995). Clearly, ORV and other management methods are currently novel tools in the prevention and control of rabies in the US (Hanlon et al. 1999), however, innovation is expensive. It has been estimated that the cost of rabies control in this country exceeds $300 million annually (Fishbein and Archangeli 1987), with as many as 40,000 people possibly receiving rabies prophylaxis each year (Rupprecht et al. 2006).

The United States Department of Agriculture–Animal and Plant Health Inspection Service–Wildlife Services (USDA–APHIS–WS) has been a major collaborator in rabies research, surveillance, and ORV programs nation-wide, working to eradicate the raccoon (*Procyon lotor*) rabies variant throughout the eastern US, as well as both the coyote (*Canis latrans)* and gray fox (*Urocyon cinereoargenteus*) rabies variants in Texas. Most efforts to control rabies in Texas have concentrated on preventing disease spread from infected wildlife to humans, domestic animals and livestock (Pool and Hacker 1982). While ORV has been effective on gray fox and coyotes, ORV using Raboral V-RG® (Merial Corporation, Duluth, GA, USA) has not produced sufficient levels of population immunity in skunks (primarily striped skunks) in the wild at the current dose, thus skunks still represent the last remaining hurdle in terrestrial rabies vaccination strategies. However, great strides have been made to develop an effective vaccine for the skunk variant (Mike Dunbar, USDA-APHIS-WS, personal communication) over the last few years, but development and field trials progress slowly.

Study Area

The Houston metropolitan area, within Harris County, served as the study area. Harris County encompasses over 5,200 km^2 and is home to 4.5 million residents. Several ecotypes are present, including: piney woods, postoak savannah, prairie, coastal prairie, coastal wetland, and freshwater swampland. Commercial growth has created extensive land-use conversions, particularly in the western part of the county where historically important rice producing farmland have been converted into single family housing developments. Urban sprawl was evident on most of the suburban/rural interface. During the course of this 2-year study, some areas in the western and southern parts of the county experienced complete commercial development. Artificially created and natural green spaces are plentiful and many freshwater drainage systems run throughout the area, supporting the city's nickname of the Bayou City. Climate generally consists of mild winters and hot summers, allowing for a long growing season. High humidity, thick fog, and heavy dews are common. Precipitation, mainly through rainfall averages approximately 114.3 cm/year.

Houston was chosen as the study area because it lies within the skunk rabies zone for Texas and rabies is endemic in resident skunk populations (www.cdc.gov). I conducted research in the northern, southern, and western quadrants of Harris County.

As a coastal city, elevation is at sea level in the easternmost part of the county and increases slightly across an east-west gradient at approximately 0.3 m/2.5 km (www.texasbest.com) This gentle slope accounts for gradual vegetation shifting from swampy, water-retaining fields in the east to drier, more open grassy vegetation in the western part of county. Easy, reliable access to properties within the drier quadrants dictated which properties were used. Although no population indices were conducted for the individual study sites nor their overall density/km^2 calculated, skunks were regularly seen on all sites.

Objectives

Striped skunks are one of the most common mammals reported with rabies each year and many live easily in close proximity with people and pets, so learning about their urban behavioral ecology is crucial to developing a management plan to eradicate rabies in skunk populations. Current formulation of oral rabies vaccination (ORV) available for other species has not worked in skunks, thus research is being conducted to find an effective formula to combat skunk rabies. When this formula is perfected and licensed for use, the need to know how, when, and where this vaccine, commonly distributed within individual bait blocks containing Raboral V-RG®, should be dispersed within urban and suburban areas is paramount to the program's success. In an effort to address some of the skunk rabies information deficiencies, USDA-APHIS-WS commissioned this study primarily to answer the following question: if an effective

ORV was developed to combat skunk rabies, how would this vaccine be distributed within an urban/suburban environment? Considering that vaccine blocks are primarily dropped from specially equipped aircraft over large expanses of land or placed by hand in small urban areas, neither of these methods would be applicable in a major city like Houston, Texas, where skunk have wide-spread distribution and reside in close proximity to ~ 4.5 million people. To answer this question, many contributing factors needed to be researched. The objectives of my study included:

1. Conducting a 2-year radio-tracking study on 99 striped skunks to determine the behavioral ecology of striped skunks, including:, habitat use, habitat preferences, home range, and body size/condition of skunks living within a rabies endemic zone;
2. Investigating effects cold weather has on skunk activity and how those effects could contribute to potential disease transmission as skunks congregate for warmth in shared and/or communal den sites;
3. Examining the availability of sound medical advice from family medical providers practicing within all Texas rabies endemic zones to assess knowledge, proficiency, and availability of rabies prophylaxes in the event of human exposure;
4. Evaluating how all these factors can be used to promote a successful ORV program for striped skunks.

CHAPTER II

HABITAT PREFERENCES, EFFECTS OF WEATHER ON HABITAT PREFERENCES, AND RESOURCE SHARING IN STRIPED SKUNK

Synopsis

Understanding habitat preferences, seasonal fluctuations, and resource sharing of striped skunks (*Mephitis mephitis*) are key components to reduce rabies transmission within urban/suburban areas. Weather variables can impact skunk movements and cause temporary migration patterns from preferred habitat into alternative habitat offering greater protection from the elements. I outfitted 99 skunks from the Houston (Harris County) Texas metropolitan area with VHF radio telemetry collars, monitored skunk movements from March 2004-June 2006, and collected over 2800 Global Positioning System (GPS) points. Analysis of movement data indicated a strong preference for short grass areas (82%) throughout most of the year, however, habitat use changed as temperatures approached or dropped below 7 C. Chi-square analysis revealed a significant difference in habitat use, $P = 0.001$, for both years and each year separately. When each year was calculated by month, December 2004, January 2005, and February 2005 were significant ($P = 0.001$) and December 2005, February 2006, and March 2006 were significant ($P = 0.045$, $P = 0.098$, and $P = 0.003$, respectively). During colder temperatures, skunks migrated from short grass feeding areas into more remote, brushy areas. Observations also revealed that skunks increased use of commercial structures for

dens in cooler temperatures, spent additional time in dens, often sheltered throughout the night. Additionally, while data points indicated that skunks spent considerable time proximate to residential dwellings, observations during colder temperatures revealed resource sharing with domestic pets and other mammals, such as opossums (*Didelphis virginiana*) and raccoons (*Procyon lotor*). These findings and observations could be important factors in managing transmission of skunk diseases, such as rabies.

Introduction

In my study, multiple skunks using the same habitat showed heavily overlapping home range polygons, indicating that skunks lived in close proximity to each other. Further, seasonal habitat use patterns and denning observations indicated that in periods of cold weather, skunks engaged in resource sharing. This communal denning practice, not only with each other, but with opossums (*Didelphis virginiana*) and raccoons (*Procyon lotor*), can highly contribute to disease transmission. Because striped skunks frequently come into contact with people and pet animals, a high potential for transmission of infectious diseases, such as rabies, is created (Rosatte 1988). Therefore, apprehension about rabies becoming established or existing endemically in skunk populations in or near large urban cities remains a critical concern and complex problem for urban managers. Rabies is viewed as a density-dependent disease, and population dynamics of reservoir hosts are regarded as critical to understanding and modeling the temporal and spatial patterns of rabies in wildlife (Hanlon et al. 1999). The fundamental assumption in the study of rabies is that contact rate is proportional to vector density (MacDonald and Voigt 1985). As vector density increases above the threshold necessary for rabies to persist, so does the contact rate, and consequently, the incidence of rabies. Therefore, reducing the contact rate among infectious animals by reducing vector density can dictate the meaning of successful disease control (Broadfoot et al. 2001

While collecting telemetry data, personal observation revealed that skunk feeding patterns changed as temperatures approached or fell below 7C throughout the winter months. While skunks were easily visible during warmer nights feeding primarily in short-grass, manicured lawns, cooler nights brought more elusive behavior as skunks presumably sought additional warmth from brushy, tall grass areas until temperatures returned to normal levels >7C. On cold nights when temperatures were close to or at freezing, skunks were not observed in the fields. Telemetry data revealed skunks chose to stay within their dens, waiting to feed when conditions were more tolerable. Often these den sites were under garages, gazebos, ball field concession stands, and other settings close to people and domestic pets. Additionally, personal observation revealed that skunks often resource shared, usually with opossums and raccoons, as they sought shelter and warmth under these structures on nights when temperatures approached or surpassed freezing. While these colder temperatures did not normally last more than a night or 2, skunks handled these irregular fasts well and did not seem to suffer any noticeable weight loss from them. Continued studies on skunk behavioral ecology, the effects of weather on skunk movement, or lack thereof, and resource sharing are crucial in understanding disease transmission both between skunks and transmission to other animals, pets, or people

Methods

Striped skunks were captured from 18 locations in Harris County from March 2004–May 2006. Locations were derived by scouting areas with large open surroundings and that would allow for long range viewing and nighttime access. These included all county and city parks, as well as golf courses, school yards, churches, ballparks, and various green spaces. Due to safety concerns and legal considerations, no skunks were captured without securing advance permission from county personnel, school district police, golf course managers, and other landowners to be on their property. Private property was seldom an option, although a large private outdoor museum was used. Locations (Table 2.1) were chosen on the northwest, west, and southeastern ends of the county (Fig. 2.1) where visual observation through spotlighting confirmed the presence

Table 2.1. Actual properties where striped skunks were captured and radiocollared within Harris County, Texas from March 2004–May 2006.

Northwest	**West**	**Southeast**
Collins Co. Park	Harris Co. Katy Park	El Franco Lee Co. Park
Raveneaux Golf Course	Katy City Park	Randolph Co. Park
Champions Golf Course	Rushing Co. Park	Memorial Park
Jack Rabbit Golf Course	Morton Ranch MS and HS	Bay Area Co. Park
Stuebner Airline Rd	Forbidden Gardens Museum	Jones Park
Fritsche Co. Park/Cemetery	Green Meadows Golf Course	Dobie High School

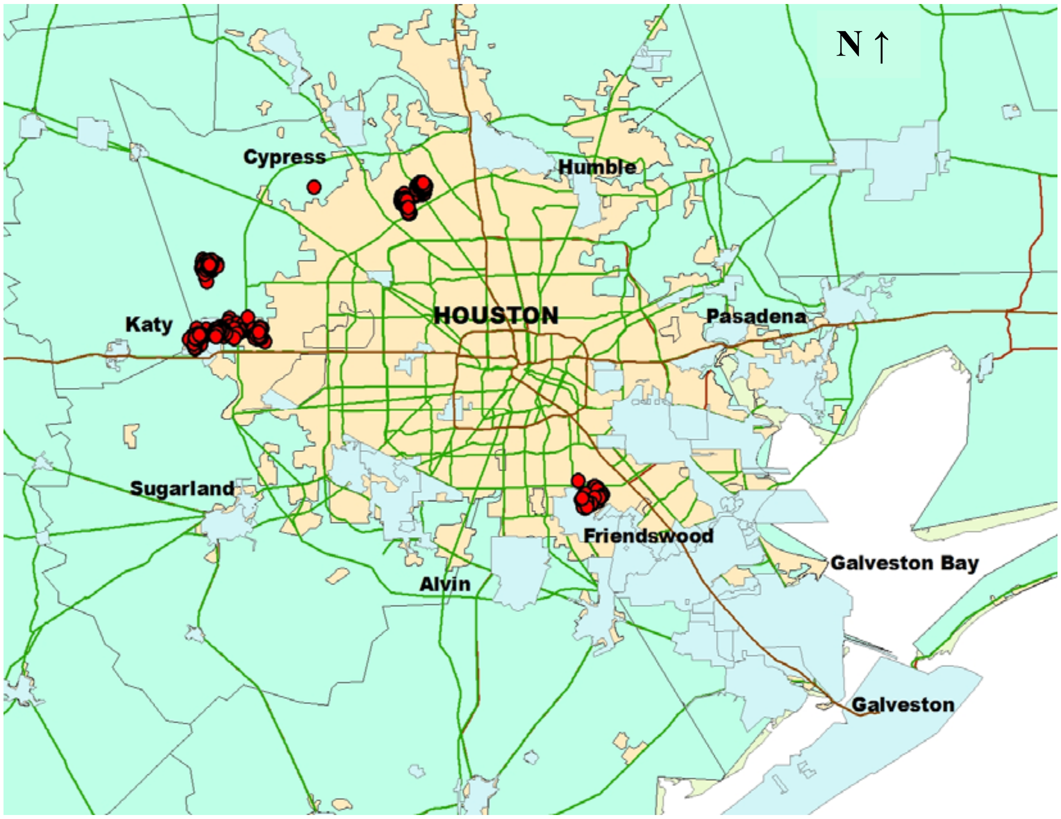

Figure 2.1. All locations where skunks were captured and fitted with radiocollars within Harris County, Texas. Map shows the northwest, west, and southeast groupings of skunk locations.

of skunks. Site groupings were approximately 75 km apart, although individual sites in each grouping were within 16 km of each other. All sights had the same general mix of habitat, with wide swaths of short grass bordered by a mix of shrubs, thicket, and large trees offering skunks a variety of habitat choices. Most locations were kept moist year-round through elaborate sprinkler systems.

Skunks were initially trapped using Tomahawk live traps (Tomahawk Live Trap Co., Tomahawk, Wisconsin, USA). After approximately 2,000 trap nights, only 6 skunks were caught. To improve capture success, skunks were captured by hand using a dip net. Throughout the 2-year period, a total of 99 skunks was captured and anesthetized with ketamine hydrochloride (Fort Dodge Animal Health, Fort Doge, Iowa, USA) and xylazine hydrochloride (Lloyd Laboratories, Shenandoah, Iowa, USA) in a 5:1 mix, as dictated by the United States Department of Agriculture – Animal and Plant Health Inspection Service – Wildlife Services (USDA–APHIS–WS), Immobilization and Euthanasia Drug Use Committee. Initial dosage was given at 0.4 ml, which was adequate to anesthetize a skunk for approximately 20 minutes. When skunks were highly agitated, a subsequent dose of 0.2 ml was often needed to anesthetize a skunk. While animals were anesthetized, an artificial tears ointment was applied to the skunk's eyes to protect corneas from drying out. Animals were evaluated for their health status and weighed. Skunks were placed back at the capture site and monitored until they fully recovered from the anesthetic. Additionally, on cool nights, a towel was placed under and on top of the skunk to help it maintain its core body temperature while recovering.

Skunks were fitted with a 12 g VHF radio transmitter (Telemetry Solutions, Concord, California, USA or Advanced Telemetry Systems, Isanti, Minnesota, USA) operating on 148 MHz to minimize bounce off buildings and trees. Because of some initial radiocollar malfunctions, results from June 2004–May 2006 were analyzed for this study. Collars possessed a mortality signal built into the unit and set to emit an inactivity alert after an 8-hour period of inactivity. Monitoring was conducted on alternating nights for 2 years, recording locations on the southern part of the county on 1 night and the northern and western parts of the county on the following night. Upon gaining a signal, a single location for each skunk was determined and recorded per night, most achieved through triangulation when roads and terrain allowed. When triangulation could not be achieved, a combination of sound and light monitors on the receiver was used to estimate the distance between myself and the skunk. Global Positioning System (GPS) coordinates were collected at the capture site, as well as additional information on weather conditions and time of capture.

Habitat information was collected when skunk locations were identified. Habitat was categorized into 6 classes: short grass, backyards, overgrown, forested areas, building, and gravel lots. Short grass, <13 cm, was a major habitat component of most locations comprised church yards, ballparks, golf courses or other manicured yards, as well as frequently mowed pastures. The category of backyard was used when telemetry results indicated that a skunk was determined to be in the backyard of a residential home. Privacy fencing, common in most urban/suburban neighborhoods, restricted my ability to view the backyard; thus I was unable to, without trespassing on private property, determine whether it was comprised of short grass or if it was overgrown. Overgrown areas contained large amounts of brush, medium to tall grass >13 cm, heavy mixed shrub areas, or any area where skunks could be concealed within the vegetation present. These brushy areas were sufficient to provide shelter from wind and provide some warmth on chilly nights. For each skunk located, GPS coordinates were recorded.

All skunk data was transferred from field data sheets to a Microsoft Office (MS) Excel 2003 (Microsoft Corp., Redman, WA, USA.) spreadsheet. Data was then exported into ArcView 9.2 (ESRI, Redlands, CA, USA) for skunk location mapping using on-line aerial photos from TerraServer-USA images (www.terraserver-usa.com).

Additionally, aerial photos were used to gather information on the concentration of habitat available to skunks. To quantify available habitat, each location was mapped to determine where skunks had been captured. From that point, a perimeter was drawn extending out 800 m from the capture spot. This area represented an estimate of their core area of movement, with habitat contained within the perimeter available to them, regardless of whether they used it. Available habitat was categorized by the same 6 categories used to describe habitat used.

Weather data were collected on site at the time of capture for each capture night. Additionally, official weather data were obtained on-line from The Old Farmer's Almanac (www.almanac.com) for all monitoring nights. Weather data were analyzed with data points generated from recorded skunk movements. After sorting each habitat class, each data point for skunk locations was sorted into 2 temperature classes, >7C and ≤7C. To analyze the effects of reduced temperatures on skunks, Chi-square analysis, comparing observed vs. expected frequencies, was used to compare the data as a 2-year time span, each year separately (June–May), and winter months (Oct–Mar) individually (Table 2.2). No direct comparison between years or between months was conducted.

No quantitative data were collected on denning and resource sharing activities. Observations were recorded as I witnessed it while collecting telemetry data. A literature review is provided to expand on this important facet to disease management.

Table 2.2. Monthly average low temperatures for nights where temperatures were ≤7 C and for nights >7 C during winter months from October 2004–March 2006. Additionally, the number of actual nights/month where temperatures ≤7 C is listed.

	Temperatures ≤7C				**Temperatures >7C**			
	01 Oct 04–31 Mar 05		01 Oct 05–31 Mar 06		01 Oct 04–31 Mar 05		01 Oct 05–31 Mar 06	
Month	# Days	$\bar{x}$ Temp	# Days	$\bar{x}$ Temp	# Days	$\bar{x}$ Temp	# Days	$\bar{x}$ Temp
Oct	0	0	2	7	18	19	14	17
Nov	4	7	4	4	14	11	2	18
Dec	16	2	9	3	9	12	4	11
Jan	9	2	8	4	11	13	11	12
Feb	9	6	5	3	14	13	8	11
Mar	3	7	2	4	14	11	13	15

Results

Habitat selection results were sorted by type and calculated to determine percent used and compared to percent of available habitat. Results revealed a strong preference for short grass fields (Fig. 2.2). Over 2,800 data points were analyzed for the 2-year time period, revealing that over 82% of skunks preferred short grass areas, even though it represented only 47% of available habitat. An additional 5% were located in backyards of residential areas, but were shielded from view by privacy fencing common in urban areas. Use of overgrown areas (7%) was mostly in cooler temperatures even though it was available to them (25%). Building and rock/pavement areas were used sporadically at 0.3% and 1%, respectively. When data points are layered with aerial photos, skunk overlap and use of short grass areas can be visualized (Fig. 2.3).

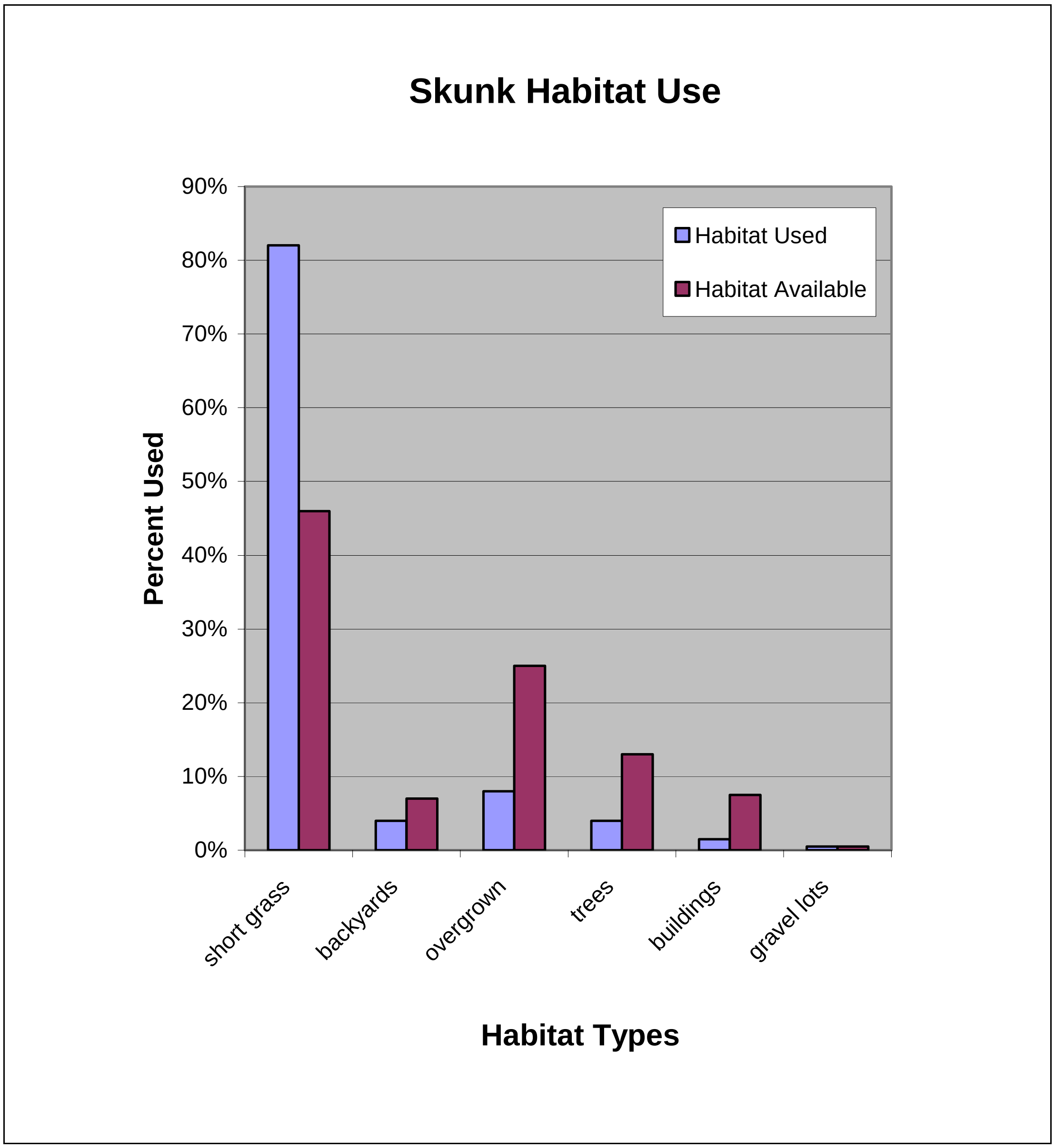

Figure 2.2. Percent habitat used compared to available habitat by radiocollared skunks from June 2004–May 2006.

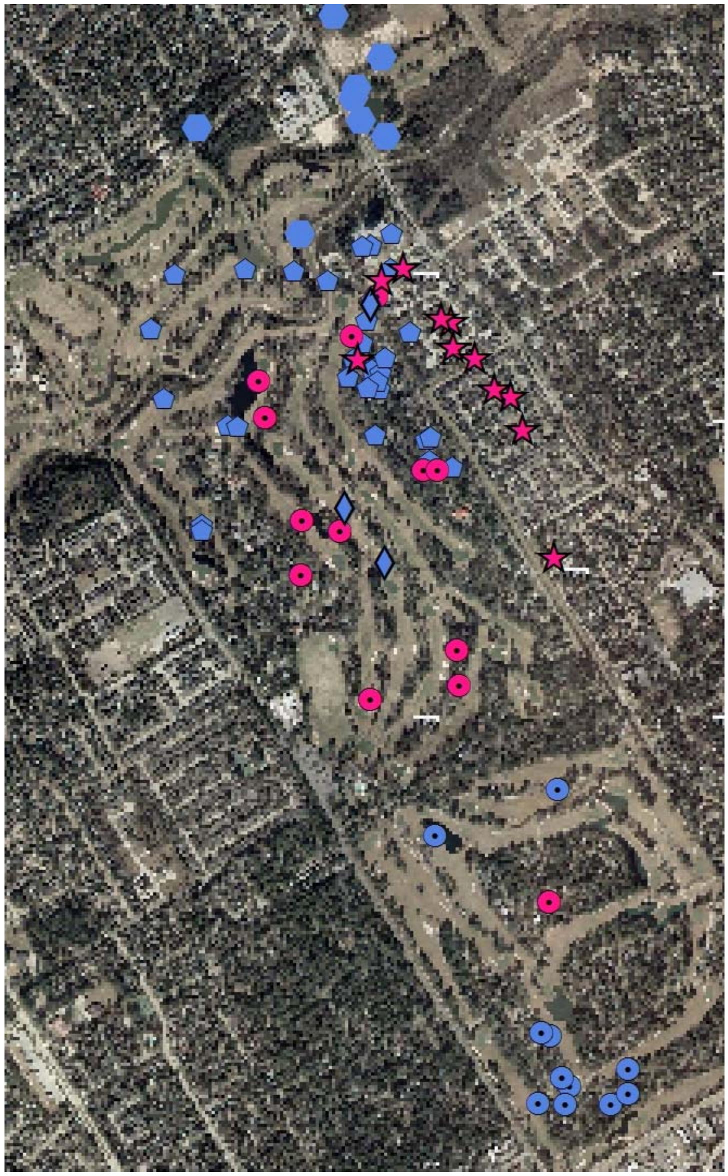

Figure 2.3. Aerial view of Champions Golf Course in the northwest skunk monitoring zone. Shapes indicate different skunks and all corresponding shapes represent movement of a single skunk. Blue shapes are males and pink are female. All movements were recorded from Oct 2004–May 2005. (Map scale is 2.54 cm = 0.5 km.)

Chi-square analysis of the 2-year period and each year separately revealed a significant ($P = 0.001$) difference in winter habitat use. Winter data of the first year revealed significant ($P = 0.001$) differences in habitat use occurring within December 2004, January 2005, and February 2005. No significant differences were found for habitat use in October 2004, November 2004, or March 2005, however, weather records indicated these were much warmer months. For the second year, December 2005 ($P = 0.045$), February 2006 ($P = 0.098$), and March 2006 ($P = 0.003$) also indicated difference in habitat use by skunks. As is the previous year, weather data revealed that October 2005, November 2005, and January 2006 had fewer nights ≤7C allowing skunks to return their warm season feeding patterns, relying primarily on short grass areas.

Discussion

Skunks use park areas and golf courses in urban/suburban areas because they have restrictions on free-ranging dogs, are generally closed to the public during night hours when skunks are active, have lighting, often use sprinkler systems throughout the year. Sprinklers and lighting, either overhead or placed at ground level, promote healthy populations of both ground dwelling and flying insects, all important to skunk diets. During early summer, skunks were regularly seen standing under mercury security lights to feed on falling June bugs (*Phyllophaga* sp.) attracted to the lights. Habitat preferences of skunks are influenced by availability of food (Lariviere and Messier 2001).

My data showed that striped skunks preferred short grass areas over other habitats available to them. I found skunks seemed to be able to move easier in these areas, possibly important in escape mentality. Additionally, for females with young, short grass offers her a better view of her offspring as they feed in the area.

Unfortunately, from a disease standpoint, most residential yards also fall under this preferred shortgrass habitat. For areas where diseases, such as rabies, are endemic in the skunk population, having a known rabies vector residing in close proximity to people and pets is a serious issue. In Figure 2.3, skunks can be seen moving throughout the adjacent golf course residential areas. Many of these houses back up directly to the golf course, with only a small strip of green space separating them from a preferred skunk habitat. Rabies management along these parkland and golf courses is paramount to a successful urban/suburban wildlife rabies control program.

Winter weather patterns in Houston are typical of most coastal communities. Houston does not have a true winter season. Rather, winter occurs as a series of cold fronts that occasionally drops temperatures <7C for possibly only a few consecutive nights, before returning to warmer normal winter low temperatures, typically from 10–15C (www.weather.com). In some years, temperatures do not dip below freezing and ice is seldom recorded in the Houston metropolitan area. However, a shift in skunk feeding activity was recorded, with inactivity correlated to colder temperatures. Because these temporary cooling events were seldom, randomly occurring, and with no pattern for comparison, winter months were not compared statistically between years or each other, as these skunk activity patterns appeared to be driven solely by temperature, not by innate seasonal movement to brush.

Early in this study, I observed a temperature induced shift in reduced activity. Telemetry monitoring results during the winter season revealed that animals were not out feeding as normal. Skunks sought shelter when temperatures dipped below 7C. Telemetry data recorded skunks in den sites or thick vegetation, presumably preferring to staying warm and wait out the colder temperatures. Further literature review revealed this activity shift has been recorded in previous studies (Verts 1967, Greenwood et al. 1985, Rosatte and Lariviere, 2003). Gehrt (2005) added that skunks can remain dormant in winter dens for extended periods dictated by weather. Though not a hibernator, skunks do have the habit of "holing up" for periods of days during winter storms or extremely cold weather (Shirer and Fitch 1970). While no winter storms or extended freezing temperatures occurred in Houston over the course of my study, telemetry data did reveal that skunks were moving back and forth from short grass areas to thicker, brushy areas or remaining in den sites as temperatures began to cool. As temperatures warmed, skunks returned to short grass areas. By spring, skunks used short grass fields almost exclusively until the next winter season again brought the occasional cold fronts. These shifts became noticeable beginning around October when cold fronts temporarily dropped temperatures and then slowly return to normal feeding patterns by April. For this reason, October–March was used in the statistical analysis as the winter season.

Of particular interest are the findings of other researchers that recorded skunk activity at temperatures much colder than 7C. Greenwood et al. (1985) found that while windchill reduced skunk movements in North Dakota, skunk activity was observed when the night's minimum temperature was -6C and maximum windchill was -24C. From this, it appears that skunks, like other mammals including humans, become acclimatized to their environment and that these periods of inactivity are relative to what temperature extremes are common to the geographic location. While skunks gain protection through thicker hair growth, extra weigh, and higher metabolism rates as needed for their location, different geographic locations appear to have a cold temperature threshold. Once exceeded, skunks seem to prefer sheltering within dens than risk exposure to extreme conditions. Understanding this threshold mentality, and at what temperatures this inactivity begins, can be very important in disease management.

During warmer winter low temperatures (10–15C), skunks were regularly observed feeding in short grass areas. They tended to be more active in areas where sprinkler systems were still active, than in non-watered areas, but they were regularly observed feeding in all areas. This was especially true at golf courses where skunks were regularly seen digging in the greens. This observation is likely due to insects burrowing deeper in the soil layers during winter months and skunks shifting their feeding locations slightly to compensate. Wood (1954) found that skunks relied on insects less in winter (52% in winter, as opposed to 76%, 96%, and 88%, respectively for fall, spring and summer seasons), supplementing their diet more with assorted vegetable matter, small mammals, and birds. While slightly less visible in winter months across their range, feeding skunks were regularly observed in short grass habitats throughout the year.

Skunks captured during warmer winter periods did not appear to be negatively affected physically by cold-induced periods of inactivity and fasting. Gehrt et al. (2005) found that striped skunks possess adaptation for surviving winter, including insulative pelage, relatively high basal metabolisms, and considerable weight gain prior to winter allowing them to metabolize fat during prolonged periods of dormancy and, although severe winter conditions likely affect skunk populations, they are probably less affected by winter than other mammals, as indicated by an extensive distribution at higher latitudes. Houston skunks did not exhibit noticeable weight gain prior to winter and did not possess thicker coats than that observed during warm seasons. These adaptations would not be needed, and likely be detrimental, for skunks living in warmer climates with mild winters.

Denning

While this study did not set out to record denning activity, activity was observed as a component to the effects of weather on skunk activity. In this capacity, observations were noted on what comprised as a den and how these areas were used throughout the year. Within developed plots of my urban/suburban study area, dens typically were located under structures, gazebos, hollowed trees, tool sheds and others offering safety and protection from outdoor conditions. For the less developed areas along electrical easements, drainages, and parks adjacent to undeveloped green space, thick vegetation areas were frequently used by skunks for protection. Throughout the summer months, skunks retreated to these dens as escape holes and utilized them as natal dens for raising young. During temporary cold snaps, prolonged denning activity took place both under structures and in thick vegetation. Additionally, a few skunks were found dead within their dens at more unusual locations, found only after receiving the mortality signal given off the radiocollar. Dead skunks were retrieved: smashed in a burrow dug into a drainage area that was being prepared for new home construction; under a concrete slab supporting bleachers at a neighborhood ballpark, approximately 9m from its entry hole on the outer edge of the slab; and under some large broken pieces of concrete at a water treatment plant where a strong smell of chlorine was coming from the den. Dens play a very important role for skunks and their use was observed throughout the year.

While a few recent skunk denning studies have been conducted in Texas (Hansen et al. 2004, Doty and Dowler 2006), most studies have occurred in the species' northern range (Lariviere and Messier 1998*a*, Lariviere et al. 1998, Gehrt 2005). Lariviere et al. (1998) stated that buildings and farmsteads were commonly used den sites for striped skunk, especially when closed spaces occurred beneath the building. He further suggested that not all farmsteads and buildings are used by skunks, thus not all farmsteads and buildings are of equal value to skunks. This suggests that striped skunks have specific preferences. However, buildings that were used for dens could be differentiated from buildings not used for dens by the presence of a closed space underneath them, important possibly for low construction and maintenance costs of dens, thermoregulatory advantages and reduced predation risk. Conversely, Doty and Dowler (2006) located no dens under buildings in their study of rural west-central Texas skunks.

They found that most dens (64%) were above ground in cactus, open grasslands, and under shrubs and that only 20% composed of burrows, mostly dug into cactus, herbaceous cover, shrubs, and at the base of mesquite trees.

Den Switching, Sharing, and Possible Disease Transmission Sites

During the recording of telemetry locations, I often received signals coming from dens located under gazebos and large storage trailers. On 3 occasions at 2 different locations, I witnessed opossums going into the lone entry hole that would have been used by the collared skunk already inside. Structures in both instances had been in their present location for a long time, having originally been placed on blocks that were partially sunk into the ground, leaving adequate space beneath the structures to allow for a small mammal den. I did not witness any hurried escape by either species. There would be no way of knowing whether these structures offered separated compartments where species could isolate from each other or if they mutually used a common space. Raccoons were present at these locations, but I did not observe them using dens. Gehrt et al (2005) found that striped skunks, opossums, and raccoons are often considered ecologically-similar species through their roles as mesopredators, similar in den selection, shared habitat use, and they are similar in body size. Shirer and Fitch (1970) postulated:

> "Neither the raccoon, striped skunk, nor opossum is known to be territorial. Rather all three seem to be somewhat tolerant of members of their own species, and to a certain extent, members of the other two species. Tolerance sometimes extends to simultaneous sharing of the same den. Some dens or refuges may be

> used only once or only occasionally as in emergencies to escape pursuit, but extensive and well- situated dens are the communal property of the population and are relatively permanent, so that they are used by successive generations of all three animals. With regards to observations of this, it could not be determined whether the animals were in actual contact in the den, but the signals received at the surface indicated that they were in the same part of the den, possibly huddling together for mutual warmth. Evidence suggests that the communal dens used by all three species were excavated by the skunks, and that raccoon and opossums benefit from the labors of the former."

Lariviere and Messier (1998*a*) recorded that 40% of skunks observed engaged in den switching. This level of sharing could promote disease transmission both between skunks and from skunks to other species. My movement data indicated that skunks moved freely throughout their local area for feeding. Shirer and Fitch (1970) found that an individual tends to stay in a familiar area, but constantly changes its routine of foraging and its choice of shelters at the end of an activity periods. When skunks were captured through hand catching with a dip net, skunks often darted to nearby holes. Not being far from dens, constructed either as living spaces or escape holes, may be vital for individuals to survive a predator, but it also could be an unhealthy situation for all individuals entering the enclosed hole. Verts (1967) felt accumulation of skunk feces inside the den may be a reason for switching dens, and Butler and Roper (1996) found a possible build-up of parasites. Given all these additional reasons, future research on den switching and multi-species use of dens will be an important consideration for wildlife disease managers.

Chapter Summary

Skunks preferred using shortgrass areas and could be regularly found feeding in them throughout the year. Winter temperatures modified regular skunk movements by reducing their movements until warmer temperatures return. As seen in this study, temperatures ≤7C changed skunk movement rate. Skunks regularly out feeding in temperatures >7C, stayed in dens when temperatures dropped. Skunks were observed sharing dens, both with other skunks and with other mammals. This can be problematic since additional time spent in dens, particularly with other skunks or with other species, could enhance the possibility of disease transmission and spread. Understanding behavioral preferences, and changes in behavior triggered by temperature, may have important impacts on management decisions designed to reduce rabies occurrence in urban/suburban areas.

CHAPTER III

STRIPED SKUNK HOME RANGE VARIATIONS WITHIN URBAN/SUBURBAN AREAS

Synopsis

Understanding animal movements of rabies vectors within an urban environment can be critical to protect against disease transmission. I outfitted 99 skunks with radiocollars and monitored skunk movements from June 2004–May 2006. Over 2800 Global Positioning System (GPS) were recorded for the study period. Weight data were collected at time of capture. Average weights of males were 1,819.0 grams in early spring and 2,135.7 grams in late spring and summer. For females, average weights were 1,152.5 g in early spring and 1,576.3 g in late spring and summer. Males were slightly larger, but no statistical significance was recorded. Twenty skunks were monitored over multiple seasons and their GPS location points were analyzed to establish overall range use and seasonal range use. Results indicated that average range use for males was 255 ha (217–345), while females averaged 126 ha (60–218). Male range use was significantly (P = 0.005) larger than female range use while seasonal movements were not significantly different. As rabies vectors, skunk movement data are very important in tracking disease spread and equally vital to establishing rabies management strategies.

Introduction

Ecologists have long known that species do not occur uniformly over space, but rather that abundances are patchy (Bowers and Matter 1997). In urban/suburban areas, many small animals react to their environment, drawn to higher quality habitats that offer more resources. Many of these resources are artificially produced and maintained throughout the year. These include golf courses, ball parks, churchyards, and large green spaces. The exact degree to which these artificial habitats affect natural behavioral ecology of skunks is unknown, but congregations of animals in 1 place can lead to disease concerns and transmission at a higher rate. Understanding the effects of urban areas on the movements of skunks can be an important factor in determining ways to vaccinate skunks and other wildlife for potentially health threatening diseases.

Most efforts to control rabies in Texas are concerned with preventing the spread of the disease from skunks, bats, coyotes (*Canis latrans*), and fox to domestic animals and humans (Pool and Hacker 1982). For striped skunk (*Mephitis mephitis*), few studies have been published on striped skunk home ranges (Frey and Conover 2006) in relation to other small mammals. Home range size is influenced by variables such as diet, latitude, habitat, and gender (Gittleman and Harvey, 1982; Sandell, 1989, Bixler and Gittleman 2000). Determinants of the size of mammalian home range can be multifarious and may vary in relative importance by season and gender. Thus, gender-specific and seasonal dynamics of size of home range can illuminate various aspects of the ecology and behavior of a species (Gehrt and Fritzell 1997). I analyzed the home range of 20 skunks to delineate skunk movements within an urban/suburban environment. These data will provide useful information for managing skunks and their role as a possible rabies vector for humans, pets and other wildlife.

Methods

Striped skunks were captured from 18 locations in Harris County, Texas from March 2004–May 2006. Locations were derived by scouting areas with large open habitats that would allow for long range viewing and nighttime access. These included all county and city parks, as well as golf courses, school yards, churches, ballparks, and various green spaces. Due to safety concerns and legal considerations, no skunks were captured without securing advance permission from county personal, school district police, golf course managers, and other landowners to be on their property. Private property was seldom an option, although a large private outdoor museum was used. Locations were chosen on the northwest, west, and southeastern ends of the county where visual observation through spotlighting confirmed the presence of skunks. All sites had the same general mix of habitat, with wide swaths of short grass bordered by a mix of shrubs, thicket, and large trees offering skunks a variety of habitat choices. Most locations were kept moist year-round through sprinkler systems.

Skunks were initially trapped using Tomahawk live traps (Tomahawk Live Trap Co., Tomahawk, Wisconsin, USA). After approximately 2,000 trap nights, only 6 skunks were caught. To improve capture success, skunks were captured by hand using a dip net. Throughout the 2-year period, a total of 99 skunks was captured and anesthetized with ketamine hydrochloride (Fort Dodge Animal Health, Fort Doge, Iowa, USA) and xylazine hydrochloride (Lloyd Laboratories, Shenandoah, Iowa, USA) in a 5:1 mix, as dictated by the United States Department of Agriculture – Animal and Plant Health Inspection Service – Wildlife Services (USDA–APHIS–WS), Immobilization and Euthanasia Drug Use Committee. Initial dosage was given at 0.4 ml, which was adequate to anesthetize a skunk for approximately 20 minutes. When skunks were highly agitated, a subsequent dose of 0.2 ml was often needed to anesthetize a skunk. While animals were anesthetized, artificial tears solution was applied to the skunk's eyes to protect corneas from drying out. Animals were evaluated for their health status and weighed. Skunks were placed back at the capture site and monitored until they fully recovered from the anesthetic. Additionally, on cool nights, a small towel was placed under the skunk and another on top of the skunk to help it maintain its core body temperature while recovering.

Skunks were fitted with a 12 g VHF radio transmitter (Telemetry Solutions, Concord, California, USA or Advanced Telemetry Systems, Isanti, Minnesota, USA) operating on 148 MHz to minimize bounce off buildings and trees. Because of some initial radiocollar malfunctions, results from June 2004–May 2006 were analyzed for this study. Collars possessed a mortality signal built into the unit and set to emit an inactivity alert after an 8-hour period of inactivity. Monitoring was conducted on alternating nights for 2 years, recording locations on the southern part of the county on one night and the northern and western parts of the county on the second night. Upon gaining a signal, a single location for each skunk was determined and recorded per night, most achieved through triangulation when roads and terrain allowed. When triangulation could not be achieved, a combination of sound and light monitors on the receiver was used to estimate the distance between myself and the skunk. Global Positioning System (GPS) coordinates were collected at the capture site, as well as additional information on weather conditions and time of capture.

Skunks were captured at different rates throughout the 2-year study and were based on the collared skunk longevity. As collared skunk numbers fell below 20, replacement skunks were captured and collared. Only at the time of capture was animal weight measured and recorded. As a result, capture data is not evenly distributed by season throughout the 2-year study. Data were sorted by gender and season to determine if weight fluctuations existed by season and if those fluctuations had any influence on movement data. Four seasons were defined as: spring = 01 March–31 May, summer = 01 June–31 August, fall = 01 September–30 November, and winter = 01 December–28 February. To examine differences in skunk weights, Chi-square analysis, comparing observed *vs* expected frequencies, was used to compare the data as a 2-year time span, each year separately (01 June–31 May), and matching season months (Table 3.1). No statistical comparison between sexes was conducted.

Data were transferred from field data sheets to a Microsoft Office (MS) Excel 2003 (Microsoft Corp., Redman, WA, USA.) spreadsheet. It was then exported into ArcView 9.3 (ESRI, Redlands, CA, USA) for skunk location mapping using on-line aerial photos (terraserver-usa.com). Once mapped, individual skunk ranges were calculated using on-line Hawth's Analysis Tools (www.spatialecology.com). T-testing was used to statistically compare male and female home ranges. Seasonal movements were tested using ANOVA to compare all seasonal movements for each gender and *t*-testing was used to compare single seasons with each other. Measurements of migration during breeding and denning were compared to findings from other times of the year and to the professional literature. Other components affecting home range values, such as weight, gender, and habitat were evaluated as to the degree those factors may influence the movements of skunks.

Results

Of the 99 skunks captured, 39 (39%) were males and 60 (61%) were females. Both males and females were captured at all 18 locations and over 2800 GPS coordinates were recorded over the study period. Skunks weights revealed no statistical significance between gender, however, males were slightly larger than females (Fig. 3.1). Skunks weights were mostly consistent, with an occasional big skunk or petite skunk being captured. All skunks captured were adults. Average weights of males were 1,819 grams in early spring and 2,135.7 grams in late spring and summer. For females, average weights were 1,152.5 g in early spring and 1,576.3 g in late spring and summer.

Table 3.1. Weights (kg) of all skunks captured from 01 June 2005-31 May 2006.

Season	01 June 04–31 May 05		01 June 04–31 May 05		01 June 05–31 May 06		01 June 05–31 May 06	
	# F	$\bar{x}$ Wt	# M	$\bar{x}$ Wt	# F	$\bar{x}$ Wt	# M	$\bar{x}$ Wt
Jun – Aug	14	1.56	6	1.72	10	1.32	5	1.72
Sep – Nov	5	1.79	10	1.65	0	0	0	0
Dec – Feb	4	1.42	6	2.00	0	0	0	0
Mar – May	14	1.51	4	1.73	9	1.33	6	1.93

Twenty skunks with more than 50 point locations, 15 females (75%) and 5 males (25%), were used to calculate home ranges using the minimum convex polygon method. Skunks analyzed in this analysis were captured from 9 different locations, with all 3 areas of the county represented (Table 3.2). Home range average for males was 255 ha (217–345 ha), while females averaged 126 ha (60–218 ha). Male home ranges were significantly (P = 0.005) larger than female ranges (P = 0.005). Additionally, home range estimates were examined seasonally for males and females (Table 3.3). No statistical significance was found.

Table 3.2. Home range calculations (ha) were analyzed for 20 skunks having more than 50 location points. Skunks were captured from all regions of the county surveyed. Female movements averaged 126 ha, while male movements averaged 225 ha.

Skunk ID number	**Sex**	**Location**	**Activity period**	**Home range** (ha)
9	F	Katy Park	06/04 – 04/05	159
10	F	Morton Ranch HS	06/04 – 01/05	166
18	F	Collins Co Park	07/04 – 09/05	218
19	F	Collins Co Park	07/04 – 08/05	134
20	F	Rushing Co Park	07/04 – 08/05	75
21	F	Rushing Co Park	07/04 – 08/05	74
33	F	El Franco Lee	10/04 – 02/06	60
47	F	Green Meadows GC	02/05 – 01/06	83
49	F	Green Meadows GC	02/05 – 12/05	132
52	F	Green Meadows GC	03/05 – 05/06	153
59	F	Rushing Co Park	04/05 – 11/05	80
66	F	Randolph Co Park	04/05 – 02/06	121
80	F	Morton Ranch HS	08/05 – 05/05	117
82	F	Green Meadows GC	08/05 – 03/06	159
84	F	Champions GC	08/05 – 05/06	160
26	M	Rushing Co Park	08/04 – 04/05	212
27	M	Rushing Co Park	08/04 – 09/05	217
39	M	Champions GC	11/04 – 09/05	239
78	M	Morton Ranch HS	07/05 – 03/06	345
83	M	Champions GC	08/05 – 05/06	262

Table 3.3. Movements of 20 skunks to determine if seasonal changes occurred in movements by males and females. Number of months is the amount of time the skunks were collared and monitored. HR represents the home range estimate (ha) for each season.

Skunk ID		**Spring**		**Summer**		**Fall**		**Winter**	
Sk	**Sex**	**# mo**	**HR**	**# mo**	**HR**	**# mo**	**HR**	**# mo**	**HR**
9	F	2	12	3	84	3	43	3	42
10	F	0	0	3	36	3	32	2	158
18	F	3	24	3	30	3	33	3	110
19	F	3	26	3	113	3	36	3	53
20	F	3	25	3	12	3	26	3	62
21	F	3	46	3	23	3	78	3	49
33	F	3	227	3	286	3	166	3	292
47	F	3	8	3	42	3	64	2	24
49	F	3	2	3	3	3	49	1	3
52	F	3	122	3	27	3	25	3	60
59	F	2	14	3	25	3	80	0	0
66	F	2	10	3	45	3	80	3	75
80	F	3	77	1	12	3	30	3	34
82	F	1	29	1	10	3	50	3	118
84	F	3	88	1	5	3	28	3	56
26	M	1	128	1	11	3	50	3	48
27	M	3	93	3	56	3	62	3	103
39	M	3	9	3	11	1	19	3	57
78	M	1	100	2	121	3	106	3	146
83	M	2	61	1	29	3	77	3	233

Discussion

While males were generally larger and heavier than females in my study, the sexes were indistinguishable upon capture prior to inspecting animal gender. Additionally, all weights may have been slightly increased by high dew associated with the Houston area. Most skunks, since at ground level, usually were completely wet at capture. Occasionally, a large female was captured, but it was more common to capture smaller females. Time of year had no significant impact on skunk weights, however, pregnancy may have accounted for the larger females.

In some studies, weight was found to be positively related to home range. Correlations between body weight and home range size generally reflect the relationship between movement and individual metabolic needs (Gittleman and Harvey 1982, Gompper and Gittleman 1991). Bixler and Gittleman (2000) found larger females had a significant positive relationship between home range size and body weight. For males, the relationship was the opposite: smaller males tended to have larger home ranges. Larger females showed significantly larger home ranges, as would be expected owing to the increase energy needs of a larger animal. However, skunks may vary significantly in weight from one season to another (Verts 1967; Bailey 1971; Fuller et al., 1985) and home range could vary accordingly. Bixler and Gittleman 2000

Hansen et al. (2004) found that males were significantly heavier than females, and weights at initial capture differed by season. Insignificant weight fluctuations observed in my study were likely due to year-round food availability. Large parks, school yards, church yards, and golf courses typically have expansive sprinkler systems to keep ground moist, attracting insects. Coupled with mild winters, skunks can dig easily for insects throughout the year. Upon inspection all skunks appeared healthy and in good physical condition. Gehrt (2005) speculated that the availability of artificial resources in urban systems may reduce seasonal weight loss and improve physical condition for urban skunks during winter. Thus, survival may not be as reduced during winter for urban skunks as for rural skunks, or artificial resources may result in an overall higher annual survival for urban skunks.

Movement Distances

Information from my skunk telemetry is patchy at best, due to several collar malfunctions early in the project. Collars were not initially waterproofed, causing the collar to short out during rainfall. While this malfunction posed no problem to the skunks, signals could not be transmitted. Some skunks with nonworking collars were recaptured and re-collared with an aftermarket attempt to waterproof the transmitter components, but coatings quickly peeled off the battery pack. The result was that many skunks had only a few points before collar failure. Additionally, points on some skunks were limited because of residents discomfort on seeing skunks in the area. At 1 household, an elderly lady shot several of my skunks shortly after they were collared. She did collect the collars in her garage, but was reluctant to return them. Movement data were only calculated for 20 skunks that had at least 50 points, allowing them enough longevity to show a clearer picture on actual skunk behavior.

Home ranges for my skunks were considerably smaller than those found by Greenwood et al. (1985), where 24 females averaged 242 ha (87–543 ha) and 15 males averaged 308 ha (98-688 ha). The park like setting of all locations probably was responsible for less movement. Plentiful food and numerous shelter locations throughout the year likely played a role in urban skunks not moving into areas with unknown conditions. Home ranges of many mammal species are typically smaller when food is abundant (Boutin 1990; Larter and Gates 1994).

Skunks living within urban/suburban areas can be a huge public health concern. These species frequently come into contact with people and pet animals, creating a high potential for transmission of infectious diseases such as rabies (Rosatte 1988, Rosatte et al. 1997). Their role as a rabies vector and as an animal drawn to backyard habitats make management of this species and disease management as a whole very important. As a comparison, Storm and Verts (1966) found that non-rabid skunks generally were within a radius of 1.6 km of their center of activity, with the vast majority with 0.8 km. Although the movements of the rabid skunk appeared to be somewhat aberrant during the last week of life, they apparently were no more extensive than those of non-rabid skunks of the same sex and age.

Home Range Shape

Skunk home ranges from my data did not retain any characteristic shape, rather skunks made use of the green space as a whole. Shape was more a component of the habitat they were in than a need for escape holes. Bixler and Gittleman, (2000) found that home ranges in his study were on average 2.5 times longer than wide, while Verts (1967) found that striped skunk home ranges were elongate in shape, and attributed this to long, straight-line movements between dens and hunting grounds. In a parkland setting, skunks were not dependent on digging their own escape holes. Numerous drainages, culverts, and out buildings were spread throughout most study sites and served as escape holes.

One observation made throughout both years of my study was the extended breeding season of skunks on my study areas. Young were regularly observed from March until early October. This extended breeding season in warmer climates that can accommodate it may help blunt an exaggerated increase in home range particularly of males in the early spring. Male skunks had considerably larger home ranges than females, which could be explained by larger movements due to late breeding attempts (Greenwood et al. 1985 and Lariviere and Messier 1998*b*)

Urban Environmental Differences

Skunk use of roads is mentioned in the literature and is generally thought of as problematic, given the common sight of roadkill skunk on Texas roadways. Although collared skunks were bordered by roads, none of my skunks were found as roadkill throughout the study. My study possessed areas with different traffic volumes along the roads that surrounded them. Some locations were accessible by small, suburban, residential roads with little traffic, others bordered by small rural roads often having light traffic, but accelerated driving speeds, and others were along major urban roads with moderate traffic throughout the night. Tracking points indicated that collared skunks readily cross roads to reach adjacent fields, especially when seeking out temporary shelter in thicker vegetation during winter. Other skunks, hit by vehicles, were seen along roads crossed routinely by my skunks. Gehrt (2004) found that difference in traffic volume between study areas did not result in an increase in road mortality for urban skunks because many skunks did not cross roads with high levels of vehicular traffic; roads formed the boundaries of their home ranges. However, increased traffic or road systems in urban areas may increase the probability of mortality by vehicles for urban skunk populations, whereas rural skunks may be more vulnerable to hunting, trapping or predation (Gehrt 2005).

Chapter Summary

Skunks were monitored from June 2004–May 2006 to determine skunk movements throughout a developed, urban environment. Range movements between seasons and between skunks indicating an overlap in shortgrass habitat use. Weight did not correlate with distance travelled, but males were found to be significantly larger than females. Range shape indicated that skunks moved across the entire study areas, as opposed to linear movement expressed in rural skunks as found in previous studies. Lastly, while study areas were bordered by roads, no skunks were killed crossing roads during the study period. Small residential roads, small rural roads, and major urban roads were crossed to get to available habitat that was adjacent, but off the primary study area. Road-crossing was especially evident when movement data revealed skunks moving to thicker habitat during nights having colder temperatures. The need to understand more about how these movements can perpetuate rabies, and potentially infect other animals not previously exposed, is vital to effective urban rabies management.

CHAPTER IV

LIVE-CAPTURING SKUNKS WITH DIP NETS

Synopsis

Many wildlife research projects are dependent on actual animal handling for sample collection, body measurements, and/or application of marking materials, including radio telemetry collars. For many projects conducted since the early beginnings of wildlife management, the cage traps have been the standard choice for small mammals. However, in certain circumstances, such as when availability of natural food resources is plentiful throughout an animal's range, trapping is needed in public areas, or where property access is limited, trapping alone may be either too slow or conditions exist that preclude cage trapping as a viable method of animal capture. I captured 93 skunks using a dip net and 6 skunks in cage traps. Over 2,000 trap nights were spent capturing 6 skunks and some traps disappeared off the properties while this project was conducted. This method is useful in urban/suburban areas where land is typically landscaped, providing relatively flat surfaces, short grass, and high visibility. Dip netting under these conditions allows for a safe, effective alternative of gathering specimens without the need of expensive traps and prolonged access to properties.

Introduction

Trapping striped skunks can be a test of patience throughout east and southeast Texas. During several prior rabies projects I have conducted throughout the eastern half of Texas, skunk trapping has yielded poor results. Unlike trapping nuisance urban/suburban skunks living under a house, deck, or shed, trapping open field conditions call for a different trapping mentality. Nuisance trapping calls for traps to be placed in a known pathway of the animal. Whether success is obtained by attracting skunks to a food lure placed within the trap or by skunks simply walking into the trap blindly, trapping for nuisance skunks is generally considered fairly easy and quite effective. However, when no known pathway has been established and researchers attempt to attract skunks from open fields into a small cage traps, trapping productivity often is significantly reduced. I also encountered this loss in production in western Louisiana, which shares the same general habitat conditions and climate as eastern Texas. Moist, clay based soils provide excellent habitat for various grubs, invertebrates, and herptiles which are important components of striped skunk diet (Wood 1954). Warm climate helps retain these plentiful food resources throughout the year, insuring that digging for food is a usually a successful venture for skunks and thereby reducing the need of going into a cage for a meal. Thus, cage trapping in these areas often yield poor response.

Use of dip nets can be an effective method to catch small mammals, such as skunks, especially in areas that have flat, highly visible landscapes, as are often found in urban/suburban areas. In areas that have public access, such as parks, school yards, and golf courses, skunk chasing can provide a safer collection alternative for the skunk, the researcher, and the general public by reducing the possibility of trap tampering and possible public contact with a known rabies vector. This study reviews the pros and cons of an alternative method of collecting skunks by using dip nets.

Methods

Using dip nets as a collection technique for skunks was initiated when cage-trapping efforts for a radio telemetry study proved inefficient. Numerous cage traps were placed within many county parks and secure green spaces where skunks were known to reside in southeast Texas counties. Traps were baited with a variety of lure baits to entice skunks into the traps. After 2,000 trap nights, conducted throughout March and April 2004, a total of 6 skunks was captured. Throughout this time, a variety of commercial lures and meat based products were used as trap bait. At the time, there was a need to capture 40 skunks, meaning it could approximately take an additional 10,000 trap nights to reach my needed total. In an effort to be more efficient, spotlights were used to locate skunks while driving on park roads and strong flashlights were used when on foot. Once a skunk was located, a syringe pole was loaded with a 4 cc mixture of ketamine hydrochloride (Fort Dodge Animal Health, Fort Doge, Iowa, USA) and xylazine hydrochloride (Lloyd Laboratories, Shenandoah, Iowa, USA) in a 5:1 mix, as dictated by the USDA-APHIS-WS Immobilization and Euthanasia Drug Use

Committee. My technician and I, clothed in Tyvek® (E. I. du Pont de Nemours and Company, Wilmington, Delaware, USA) coveralls and gloves, assisted each other in the capture. One served as the chaser, while the other assisted in locating the skunk and keeping a light on it. To give added protection, the chaser also wore a Tyvek® hood and visor-style polyurethane face shield (Fig. 4.1). Initially, skunks were to be captured by hand. This proved quite labor intensive for the chaser, so a standard fishing net attached to a 1.3-m pole was used to assist in the capture. The chaser carried a flashlight and net in one hand and a 1.3-m syringe pole in the other. The assistant carried a flashlight and additional syringes, needles, and immobilization drugs. Skunks were chased until captured in the net, usually following a 20-30 m run. The skunk was rolled in the net to reduce the chance of spraying and to assist in locating a proper injection site, typically in the thigh region. Skunks were given time to allow immobilization drugs to work before being moved to a location where radiocollars could be applied. Pending the length of the run, often a second smaller injection of immobilizing drugs was needed to calm highly excited skunks. All skunks were monitored during the time they were immobilized. Monitoring continued until the skunk regained consciousness and walked off under its own power.

Figure 4.1. Personal protective equipment needed to chase skunks included a construction-style polyurethane face shield, disposable gloves, and Tyvek® coveralls and hood. A dip net pole was used to capture the skunk and a syringe pole to administer an immobilizing drug injection.

Results

Ninety-nine skunks were fitted with radiocollars, 6 captured in cage traps and 93 with dip nets. Additionally, other skunks deemed either too small to carry the weight of a transmitter collar or in poor physical condition were captured with dip nets, but were able to be released unharmed immediately. While some nights yielded no captures in spite of extensive searching, other nights yielded up to 5 skunks. All skunks were captured in flat, somewhat level fields containing short grass where visibility of skunk movements was not hampered by tall, brushy vegetation. Because I was in control of what was chased and captured, no non-targets were captured. Additionally, approximately 75% of skunks sprayed when captured with the dip net.

Discussion

Although their appearance and characteristic waddle may suggest otherwise, striped skunks are highly mobile animals, when necessary. With vision impaired by bright, white lights quickly moving toward them, I typically never got within 20 m before skunks broke out in a fast run. Their speed alone is not excessive and most people would be able to get within capture distance, especially with a net, but striped skunks can change direction in an instant. Skunks do not rely on a speedy flight to escape a predator so one would think they would be easy to run down. However, due to a low center of gravity, they are able to make some remarkable directional changes (Dragoo 1993). With speed and frequent shifts in direction, without losing speed, capturing skunks with a dip net can leave one with an empty net and gasping for breath.

Ironically, Van De Graff et al. (1982) upon measuring various skeletal features of skunks, stated that when pressed to run, striped skunks select a slow transverse gallop with only a brief, if any, gathered suspension phase. The gallop selection selected by the skunk reflects its lack of stability and non-cursorial specialization, suggesting that the posture, gait selection, and musculoskeletal structure of the striped skunk are primitive. Primitive or not, skunks are highly adapted at running and cutting, allowing them to save their protective spray for when escape is not feasible. Interestingly, I did not have the experience of a single skunk stopping to spray while I was in pursuit. Skunks seemed fixated on locating holes to escape into or simply getting away. However, when it was clear the net was coming down on them, many (approximately 60%) emitted a massive cloud of spray while some (approximately 40%) never sprayed throughout the entire capture sequence. Lariviere et al. (1998) found the efficiency of juvenile behavioral displays may not be as developed as that of older skunks. Moreover, inactive adults may be more at risk because the efficiency of their chemical defense relies on their perception of predators (Lariviere and Messier 1996). This suggests that some skunks, relatively safe from large predators in urban/suburban areas, may not have sprayed because they were caught off guard while feeding. Not being accustomed to being pursued, some skunks may not have had adequate time to prepare for being pursued.

Trapping and dip netting were not directly compared in terms of person-hours of search time or how many person-hours of actual capture time were spent once skunks were located. Variables, including the existence, number, and proximity of escape holes, the speed and agility of the skunk, the terrain, and lighting conditions all factor into the amount of time expended and would vary from skunk to skunk. The benefit of dip netting is that, being a nocturnal animal, skunks could be collected and monitored at the same time, saving many hours over trapping by day and monitoring by night. Additionally, schedules could be rearranged easily as needed because no animals were possibly sitting traps. When the factors of convenience, scheduling, and performing 2 activities at the same time, dip netting was very time efficient.

My first introduction to dip netting skunks was as an undergraduate at Texas A&M University. A graduate student used dip netting as a method of collecting skunks when trapping success was slow. While he was very successful in his captures, he wore no protective clothing to shield him from skunk discharges and there was little doubt that he had frequent encounters with skunks. Dragoo (1993) recounts his Texas A&M University skunk chasing experiences by summing up with: "when I am chasing a skunk, I have only two things on my mind, one of which is where is the tail: I watch were it goes and what it does. As long as it goes up I know that animal is mine. However, if the tail goes down, I know I'm about to be impaled on mesquite or cactus, or flip over a barbed wire fence." Having heard the stories and smelled the smells, I was very apprehensive to find myself some 15 years later about to embark on my own experiences as a skunk chaser. As such, I highly recommend the protective Tyvek® coverings and plenty of Fabreze® (Procter and Gamble, Cincinnati, Ohio, USA) for the research vehicle. Additionally, when weighing the pros and cons of chasing skunks, I offer the following considerations to ponder:

Pros:

- Eliminate the need for purchasing expensive cage traps or baiting material. Saved vehicle expenses by not needing to drive to check traps daily.
- Can manage research hours more efficiently by acquiring and collaring new animals while recording Global Positioning System (GPS) locations for those already collared in the same areas. This saves time, money and vehicle expenses.
- No concern over trap-induced stress attributed to daytime heat and long confinement within the trap, both important humane concerns for projects conducted in southeast Texas or other warm environment.
- No accidental exposure to the public or domestic pets to a trapped animal, especially a primary rabies vector.
- Eliminates the chore of trying to inject an animal in the proper place while its moving around inside of a trap.

- No non-target capture issues.
- No concern over stolen, flooded, or damaged equipment.
- You know exactly what you have as the night goes on. Have some limited control over collection success, by not just being limited to what may happen to stumble into a trap.
- Great stories for your friends and family!

Cons:

- Chasing can be dangerous for the chaser, especially on land that may not be level. Additionally, in areas with a high dew point or park setting with elaborate automatic sprinkler systems, wet grass can be very slippery and potentially damaging to ankles and knees.
- Dark fields may have tripping hazards, such as holes from livestock, drainage ditches, old fencing and construction material, branches, poisonous plants, snakes, ant hills, or patches of heavy, thorny vegetation.
- Running with a syringe pole can be very hazardous if too short. I used a 1.3 meter syringe pole to help insure that the chaser would not be impaled if they fell.
- Chaser will often get sprayed, especially when the net comes in contact with the skunk. This seemed particularly true of females when young also were present.
- Excitability from the chase, especially if prolonged, often reduced initial effectiveness of immobilization drugs, necessitating additional doses to fully immobilize the skunk. Often this means handling drugs and needles in limited light. Additional care is needed to account for all needles used in the immobilization.
- Skunks were often lost in the dark when lighting was not sufficient or when skunks located and used protection holes in close proximity of the chasing location.
- Many skunks were overlooked due to low visibility, even with spotlights. By far, lighting was the biggest issue throughout the projects. The constant need

for fresh batteries, replacement bulbs, spotlight fuses, and truck fuses were minor compared to the general lack of spotting skunks in the field. Gehrt et al. (2005) found that spotlighting is most effective when it elicits eyeshine from nocturnal furbearers or other mammals, such as white-tailed deer. Skunks are rarely observed via eyeshine, and must be closer to observers for detection than other species.

Chapter Summary

Time management is usually a critical factor in the development of research protocols, thus it is important to get projects moving. Trapping small mammals, such as skunks, can be prolonged and labor-intensive when collecting in areas where food resources are plentiful, study areas can not be secured from the public, and/or land access is limited. In these cases, skunk chasing can provide an effective collection alternative by allowing the researcher to use a naturally "baited" area to their advantage, get in and out of areas quickly, and to work without much notice from area residents. One must carefully consider the pros and cons of trapping skunks with dip nets, but under certain situations, the pros may heavily outweigh the cons. With careful consideration to detail, capturing skunks with a dip net can be a valuable collection tool when conducting disease surveillance, ecological research, and species management.

CHAPTER V

ASSESSMENT OF TEXAS MEDICAL PROVIDERS CONCERNING RABIES VACCINES

Synopsis

Rabies is an important disease globally and thousands of people each year either request or require pre-exposure vaccination because they have “high risk” jobs or are exposed to the disease. After experiencing difficulty in receiving rabies prophylaxis from physicians, I conducted a survey of 297 Texas primary care medical providers to assess their knowledge of rabies vaccine procedures and their experience with rabies vaccines. Providers were randomly chosen based on their practice location being inside or outside Oral Rabies Vaccination (ORV) baiting zones and whether they practiced in a small town or large city. Mass media campaigns, conducted yearly to advertise ORV baiting with established zones, were hypothesized to be sufficient to educate resident providers to rabies and rabies prophylaxis. However, while small town providers within the zone was significantly more aware of rabies and rabies prophylaxis ($P < 0.03$), most providers (>95% of 297) rarely saw patients for rabies prophylaxis; therefore, providers have minimal, if any, experience with the procedures of acquiring and administering the vaccine. Providers varied greatly in their responses to my questions of where to acquire the vaccine, how and where to administer the vaccine, and where to acquire information about the vaccine. State and local health departments, in cooperation with federal

agencies, should target medical clinics and physician associations as outlets to disseminate information regarding rabies, rabies prophylaxis, and treatment.

Introduction

Rabies is an important zoonotic viral disease in the United States (US) that causes an acute encephalitis. While there have been 6 reported survivors following intensive supportive care (Rupprecht et al. 2006), if left untreated, rabies has a prognosis that is almost always fatal. Epizootics of rabies have been reported in raccoons (*Procyon lotor*) along the Atlantic coastal states (Hanlon et al. 1989), in red fox (*Vulpes vulpes*) from northeastern states (Johnston et al. 1988), in striped skunks (*Mephitis mephitis*) from central states (Rupprecht et al. 1996), in coyotes (*Canis latans*) in southern Texas (Farry et al. 1998*a*, *b*), in gray fox (*Urocyon cinerargenteus*) in central Texas (Steelman et al. 2000), and in bats sporadically throughout the continental US (Rupprecht et al. 1996).

Human exposure to rabies has occurred in each epizootic. Krebs et al. (1998) reported that approximately 16,000–39,000 people in the US receive post-exposure prophylaxis (PEP) annually. In addition, pre-exposure vaccinations are needed by persons in high-risk groups, such as veterinarians, animal handlers, wildlife biologists, etc. All rabies prophylaxis are routinely available with a physician’s prescription. However, knowledge of physicians as to the process to acquire rabies vaccine (i.e., pre- and post-exposure) is uncertain. I became involved in this issue when I had difficulty in acquiring pre-exposure vaccination for myself and employees. Medical providers I contacted in Texas either denied services, were hesitant, or unsure how to acquire rabies prophylaxis. In addition, some physicians were uncertain of potential side effects to rabies prophylaxis or how to interpret the vaccination site after injection. Therefore, my objectives were to compare knowledge of medical providers concerning rabies vaccines between physicians whose practice was located within and outside the historic Oral Rabies Vaccination (ORV) baiting zones in Texas, and to compare knowledge of medical providers concerning rabies vaccine between small and large cities within Texas. Through a cooperative effort, the ORV program is a cooperative effort between the US Department of Agriculture-Animal and Plant Health Inspection Service-Wildlife Services (USDA-APHIS-WS), Texas Department of State Health Services (TDSHS), the Texas A&M University System, the US National Guard and others interested in stopping the spread of rabies in Texas. Houston, Dallas/Ft. Worth, and Austin contain large concentrations of skunk and bat rabies, endemic in those populations, and for which ORV is not available. Due to mass media attention that occurs during ORV campaigns, I have included these cities inside the rabies zone, although no bait has ever been placed there. My hypothesis was that medical providers whose practices occurred within the rabies ORV baiting zones would potentially have more requests for pre- and post-exposure rabies vaccines; therefore, would be more familiar with procedures for acquiring and administering rabies prophylaxis.

Methods

Medical providers were contacted throughout Texas and either the physician or nurse was interviewed concerning their knowledge of pre-exposure vaccination and PEP. Since many insurance companies require an initial visit to a primary care physician, medical providers surveyed were limited to those in family practice. Medical providers were placed into 1 of 4 categories: either within or outside the rabies endemic zone and either in a small (<60,000 population) or large (>100,000 population) city. Rabies endemic zone was defined as areas that occurred within the historic bait drop zones for coyotes, and gray foxes in Texas (Bradley Hicks, USDA-APHIS-WS, personal communication). Medical providers were randomly selected from the yellow page listings from cities that met our size stipulation. Medical provider selection continued until 10 clinics were interviewed from each city. In some cases, small cities were not large enough to have 10 clinics or had fewer than 10 clinics willing to participate. Cities with less than 10 respondents are noted. Medical providers that occurred in small cities within the rabies endemic zone included: Fort Stockton (n = 5), Harlengen (n = 6), Raymondville/Port Isabelle (n = 7), Junction, Fredericksburg, Stephenville, Kingsville, and Kerrville; medical providers that occurred in large cities with the rabies endemic zone included: McAllen, Laredo, Abilene, Corpus Christi, Ft. Worth, Austin, San

Antonio, Dallas, and Houston; medical providers that occurred in small cities outside the rabies endemic zone included: Corsicana (n = 9), Galveston, Lufkin, San Marcos, Georgetown, Bay City, and Victoria; medical providers that occurred in large cities outside the endemic rabies zone included: Wichita Falls, Lubbock, Midland, Odessa, Amarillo, Waco, and El Paso (Fig. 5.1). Physicians or nurses were asked a series of questions concerning rabies pre- and post-exposure vaccines (Table 5.1), and their responses were recorded.

Answers of respondents were analyzed using *G*-tests (Sokal and Rohlf 1981) to compare the mean proportion of categorical responses given between respondents by region (inside or outside the rabies endemic zone), city size (large or small), and interactions of main effects. Statistical tests were considered significant at $P \leq 0.05$. Unless otherwise specified, data were pooled and graphically represented due to non-significant differences between regions and city sizes.

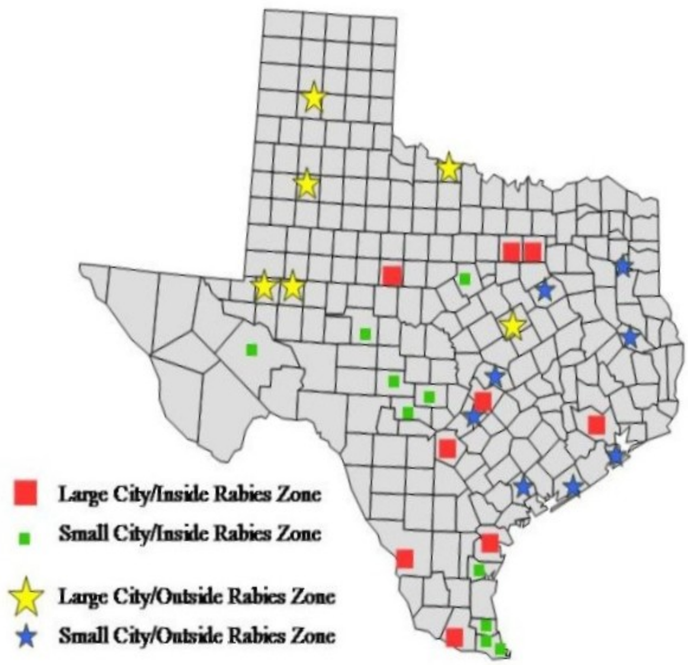

Figure 5.1. Locations of medical providers who participated in a survey regarding rabies vaccines. Red squares are large cities (>100,000 population) within the rabies endemic zone; small green squares are small cities (<60,000 population) inside the rabies endemic zone; yellow stars are large cities (>100,000 population) outside the rabies endemic zone and small blue stars represent small cities (<60,000 population) outside the rabies zone.

Table 5.1. Survey questions asked of Texas physicians concerning pre- and post-exposure rabies vaccines.

1. Do you administer pre-exposure rabies vaccine?
2. Do you administer post-exposure rabies vaccine?
3. Why do you not administer pre-exposure rabies vaccine?
4. Why do you not administer post-exposure rabies vaccine?
5. Where can a person get pre-exposure rabies vaccine?
6. Where can a person get post-exposure rabies vaccine?
7. Is the pre-exposure rabies vaccine a single shot or a shot series?
8. Is the post-exposure rabies vaccine a single shot or a shot series?
9. If a series, how many shots are in the pre-exposure series?
10. If a series, how many shots are in the post-exposure series?
11. Where on the body are the rabies pre-exposure vaccines given?
12. Where on the body are the rabies post-exposure vaccines given?
13. What side effects can occur with rabies pre-exposure vaccines?
14. What side effects can occur with rabies post-exposure vaccines?
15. Are pre-exposure vaccines kept in stock or ordered on an individual basis?
16. Are post-exposure vaccines kept in stock or ordered on an individual basis?
17. To how many patients did you administer pre-exposure rabies vaccine in the last year? Last 5 years?
18. To how many patients did you administer post-exposure rabies vaccine in the last year? Last 5 years?
19. Where would one get information about rabies vaccines?

Results

I contacted 344 clinics, of which 297 medical providers participated in my survey. Of the 47 non-participating clinics, a greater number ($\chi^2 = 17.1$, $df = 3$, $P < 0.001$) of medical providers were from large cities outside the rabies endemic area (75% of the Chi-square value) than the remaining regions and city sizes.

Significant interactions occurred between regions and city sizes ($\chi^2 > 9.3$, $df = 3$, $P < 0.03$) when medical providers were asked how many patients they administered pre- and post-exposure rabies vaccine to during the last year and past 5 years. More medical providers from small cities within the rabies endemic area treated more patients with rabies prophylaxis than medical providers from the other regions and city sizes (Fig. 5.2*a-d*). However, the majority of medical providers (>95%) did not have a history of rabies prophylaxis treatment. Significant differences between region, city size, and interactive effects were not noted ($\chi^2 < 6.0$, $df = 3$, $P > 0.14$) for the remaining questions of our survey.

In general, medical providers had varied responses to our questions. Nearly 70% of the 297 medical providers stated they would provide post-exposure rabies vaccine to patients; however, only 52% responded they also would administer the pre-exposure prophylaxis. Answers varied as to why medical providers ($n = 143$) did not administer pre-exposure vaccination (Fig. 5.3), but the majority of medical providers that would not give PEP (58% of 92) stated that they had no authority to administer the vaccine (Fig. 5.3). Of the same medical providers who would not administer rabies prophylaxis,

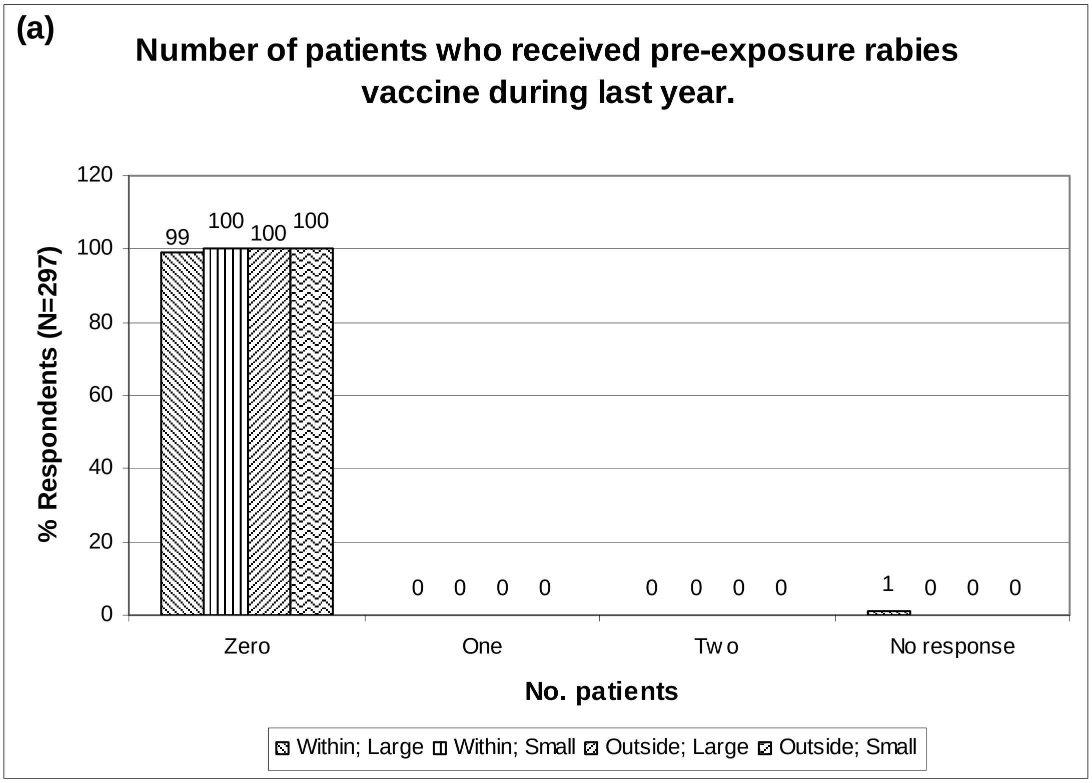

Figure 5.2a. Percent of respondents (n = 297) who stated that they treated patients with pre-exposure prophalaxis during the last year. No differences were observed between respondents within and outside rabies endemic zone, city size, or interactive effects.

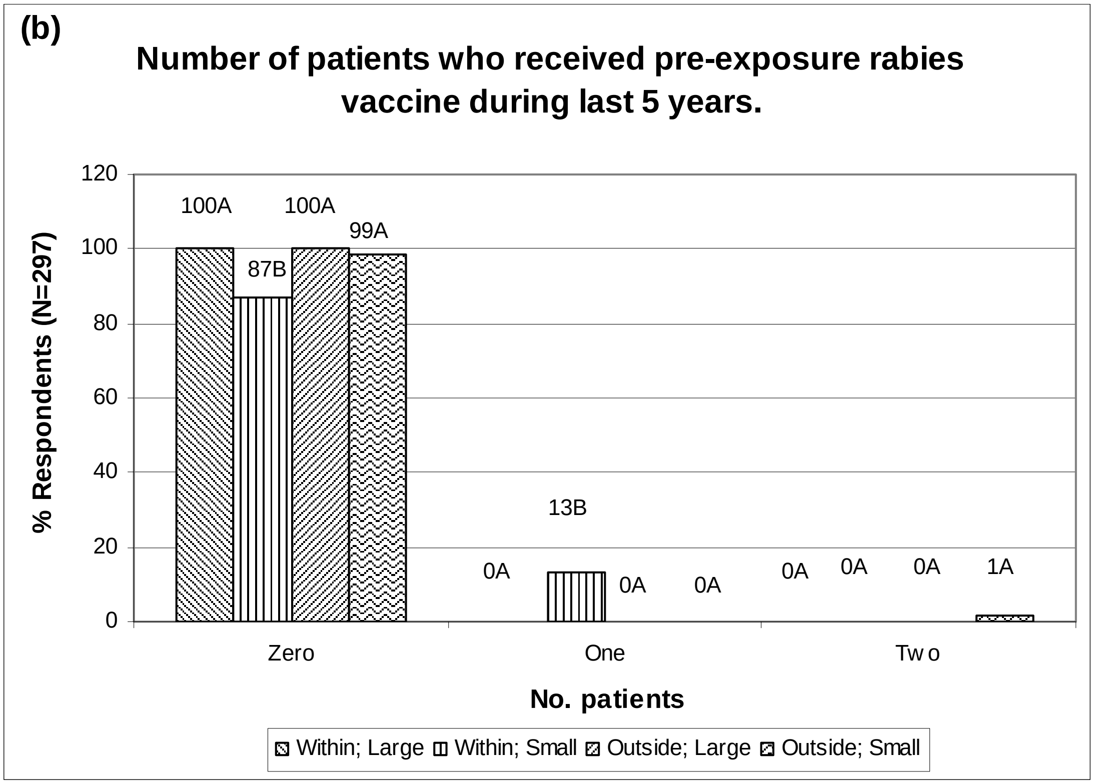

Figure 5.2b. Percent of respondents (n = 297) who stated that they treated patients with pre-exposure prophylaxis during the last 5 years. The same capital letter within each category for patient number is not different ($P > 0.05$).

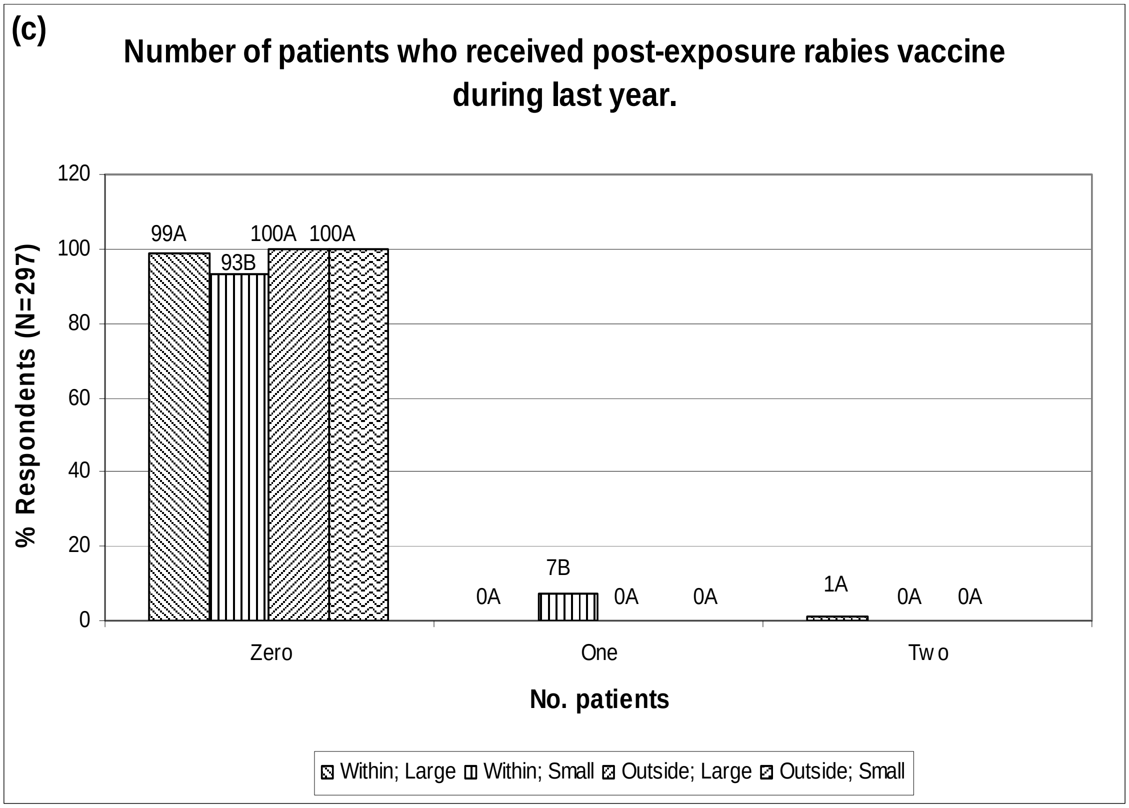

Figure 5.2c. Percent of respondents (n = 297) who stated that they treated patients with post-exposure prophylaxis during the last year. The same capital letter within each category for patient number is not different ($P > 0.05$).

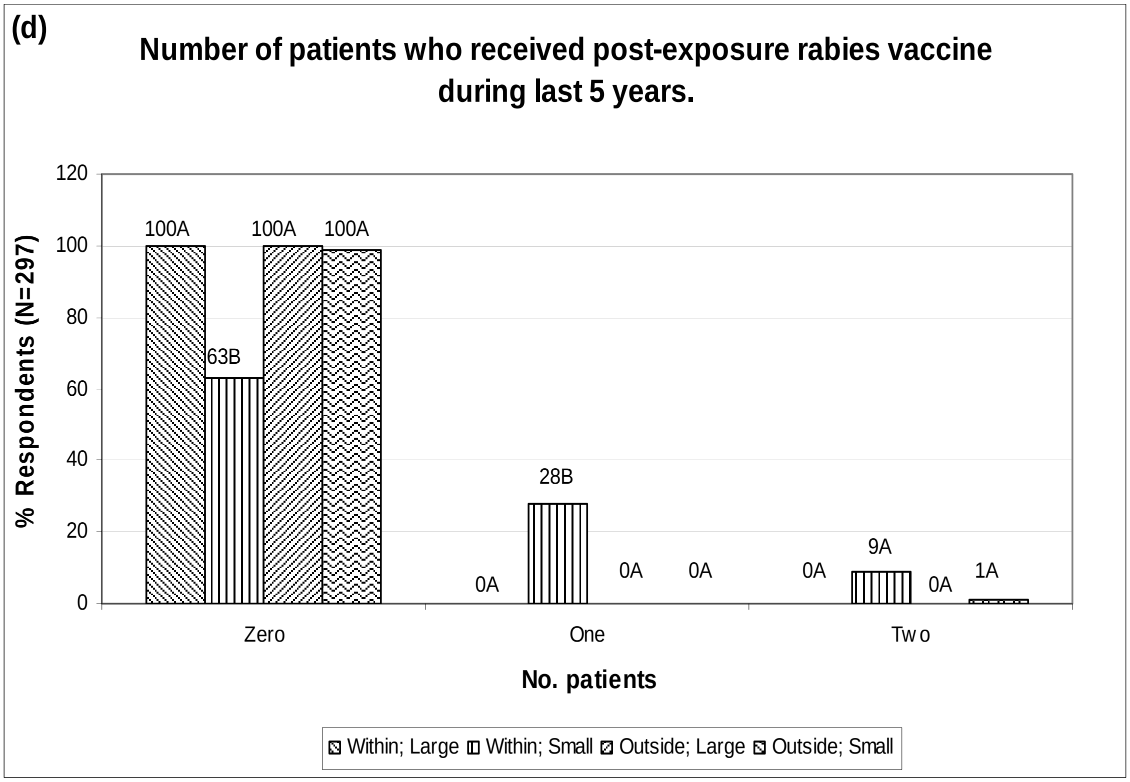

Figure 5.2d. Percent of respondents (n = 297) who stated that they treated patients with post-exposure prophylaxis during the last 5 years. The same capital letter within each category for patient number is not different ($P > 0.05$).

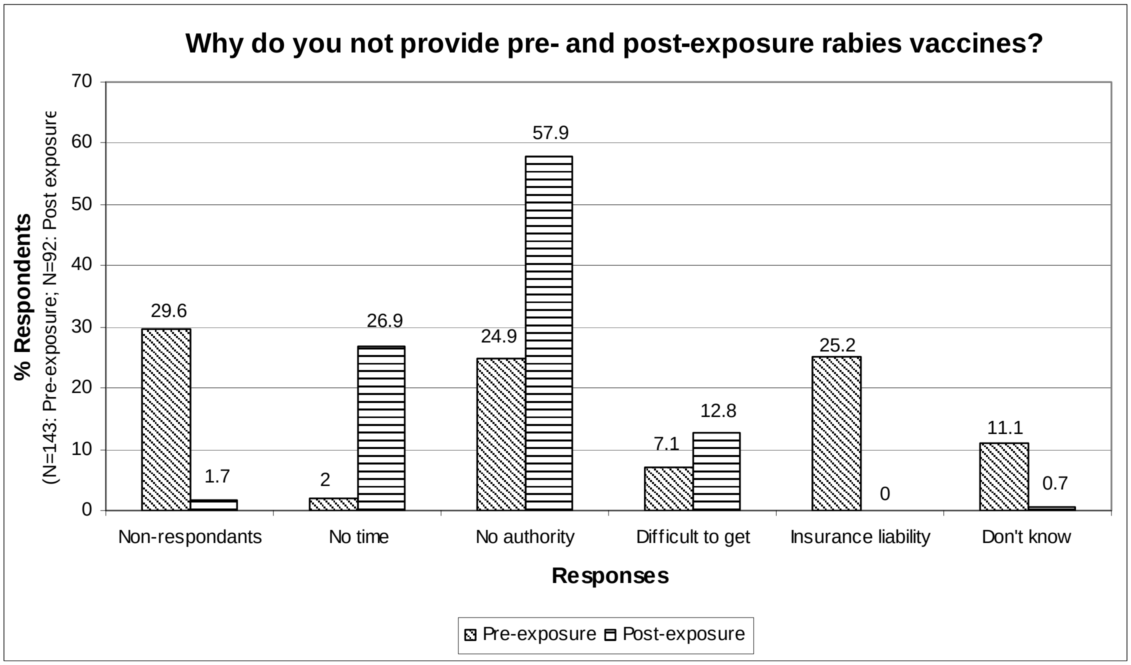

Figure 5.3. Reasons given why certain medical providers did not provide pre- and post-exposure vaccines to their patients.

when asked where a person could acquire rabies vaccines, the majority of providers responded that patients should go to county health offices (41.8% of 143) and hospitals (66.3% of 92) for pre-exposure and post-exposure rabies vaccines, respectively (Fig. 5.4). Of the medical providers who did provide rabies prophylaxis to their patients, only 1 of 154 providers maintained the pre-exposure vaccine in stock while the vast majority of providers ordered the vaccine on an “as needed”

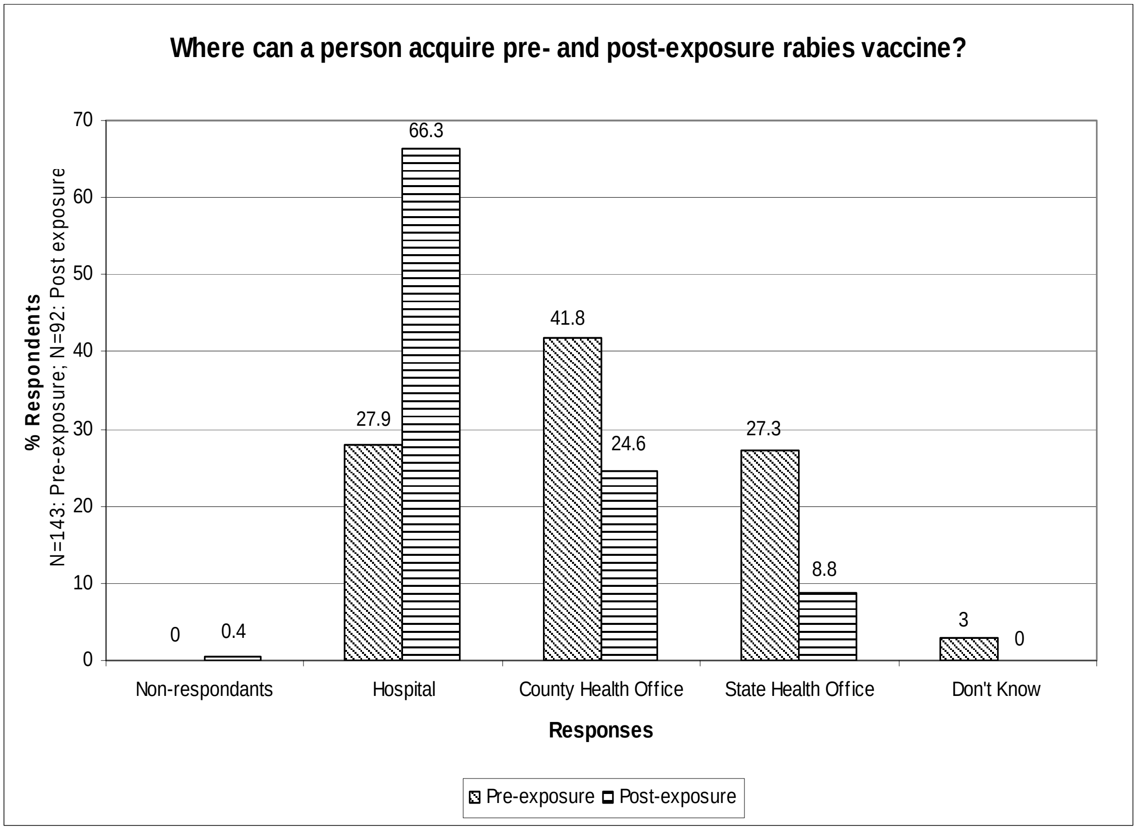

Figure 5.4. Places suggested by medical providers who would not provide pre- and post-exposure vaccines to their patients as to where the patients could acquire the rabies vaccine.

basis. All medical providers who were willing to provide PEP to their patients (n = 205) ordered the vaccine on an "as needed" basis. When asked if pre-exposure rabies vaccination was a single injection or a series of injections, 33.3% and 48.1% of the medical providers said the vaccine was a single shot and shot series, respectively, while the remaining providers either did not know or chose to not respond to the question. When the same question was posed concerning the post-exposure vaccine, 0% and

81.8% of providers said the vaccine was a single shot and shot series, respectfully, while the remaining 18.2% of providers did not know or chose to not answer the question. Of the medical providers who responded that rabies prophylaxis was

a series of injections, 23.9%, 24.2%, and 51.9% of the providers (*n* = 143) stated that the pre-exposure vaccine was a series of 2-5 shots, 6-9 shots, and “did not know”, respectfully, while 0.7%, 31.0%, and 68.3% of providers (*n* = 243) stated that the post-exposure vaccine was a series of 2-5 shots, 6-9 shots, and “did not know”, respectfully. The majority of medical providers believed that pre-exposure vaccines are administered in the arm of patients, while the stomach was considered the injection of choice for post-exposure shots by more providers (Fig. 5.5). Responses by medical providers concerning the side effects of pre and post-exposure vaccines varied widely (Fig. 5.6). Lastly, when asked where a person should go to acquire information about rabies vaccines, 18.2% responded their family physician, 60.3% said the county health department, 21.4% said the state health department, and 0.4% of the 297 medical providers responded that they did not know.

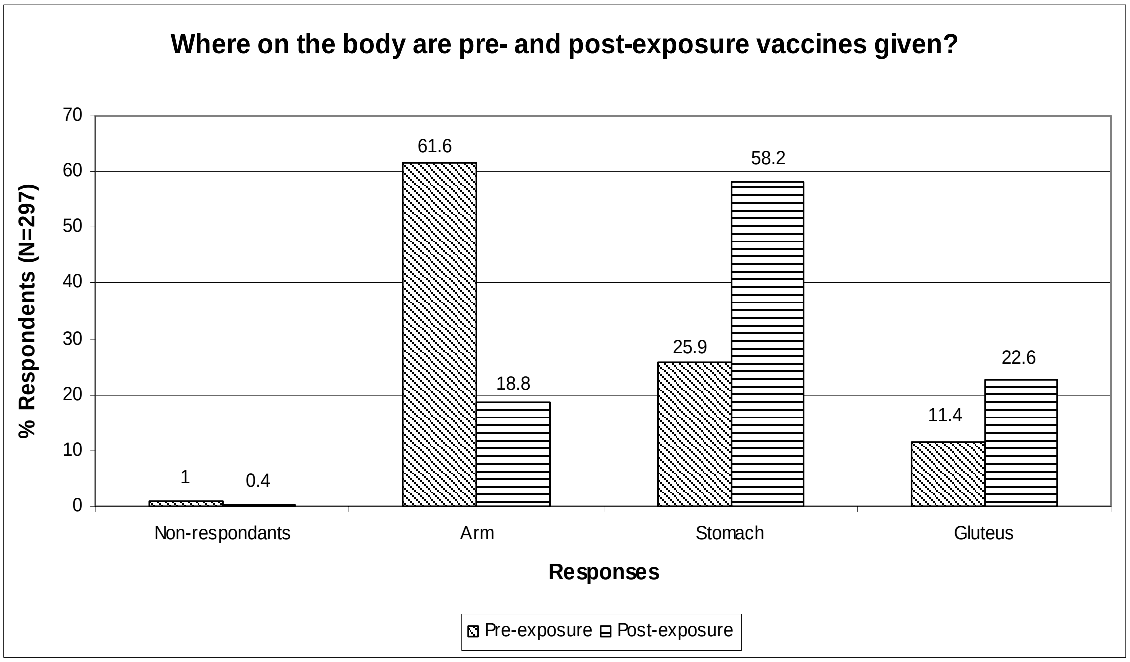

Figure 5.5. Injection site locations suggested by medical providers as to where on the body pre- and post-exposure rabies vaccines should be given.

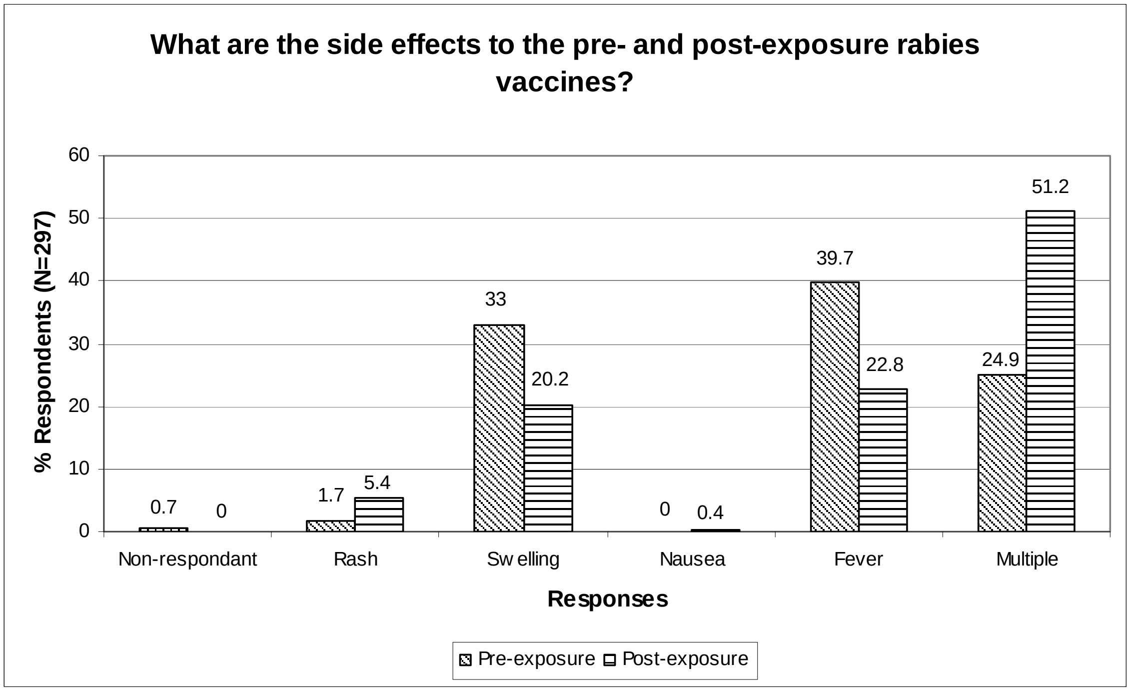

Figure 5.6. Side effects suggested by medical providers that can potentially occur after pre- and post-exposure rabies vaccines are given.

Discussion

Despite its rarity in our modern culture, rabies still invokes a deep fear. Since antiquity, rabies has been one of the most feared diseases (Jackson 2002). Many of these fears were played out before our eyes as some of our movie and television heroes fought the good fight before succumbing to rabies, usually occurring during western-themed genre. Even Roy Rogers died of rabies in his last movie role as a predator trapper on a large Texas ranch (“Mackintosh and T.J.”, 1975, Penland Productions). Little wonder then that many envision rabid dogs in rural areas when considering rabies. This ingrained lesson may be partially responsible for our observance of statistical significance regarding the number of physicians from small cities/within the established rabies zones willing to give pre- and post-exposure vaccinations to residents, when compared to all other groups. Other reasons might include expanded media coverage of rabies due to rabies control activities occurring within and around their town, observed economic boosts to the local economy as rabies control activities are conducted in their area, and recognition by local physicians of zoonotic disease concerns present within the vicinity. Additionally, enhanced awareness of wildlife and wildlife issues by residents of small cities, typically more tied to the land as compared to large, metropolitan areas, may create a very small, but continuous demand for rabies treatment. Figure 3 depicts this small, but steady demand as observed in the number of shots given across all categories in the last 5 years.

Pre-Exposure Vaccination

The World Health Organization (WHO 2002) states that pre-exposure rabies vaccination should be given to groups of persons at high risk of exposure to live rabies virus, including laboratory staff, veterinarians, animal handlers, wildlife officers, and others who's hobbies may expose them to rabies. Pre-exposure vaccination is beneficial for the following reasons: 1) the need for rabies immune globulin is eliminated, 2) post-exposure vaccine regimen is reduced from 5 to 2 doses, 3) protection against rabies is possible if PEP is delayed, 4) protection against inadvertent exposure to rabies is possible, and 5) the cost of PEP is reduced (Briggs 2002). In spite of these easily obtained findings, roughly half of all respondents indicated that they did not offer pre-exposure vaccination. Reasons given were unexpected at best and totally confusing at worst. Of those providers not offering pre-exposure vaccinations, insurance liability (25.2%) and lack of authority to give these shots (24.9) were cited as the leading reasons, with difficulty in getting vaccine coming in third (7.1%).

Liability is a concern when providing most any service, especially if the service is considered an elective procedure. Given that rabies exposure is sometimes achieved without the awareness of the individual, classifying pre-exposure vaccination as "elective", and thereby not readily available, could prove fatal to those with any risk of exposure. As with all prescription drugs available legally in the US, rabies prophylaxis is manufactured under Food and Drug Administration (FDA) regulations and given FDA approval as safe when used as directed. Briggs (2002) reported that while allergic reactions have been reported after booster vaccination, a maintenance requirement for maintaining pre-exposure protection, no serious or lasting medical conditions developed. All have been treated successfully with antihistamines, epinephrine, and steroids. Exactly why certain medical facilities would look at rabies prophylaxis differently from any other prophylaxes, such as tetanus vaccine, is unclear and needs to be further studied within the legal arena.

More puzzling is the feeling that medical providers did not have the authority to give pre-exposure vaccinations. As a prescription drug, only medical physicians can prescribe it. Many medical providers cited the need to contact local and state health department officials for assistance. After calling a small random sample of county heath departments, several said that they could assist in administering the shot series. However, no department had a physician on staff to prescribe the shot series, thus leaving the first essential step of prescribing the vaccination to physicians. All county and state health officials expressed surprise at the “no authority” response and restated their role as a support role, not the leading force in controlling disease at the ground level.

Difficulty in obtaining the vaccine was identified as a reason to not offer the vaccination series. In reality, pre-exposure vaccine is kept in stock and available at all state health regional offices and many county health offices across the state (Tom Sidwa, TDSHS, personal communication). Additionally, vaccine can be ordered from the manufacturer directly by toll free numbers supplied by state health officials and listed on the Centers for Disease Control (CDC) website (www.cdc.gov/ncidod/dvrd/rabies/professional/professi.htm). Also, CDC offers a 24 hours a day/7 days a week information line for physicians, nurses, pharmacists, veterinarians, and other health officials that have questions about rabies and rabies prophylaxis.

Post-Exposure Treatment

Rabies is a unique neurologic infection that can be prevented by PEP, at least when the vaccine is administered to patients within a reasonable period of time after a rabies exposure (Lafon 2002). However, nearly one-third of our respondents did not offer PEP. A shocking 60% felt they had no authority to administer the treatment regiment followed by an equally shocking response by 26.9% that they did not have time. These attitudes are not particularly helpful to someone that has been exposed to rabies, a potentially fatal disease.

As stated earlier, it is difficult to understand exactly how physicians came to believe they have no authority to prescribe a vaccine to combat a medical condition. Whether this is specific to rabies or extends to other diseases is unknown. However, it is particularly troubling given the urgent need for medical care. Both the World Health Organization (WHO 2002) and CDC (2005) state that rabies PEP should be initiated as soon as possible following exposure. Furthermore, WHO considers PEP to constitute an emergency situation. While emergency care and initial shots can be initiated at most hospital emergency rooms, it is important to note that rabies vaccines are very expensive. Estimated cost of a course of rabies immune globulin and five doses of vaccine given over a 4 week period typically exceeds $1000 (CDC 2003). Wound care, tetanus shot, and any additional antibiotics needed are in addition to this figure. Added costs associated with emergency room care could quickly and easily exceed an individual's available funds. Given rabies' life threatening potential, health care is a necessity and availability of treatment at one's primary health care facility could help substantially reduce the associated financial burden.

Every potential rabies exposure should be evaluated on a case-by-case basis, considering the epidemiology of the area, species involved, type of contact between victim and suspected rabid animal (provoked vs. unprovoked), and the anatomical location and severity of exposure (Briggs 2002). Need for medical treatment of non-treatment could then be evaluated from these results. While this procedure may take some time away from the usual stream of common ailments, it can not be stressed enough of the potential death of a patient exposed to rabies. Of our respondents surveyed who did not treat patients possible exposed to rabies, 26.9% claimed they did not have time to treat them. Although not specifically asked as to the meaning of the statement, it is assumed that the amount of time researching necessary procedures and vaccine procurement would seriously hamper their ability to provide heath care for all patients. Recognition and utilization of associated consulting staff at local and/or state health departments, as well as CDC's rabies support hotline, would greatly reduce the time burden possibly felt by uninformed health care providers.

The percentage of providers who did not treat rabies exposure seemed consistent with the number of providers that gave incorrect answers to how rabies prophylaxes are given. Figure 5 showed that while most medical providers understood rabies treatments (pre- and post-exposure) were given as a series of shots, most were confused as to where the shots were administered. Older vaccines were given in a variety of locations, including the stomach region. In 1980, a new vaccine was licensed by FDA for use in rabies treatment in the U.S. (Vodopija and Clark 2000). Currently, all vaccine is given in the deltoid region of the arm for adults and can be administered in the thigh area for children. My results indicated that over half (58.2%) believed that PEP was still given in the stomach, while 22.6% believed them to be given in the gluteus. WHO (2002) stated that PEP should ever be given in the gluteal region and Briggs (2002) added that shots in the gluteal area may lead to lower antibody levels and failure of PEP. Ironically, a recent San Antonio new story told of a south Texas child, exposed to a rabid animal, as facing a series of shots in the stomach (Gary Nunley, USDA-APHIS-WS, personal communication). Even after 25 years, the perceived discomfort of shots in the stomach is apparently hard to remove from the American psyche.

Lastly, when asked where one should go to get information about rabies prophylaxis, 81.7% indicated that either state or county health departments could provide this information. Only 18.2% of respondents felt one could get information from their family physician. Consistent with my findings, family physicians may indeed be the last place one should attempt to get information about this important disease. To resolve confusion, information packets need to be developed and distributed to family physicians. Aided by a quick reference, medical personnel could cut their research time significantly, disseminate correct information to the patient, and be guided by experts when making important rabies treatment decisions. To spare expense, hard copies could be distributed periodically, with the TDSHS website serving as the appropriate place to get up to date information between hard copy printings. Information sharing between health officials and physicians is paramount to adequately protecting Texas residents from this rare, but ever present disease.

Chapter Summary

Rabies is endemic in several wildlife species in Texas, making human exposure a rare, but real threat to human life. Many residents, not educated in the disease, its prevention, and/or its treatment, are dependent on their medical providers to provide swift and complete medical treatment. My survey indicated that 297 primary care medical personnel throughout Texas were deficient in their knowledge of rabies prophylaxis, resulting in a serious reduction of treatment outlets for exposure cases. My hypothesis was that more providers in small towns within the ORV baiting zones would be more knowledgeable about rabies prophylaxis than others outside of the ORV zones, die to the media attention attracted by the baiting operations. More medical providers from small cities within the rabies endemic area treated more patients with rabies prophylaxis than medical providers from the other regions and city sizes, however, the majority of medical providers (>95%) did not have a history of rabies prophylaxis treatment. Results indicate that a state-wide educational program, targeted at primary care physicians and their staff, needs to be implemented to increase awareness of rabies prophylactic procedures and treatment. Information sharing between state and federal health agencies and physicians is paramount to adequately protecting Texas residents from this rare, but ever present disease.

CHAPTER VI

CONCLUSIONS

Researching varying issues involving skunks has provided useful information that can be used to work toward eliminating terrestrial rabies in skunk populations. As rabies management has begun addressing problems in the spread and control of coyote (*Canis latrans*), fox, and raccoons (*Procyon lotor*) rabies, skunks represent the last hurdle in eliminating rabies from the landscape.

This study was commissioned by the US Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services (USDA-APHIS-WS) program as a portion of a larger study to address skunk rabies. My objective was to determine how vaccine laden baits could be applied in an urban/suburban environment. My objectives were formed to answer that question, requiring some basic ecological information about urban/suburban skunk ecology. The final objective of this study was to determine how these components could fit together to address the logistics needed in administering an urban skunk ORV project.

The primary question posed by USDA-APHIS-WS was: when bait blocks, specifically designed to vaccinate skunks for rabies, become available, how would they be distributed in the urban/suburban interface? In rural areas, coyote and fox baits are currently dropped from aircraft. However, this would not work as well within a populated area and would likely create legal issues as people and property were potentially struck by falling baits. Understanding where vaccine baits could be placed within the urban environment enabling skunks to find them became the central theme of my study.

One of the important facts to come out of this research is skunk dependence and preference on short grass habitats. When given other habitat choices, skunks preferred this habitat at 82% of the time they were monitored throughout the year. This is an important finding, given that it was available to them on a much smaller scale. Within urban areas as a whole, short grass areas can be found readily through various green spaces, drainages, and electrical easements, all areas that could be targeted for a broad scaled, county-wide ORV project. These long stretches of open, short grass areas, supplemented with the ball fields, school grounds, churchyards, golf courses, and other smaller green spaces studied in my research could provide an effective base to establishing corridors for an ORV program. By placing baits there along the ground, skunks would easily find them and hopefully consume them. Previous studies that I have been involved in have studied uptake of placebo baits. Because the baits are small sachets, resembling ketchup packets, short grass is vital to provide visibility of the baits to skunks.

The impact of weather was another important facet revealed in this research. Determining that skunks will routinely stay in their dens when temperatures drop is very important to address when baits should be distributed. In present coyote and fox rabies control projects, baits are routinely dropped in winter time to both increase visibility of the baits lying on the ground, but also to decrease incidence of various ants. Coyotes and fox have not exhibited reduced movement in response to colder temperatures.

However, skunks did exhibit reduced behavior when temperatures fell to <7C. Because bait drops are very expensive, take months to plan, typically involve approximately 50 people from multiple agencies from across the state, and involve procurement of storage facilities for equipment and lodging for workers, weather forecasts would be too unpredictable during the winter months to conduct a skunk ORV program. When baits become available, Texas should adjust their rabies management timeframes to work on skunk rabies projects.

Lastly, this research confirmed that urban skunks are not as mobile as rural skunks described in the literature, and that is very important in a rabies management program. Skunks stayed in areas where resources were plentiful. From body weight data, it was confirmed that skunks did not seem to shift toward large weight gains associated with winter preparation. This reinforces my theory that all forms of urban green spaces should be the used as potential baiting sites when a vaccine is developed.

Because rabies is potentially fatal, agencies involved should collaborate on educational material, not only for the public, but also for medical providers. Survey results revealed that wildlife professionals have not done an adequate job in relaying important facts about wildlife rabies management to physicians and their staff, thus interfering in their ability to provide prompt medical treatment to those possibly exposed to rabies. When the threat of rabies is present, people are dependent on their physicians to guide them in obtaining the health care needed. When physicians do not know what is required, the general public has been put at serious risk.

From my results, I conclude that ORV for Texas skunks should be conducted in mid to late fall when vegetation is dying back allowing increased bait visibility, but occasional cold fronts will not threaten to keep skunks in their dens. Additionally, a fall bait drop also reduces the chance that extended breeding seasons for male skunks and extended natal seasons for females would not interfere in allowing them to consume baits. Also, the vast majority of young would be at a stage of development that they also could consume the baits. Lastly, a mid fall bait drop would allow for collection activities, necessary to determine uptake of the bait by examination for biomarker induced tooth rings, could be conducted in winter, as opposed to spring when it might be more challenging to overcome skunk mating rituals and unpredictable behavior. Because collection activities can be done anytime when winter weather is cooperative and does not necessitate the extensive planning needed for the bait drop, skunks would be easier to find and collect during winter months than during the spring.

This study indicated that biologists involved in rabies management have much to learn about specific rabies vectors, their ecology, and how their behavioral patterns might be incorporated into management schemes. What has been learned from ORV projects for coyotes and fox in Texas is not necessarily applicable to skunks. What is useful includes: the understanding that skunks rely on short grass areas, common in any urban area; that skunk activity is reduced in extreme temperatures and that those activity thresholds will be different for different locations, due to temperature acclimation by skunks; and that skunks share dens with other skunks and other mammals, potentially aiding in disease spread through contact. These factors are not exclusive of the Houston area, but rather could likely be applied to any location where skunk rabies is an issue, with only minimal local research needed in advance. Additional research in different locations throughout the US is needed to determine if this is true, but only through continued studies will the answer of how to eliminate skunk rabies be revealed.

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