THE SUBURBAN COYOTE SYNDROME, FROM ANECDOTE TO EVIDENCE: UNDERSTANDING ECOLOGY AND HUMAN SAFETY TO IMPROVE COEXISTENCE

A Dissertation

Presented to the Faculty of the Graduate School

of Cornell University

In Partial Fulfillment of the Requirements for the Degree of

Doctor of Philosophy

by

Daniel A. Bogan

May 2012

THE SUBURBAN COYOTE SYNDROME, FROM ANECDOTE TO EVIDENCE: UNDERSTANDING ECOLOGY AND HUMAN SAFETY TO IMPROVE COEXISTENCE

Daniel A. Bogan, Ph.D.

Cornell University 2012

Understanding the behavioral ecology of carnivores and their interactions with humans is necessary to inform modern wildlife management programs that seek to maintain ecological integrity while managing human–carnivore interactions. Coyotes (*Canis latrans*) are one of the most successful carnivores in North America, and have recently extended their range into urbanized landscapes. However, coyotes inhabiting urbanized landscapes generate concern and require management to contend with conflicts. I investigated incident reports to understand the types of human–coyote interactions reported to the New York State Department of Environmental Conservation (NYSDEC; 2005–2009), and a coyote study website reporting system (CWR) for Westchester County, New York (2006–2008). In Westchester County, I live-captured and radio-tracked coyotes (n = 30) to study their spatial ecology, and identify opportunities to field-test aversive conditioning methods to curtail conflict behaviors of emboldened individuals. Additionally, I conducted a diet study of 493 scats to identify if coyotes used anthropogenic foods that could lead to conflicts. Of incidents (n = 447) reported to NYSDEC, 4.3% involved aggressive coyote interactions with people, and 33.8% involved a coyote threatening, attacking or killing a pet. Most reports were sightings of coyotes. Incident reports filed with NYSDEC and CWR occurred in different frequencies (χ_3^2 = 28.721, $P \leq 0.001$), as more sightings were reported to CWR. I found a positive association between incident reporting and human population size. Coyotes (*n* = 22) used 95% fixed-kernel home-ranges (*n* = 34) during 3 years that averaged 5.67 ± 3.25 (SD) km^2, ranging 1.25–13.94 km^2. Compositional habitat analyses revealed coyotes were selective when locating home ranges within Westchester County, and when moving within home ranges (Wilk's lambda < 0.3035, $P < 0.002$). Coyotes consumed primarily natural foods, and few scats contained non-nutritive anthropogenic items (5.9–16.7%). I found no evidence for targeted management intervention in Westchester County, as most coyotes appeared to avoid human interactions, and primarily used natural areas and food items. Future research should examine strategies to align stakeholder concern of perceived risks with objective risks from coyotes, and the role of coyotes to moderate ecological processes in urban landscapes.

BIOGRAPHICAL SKETCH

Daniel A. Bogan received a Bachelor of Science in Environmental and Forestry Biology from State University of New York College of Environmental Science and Forestry, and a Master of Science from State University of New York, University at Albany. He is the first in his family to earn a BS, and to continue on to earn an MS and a PhD.

To Lynn, family, and friends

ACKNOWLEDGMENTS

I would like to thank my advisor, and committee chair, Paul Curtis, and committee members Daniel Decker, Evan Cooch, and Milo Richmond for all their support and guidance throughout this project. Thank you to past and present NYSDEC Region 3 biologists Scott Smith, Mike Putnam and Kevin Clarke. Thank you to Gordon Batcheller and Lou Berchielli, and the members of the Fur Management Team and Coyote Contact Team. Thank you to all the folks in Westchester County that helped to facilitate this project: Westchester County Department of Parks, Recreation and Conservation staff Jeff Main, Brenda Freeman Bates, Beth Herr, Rick Rogers, and Dan Atchison; Westchester Cornell Cooperative Extension staff Jeannie Wilcox, Jim Lee, Richard Harper and Gerald Giordano, and Towns of Greenburgh, Mt. Pleasant, Somers and Yorktown staff Tine Barber, Doug O'Dell, Marty Rogers, Peter Gillis. Special thanks to Westchester residents: Steve Cole and Leda Blumberg, Mary Kornblum, and Bob Trullinger for lending access to their property and discussions. Jim Dreisacker provided help with trapping and knowledge of natural areas in Westchester County. The NYSDEC, Department of Natural Resources and the Graduate School of Cornell University provided funding and support of this research.

Thank you to all the field technicians that assisted with this research by conducting hours of radio telemetry, walking many kilometers for scat collections, and helping with trap-checks (in chronological order: Neil Tregger, Dustin Dominesey, Becky Reisner, Varian Bosch, Kamen Campbell, Geriann Albers, and Russell Howard). Thank you to the lab technicians for assisting with processing scats for diet analyses and data entry (in chronological order: Varian Bosch, Lisa Archer, Katherine Anguish, Amy Bleisch, and Katherine Boyd). I am thankful and appreciative of your hard work and camaraderie. And, thank you to the graduate students of the Department of Natural Resources. I thank my wife, Lynn, for her support, and encouragement throughout this degree.

TABLE OF CONTENTS

BIOGRAPHICAL SKETCH iii
DEDICATION iv
ACKNOWLEDGMENTS v
LIST OF FIGURES x
LIST OF TABLES xiii

CHAPTER 1: INTRODUCTION: THE SUBURBAN COYOTE SYNDROME 1

Review of Human–Coyote Issues 3
Human–Coyote Conflicts in Urban Locales 6
The 7-Step Sequence, Skepticism, and Research Needs 7
Conceptualization and Research Focus 9
Wildlife Management Concerns in New York State 12
SCOPE OF THE DISSERTATION 13
Chapter 2: overview 15
Chapter 3: overview 16
Chapter 4: overview 16
Chapter 5: overview 17

REFERENCES 18

CHAPTER 2: PUBLIC REPORTED HUMAN–COYOTE INTERACTIONS: THEORETICAL LIMITS AND UTILITY FOR WILDLIFE MANAGEMENT 26

STUDY AREA 29
METHODS 30
Data Collection 30
Coyote incident reports.— 30
Coyote study web reports.— 31
Analysis of Statewide Patterns 31
General interactions.— 32
Dogs at risk.— 33
Reporting Trends by Category Rating 33
Comparison of Report Collection Methods 34
Statistical Analyses 34
Statewide Spatial Analysis 35
RESULTS 38
Statewide patterns.— 38
General interactions.— 40
Dogs at risk.— 42
Reporting Trends by Category Rating 43
Category 1.— 43

Category 2.— 44
Category 3.— 44
Category 4.— 45
Coyote Study Web Reports 45
Comparison of Report Collection Methods 45
Statewide Spatial Analysis 47
DISCUSSION 48
Reported Interactions 50
Statewide patterns.— 50
General interactions.— 51
Dogs at risk.— 52
Theoretical Limits 52
Comparison of Report Collection Methods.— 52
Statewide Spatial Analyses.— 54
MANAGEMENT IMPLICATIONS 59

REFERENCES 61

CHAPTER 3: COYOTE SPATIAL ECOLOGY, BEHAVIOR AND HUMAN INTERACTIONS IN SUBURBAN NEW YORK 65

CONCEPTUAL MODEL OF THE SUBURBAN COYOTE SYNDROME 69
Avoidance.— 71
Habitation.— 71
Attraction.— 72
Competition.— 72
Emboldened Wildlife.— 73
Aggression.— 73
Attack.— 74
Transitions.— 74
Expectations for Field-Testing Aversive Conditioning 76
STUDY AREA 77
METHODS 80
Live Capture and Radio Tracking 80
Radio Tracking Sessions.— 82
Spatial Ecology and Behavior 83
Nocturnal movements.— 83
Home ranges.— 84
Home range complexity.— 84
Resource use and selection.— 85
RESULTS 89
Live Capture and Radio Tracking 89
Spatial Ecology and Behavior 90
Second-order use and selection.— 90
Third-order use and selection.— 93

DISCUSSION 97
Spatial Ecology and Behavior 98
Conceptualizing the Suburban Coyote Syndrome 101
Considerations for field-testing aversive conditioning 103
MANAGEMENT IMPLICATIONS 104

REFERENCES 107

CHAPTER 4: COYOTE DIET USE WITHIN A SUBURBAN LANDSCAPE GRADIENT NORTH OF NEW YORK CITY 118

STUDY AREA 120
METHODS 121
Field Collections 121
Laboratory Analyses 124
Landscape Response 125
RESULTS 126
Landscape Response 131
DISCUSSION 132
Considerations of Scat Surveys 135
MANAGEMENT IMPLICATIONS 136

REFERENCES 137

CHAPTER 5: MANAGEMENT IMPLICATIONS AND CONCLUDING REMARKS 143

Monitoring Coyote Incident Reports 144
Urban Ecology and Conflicts 146

REFERENCES 150

APPENDIX A: NATIONAL LAND COVER DATA 154
APPENDIX B: DEMOGRAPHIC INFORMATION 155

LIST OF FIGURES

Figure 1.1. The spatial expression of generalized animal behavior spans a continuum of negative, neutral, and positive movements in response to stimuli (a); however, the behaviors may be expressed in a nonlinear sequence (b). Concern exists that decreased distances between humans and coyotes may increase the potential for conflicts through animal aggression or attack. Further research is necessary to guide intervention techniques. 11

Figure 2.1. Preliminary coyote incident reports noted prior to data collection (January 2003–April 2005) and initial coyote incident report data (May 2005–August 2005) for the lower Hudson Valley, New York, USA. A press release in May 2005 announced the New York State Department of Environmental Conservation (NYSDEC) monitoring efforts. Data provided by NYSDEC. 28

Figure 2.2. Cumulative frequency of coyote incident reports (n = 447) by categorical rating reported by month for the duration of a 4-year monitoring period in New York, USA, May 2005–April 2009. Categorical ratings are 1) Reports of coyotes threatening or attacking people, 2) Reports of coyotes threatening, attacking or killing pets, 3) Reports of coyotes sighted repeatedly, typically in the same setting, 4) Reports of first time sightings of coyotes. 40

Figure 2.3. Frequency (bars) and cumulative percent distribution (line) of the number of coyotes described per incident reported to New York State Department of Environmental Conservation, New York, USA, May 2005–April 2009. 41

Figure 2.4. Association between dog mass (kg) and the highest level of aggressive behavior exhibited by coyotes (n = 73) reported across New York, USA, to New York State Department of Environmental Conservation, May 2005–April 2009. 43

Figure 2.5. Association between the cumulative human–coyote incident reports and human population size for 55 counties of New York, USA, collected May 2005–April 2009, with (a) the fitted values and predicted reporting rate (trend) and (b) the residual values deviating from the predicted reporting rate (trend removed). 48

Figure 2.6. Map of the dispersion of human–coyote interactions reported to New York State Department of Environmental Conservation across 55 counties of New York, USA, May 2005–April 2009. 57

Figure 2.7. Map of human–coyote interaction reports aggregated by 55 counties of New York, USA, May 2005–April 2009. 57

Figure 2.8. Map of the residual values deviating from the predicted reporting rates based on coyote incident reports regressed on human population size for 55 counties of New York, USA, May 2005–April 2009. 58

Figure 3.1. The conceptual model of coyote behavioral changes leading to conflicts with respect to humans and pets (a). Emboldened coyotes may result from multiple coyote behavioral responses (b). Solid lines represent transitions to behaviors with increasing risks to people and pets. Dashed lines represent maintenance of behavior tendency, or reverting from behavior events to less risky behaviors. Dotted lines represent alternative behavioral pathways, such as a diseased animal rapidly transitioning from avoidance to aggression or attack, or a territorially defensive animal quickly reverting to avoidance after an incident. 75

Figure 3.2. Spatial ecology and behavior of coyotes (*Canis latrans*) was studied in Westchester County, New York, USA, the full extent of the study area during 2006–2008. Coyotes were captured within the 4 study towns though home ranges overlapped areas outside of the focal towns. 78

Figure 3.3. Second-order selection (*home ranges within the study area*): Manly's selection ratios comparing the proportional cover types used within 95% fixed-kernel home ranges (use) compared with the proportional land cover types available within the study area (available) of Westchester County, New York, USA, during 2006–2008 91

Figure 3.4. Eigenanalysis of selection ratios for comparison of proportional land cover types used within 95% fixed-kernel home ranges compared with the proportional land cover types available within the study area in Westchester County, New York, USA, during 2006–2008. 93

Figure 3.5. Third-order selection (*locations within home ranges*): Manly's selection ratios comparing the proportional land cover types used within 72-m buffered locations (use) compared with the proportional land cover types available within 95% fixed-kernel home ranges (available) in Westchester County, New York, USA, during 2006–2008. 95

Figure 3.6. Eigenanalysis of selection ratios for comparison of proportional land cover types used within 72-m buffered locations compared with the proportional land cover types available within 95% fixed-kernel home ranges in Westchester County, New York, USA, during 2006–2008. 96

Figure 4.1. Proportion of land-use categories in 4 study towns and Westchester County, New York, USA, during 2006–2008. The 6 land-use categories were generalized from 14 land-use categories of the 2006 National Land Cover Data for Westchester County. 121

Figure 4.2. The study area with trail-transects used for collecting coyote scats in Westchester County, New York, USA, during 2007 and 2008. 123

Figure 4.3. Coyote diet composition by frequency of occurrence and percent volume for 11 categories found in scats (n = 442) collected along standardized trail-transects within Westchester County, New York, USA, during January 2007–December 2008. 130

Figure 4.4. The approximately asymptotic association of unique items detected within scats and linear association of total items detected within scats (with repeat items) collected along each of 31 trail-transect samples in Westchester County, New York, USA, during January 2007–December 2008. 131

Figure 4.5. The frequency of occurrence of diet items found within diet categories of scats collected in the towns of Somers and Yorktown (North, n = 299) and Greenburgh and Mt. Pleasant (South, n = 143), Westchester County, New York, USA, during January 2007–December 2008. .... …………….. 132

LIST OF TABLES

Table 1.1. Research phases and corresponding objectives for a study of coyote behavioral ecology and human interactions conducted by New York State Department of Environmental Conservation and the Department of Natural Resources, Cornell University in Westchester County, New York, USA, during 2005–2010. 13

Table 2.1. Human–coyote incident reports and percentage of categorical ratings by study year (May yr_t to April yr_{t+1}) reported across New York, USA, May 2005–April 2009. Categorical ratings are 1) Reports of coyotes threatening or attacking people, 2) Reports of coyotes threatening, attacking or killing pets, 3) Reports of coyotes sighted repeatedly, typically in the same setting, 4) Reports of first time sightings of coyotes. 39

Table 2.2. Cumulative human–coyote incident reports and percentage of categorical ratings by biological seasons reported across New York, USA, May 2005–April 2009. Biological seasons are defined as Breeding (January–April), Pup-rearing (May–August), and Dispersal (September–December). Categorical ratings are 1) Reports of coyotes threatening or attacking people, 2) Reports of coyotes threatening, attacking or killing pets, 3) Reports of coyotes sighted repeatedly, typically in the same setting, 4) Reports of first time sightings of coyotes. 39

Table 2.3. Coyote website incident reports and percentage of categorical ratings by year reported for Westchester County, New York, USA, January 2006–December 2009. Categorical ratings are 1) Reports of coyotes threatening or attacking people, 2) Reports of coyotes threatening, attacking or killing pets, 3) Reports of coyotes sighted repeatedly, typically in the same setting, 4) Reports of first time sightings of coyotes. 46

Table 2.4. New York State Department of Environmental Conservation coyote incident reports (CIR), May 2005–April 2009 and Coyote Study Web Reports (CWR), May 2006–December 2008, originated from Westchester County, New York, USA. Categorical ratings are 1) Reports of coyotes threatening or attacking people, 2) Reports of coyotes threatening, attacking or killing pets, 3) Reports of coyotes sighted repeatedly, typically in the same setting, 4) Reports of first time sightings of coyotes. 46

Table 3.1. Land-use metrics for study towns in Westchester County, New York, USA, during 2006–2008. 79

Table 3.2. Sex and age groups of radio- and GPS-tracked coyotes in Westchester County, New York, USA, during March 2006–December 2008. 89

Table 3.3. Second-order selection (*home ranges within the study area*): simplified ranking matrices of compositional analysis for coyote habitat selection based on comparison of proportional land cover types used within 95% fixed-kernel home ranges compared with the proportional land cover types available within the Westchester County study area, New York, USA, 2006–2008. Positive signs indicate use greater than available and negative signs indicate use less than available while triple signs represent significant deviation from random with $P < 0.05$. 92

Table 3.4. Third-order selection (*locations within home ranges*): simplified ranking matrices of compositional analysis for coyote habitat selection based the comparison of the proportional land cover types used within 72-m buffered locations compared with the proportional land cover types available within 95% fixed-kernel home ranges from Westchester County, New York, USA, 2006–2008. Positive signs indicate use greater than available and negative signs indicate use less than available while triple signs represent significant deviation from random with $P < 0.05$. 94

Table 4.1. Frequency of occurrence of diet items detected in scats collected in Westchester County, New York, USA, during January 2006–December 2008. Scats were collected opportunistically and at coyote capture sites within the study area, and along 26 systematically sampled trail-transects. Values (%) greater than 100% account for >1 item per category (i.e., multiple anthropogenic items) found in scats. Columns sum greater than 100% because multiple items can occur per individual scats. 129

Table 4.2. Frequency of occurrence of diet items detected in scats collected along 26 systematically sampled trail-transects in Westchester County, New York, USA, during January 2007–December 2008. Biological seasons are Breeding (January–April), Pup-rearing (May–August), and Dispersal (September–December). Diet composition varied by biological season ($\chi_{14}^2 = 118.70$, $P < 0.001$). 130

CHAPTER 1

INTRODUCTION: THE SUBURBAN COYOTE SYNDROME

Understanding the behavioral ecology of wildlife and their interactions with humans (*Homo sapiens*) is necessary to inform modern wildlife management programs that seek to maintain ecological integrity and function while managing human–wildlife interactions. Managing human–wildlife interactions is increasingly an important focus of wildlife conservation and management as the occurrence of interactions may increase the potential for conflicts to occur (Decker and Chase 1997, Bruggers 2009, Messmer 2009). This issue is important in urbanized landscapes where once historically suppressed wildlife populations, such as carnivores, are now recovering and are increasingly interacting with people (Decker and Chase 1997, Baruch-Mordo et al. 2008, Kretser et al. 2008, Markovchich-Nicholls et al. 2008, Gehrt et al. 2009, Don Carlos et al. 2009, Howe et al. 2010). The occurrence of carnivores in urbanized landscapes challenges our understanding of animal behavioral ecology, generates human–wildlife interactions, and reveals the need for effective management options to contend with conflicts. Basic and applied research is necessary to address these knowledge gaps and to inform management programs (Curtis et al. 2007, Siemer et al. 2007).

Adaptive impact management (Riley et al. 2003) may provide an appropriate conceptual framework for managing human–wildlife interactions while maintaining ecological integrity. Interactions between humans and wildlife may range from positive to negative events that can be defined in terms of significant impacts (Decker and Chase 1997, Riley et al. 2002, Riley et al. 2003). Human–wildlife impacts provide a basis for wildlife management (Decker and Chase 1997, Riley et al. 2002, Riley et al. 2003). That is, impacts serve as a basic unit of measure within the adaptive impact management framework (Riley et al. 2002, Riley et al. 2003). Within this framework, impacts may consist of human–wildlife interactions such as conflicts and benefits (Riley et al. 2002), yet may also include esoteric concepts such as ecological integrity and function. While managing conflicts (i.e., negative impacts) may be necessary at times, these actions should support modern wildlife conservation and management objectives aimed at safeguarding humans while maintaining ecological integrity and function (Grumbine 1994, 1997; Christensen et al. 1996). Maintaining ecological elements, including carnivores, within ecosystems can maintain ecological function and benefits (i.e., positive impacts) for humans (Crooks and Soulé 1999, Beschta and Ripple 2010). However, research in urban landscapes is necessary to better understand the complex relationship between humans and carnivores, and to identify impediments towards reaching these objectives.

Carnivores are integral to maintaining ecosystem integrity and function by moderating functional and numerical responses of fauna and flora through trophic dynamics (Crooks and Soulé 1999, Schmitz et al. 2000, Smith et al. 2003, Ripple and Beschta 2004, Prugh et al. 2009, Beschta and Ripple 2010). However, carnivores in urban landscapes present challenges as their behavior and ecological role may conflict with human interests and safety. Current behavioral information for carnivores is necessary to understand the magnitude of human–wildlife conflicts by providing insights including frequency, intensity, and duration of conflict events. Gaining such insights will provide beneficial information for making informed management decisions when responding to specific events. Furthermore, understanding the ecology of carnivores inhabiting urban landscapes will help inform management programs by considering both positive and negative human–wildlife impacts.

The coyote (*Canis latrans*) is the most successful carnivore in North America (Prugh et al. 2008). As a generalist species exhibiting highly flexible life strategies, the coyote now inhabits a geographic range extending from the Arctic to Panama (Bekoff 1977, Gehrt 2006) and is extant in many biomes throughout this range. Recently, the species range has extended into areas of high human density such as urban landscapes (Howell 1982, Gompper 2002*a*, *b*; Gehrt 2006). Subsequently, human–coyote interactions occur within many urban lands (Howell 1982, Carbyn 1989, Baker and Timm 1998, Timm et al. 2004, Wieczorek Hudenko et al. 2008*a*, *b*, *c*; White and Gehrt 2009). While people may enjoy the opportunity to view coyotes in some settings (Bounds and Shaw 1994), negative interactions between people and coyotes can lead to human risks and property damage. In urban areas, conflict interactions have motivated public demand for the reduction or elimination of coyotes (Howell 1982, Lukasik and Alexander 2011). Gaining understanding of coyote ecology and the range of human–coyote interactions in urban landscapes through basic and applied research is necessary to inform management decisions and policy formulation (Curtis et al. 2007, Siemer et al. 2007).

Review of Human–Coyote Issues

Human–coyote interactions began to solidify as an important wildlife issue in Los Angeles County, California. During 1975–1981, coyotes attacked 9 people of which 6 were children ≤age 5 (Howell 1982). The issue escalated in August 1981 when a 3-year-old girl died from injuries sustained by a coyote attack at her home in Glendale, California (Howell 1982)[1]. These incidents, particularly the death of a young child, drew attention to the occurrence of negative interactions and risks to

[1] At the start of this research project in 2005, this was the only known human fatality due to coyote aggression and attack. Following the start of this project, a young adult woman died after an attack by coyotes in Cape Breton National Park, Canada in October 2009 (Caudell 2010). The death of the young child (1981) and adult women (2009) are the only known human deaths on record due to coyote attacks.

human safety (Howell 1982) and subsequently motivated further investigation in areas where humans and coyotes interact (Carbyn 1989, Bounds and Shaw 1994).

Carbyn (1989) investigated multiple incidents of coyote aggression and attacks on people in national parks in Canada (Banff and Jasper) and the United States (Yellowstone). The retrospective study identified 21 attacks within a 29-year period (1960–1988) and categorized each by the nature and intensity of the interactions. The most serious attacks (n = 4) involved infants (<3 years of age). Similar among the 4 incidents was that the children were left unattended for a brief period when the attacks occurred (Carbyn 1989). Minor attacks (n = 10) involved people of various ages, however details were limited in the report (Carbyn 1989). This review focused specifically on describing coyote aggression and attacks on people (Carbyn 1989). It is also informative to understand the frequency of coyote attacks on humans, in comparison with other types of human–coyote interactions, to assess the potential for risks to human safety.

Bounds and Shaw (1994) conducted a survey in 1992 to examine the frequency and nature of human–coyote interactions throughout all (n = 359) U.S. National Parks Service units. Their survey revealed that coyotes reportedly inhabited 46% (n = 165) of parks or occurred within 8 km of 43% of parks (n = 154) in 41 states (Bounds and Shaw 1994). The most commonly reported human–coyote interactions in national parks (n = 359) were wildlife viewing (41%, n = 148) followed by wildlife photography (28%, n = 99). Various food-related interactions occurred in fewer (6%–12%, $n \leq 42$) parks, yet accounted for the greatest percentage of conflict interactions. Coyote aggression towards people was the least frequent type of interaction, and occurred in 9 (3%) parks. Only one person was reported as bitten by a coyote. Aggressive coyotes were associated with wildlife feeding near human-activity areas (Bounds and Shaw 1994). While positive benefits (or impacts) of wildlife viewing in national parks were far more numerous than negative interactions (Bounds and Shaw 1994), a few severe negative interactions may influence perceptions of coyotes and further decrease wildlife stakeholder acceptance of the presence of coyotes (Howell 1982, Lukasik and Alexander 2011). These studies (i.e., Carbyn 1989, Bounds and Shaw 1994) are important because the findings suggest that human–coyote conflicts are not limited to high-density residential lands, but are more an issue where overlap exists between high-density human activity and wildlife populations, as found in national parks (Carbyn 1989, Bounds and Shaw 1994). This may be informative when examining human–coyote conflicts in urbanized landscapes.

Events where humans, particularly young children, were injured by coyotes have influenced human acceptance and tolerance of wildlife living in and near residential areas. Following incidents in Glendale, California; Calgary, Canada; and Middletown, New Jersey; segments of the public demanded the reduction or removal of the coyote population (Howell 1982, Lukasik and Shelley 2011, Caudell 2007, Kelley 2007). For example, in response to the 1981 death of a young child that was reportedly attacked by 1 coyote in southern California, 55 coyotes were killed by trapping or shooting within a 0.8-km (0.5-mile) radius of the incident (Howell 1982). In Calgary, Canada, public outcry to remove and eliminate coyotes from the city followed an incident where a 3-year-old girl was attacked and injured by coyotes (Lukasik and Alexander 2011). Wildlife professionals in Middletown, New Jersey, attempted to lethally remove coyotes from the vicinity where children were attacked. Determining the prevalence of human–coyote conflicts, finding effective management options to circumvent these issues (i.e., preventing feeding of coyotes near human activity areas), and determining appropriate responses to the occurrence of conflicts is important for protecting human safety. Preventing human injuries may, in turn, benefit wildlife populations by promoting human tolerance of coyotes in urban lands.

Human–Coyote Conflicts in Urban Locales

Human–coyote interactions may lead to various types of direct conflicts (e.g., people attacked by coyotes) and indirect conflicts (e.g., pets attacked by coyotes) with humans (Timm et al. 2004, Farrar 2007, White and Gehrt 2009, Lukasik and Alexander 2011). Direct human–coyote conflicts include coyote aggression and attacks (e.g., growling, snarling, showing teeth, stalking, nipping and biting), and can lead to possible disease exposure, human injury, and in extreme cases death (Howell 1982, Carbyn 1989, Bounds and Shaw 1994, Baker and Timm 1998, Gompper et al. 2003, Krebs et al. 2003, Timm et al. 2004, Carrillo et al. 2007, White and Gehrt 2009). In urban areas, people have been intimidated, scratched or bitten by coyotes reluctant to flee from residential yards and other human-developed areas (Baker and Timm 1998, Carrillo et al. 2007, White and Gehrt 2009). In some scenarios, coyotes have aggressively attacked young children, causing severe injuries to the head, neck, and legs of victims (Howell 1982, White and Gehrt 2009). Indeed, risks to human safety can result from direct coyote attacks. However, it is also important to consider that indirect conflicts may lead to human injury.

Coyotes indirectly conflict with human interests in ways other than by direct aggression towards people. Coyotes kill domestic cats (*Felis catus*) and dogs (*Canis lupus familiaris*), and these events occasionally lead to human injury (Timm and Baker 2004, Farrar 2007). This occurs during events that begin as a coyote attack on a pet, and the pet-owner intervenes and suffers subsequent injury (Baker and Timm 1998, Timm et al. 2004). Additionally, coyotes may carry pathogens such as endoparasites (Gompper et al. 2003, Trout et al. 2006) and viruses that are potentially zoonotic to pets and people (Chang et al. 2002, Huffman 2005), which is a public health concern (Bounds and Shaw 1994, Wieczorek Hudenko 2008*a*). According to Center for Disease Control and Prevention (CDC) records, during 1960–2000 there have been 629 reported cases of rabid coyotes across the United States, of which 15 cases occurred in New York State (Krebs et al. 2003). While public concern for the perceived risk of disease transmission may be high, such as for rabies, the actual risk may be far less common. Concern for potential disease transmission, risks to pets, and risks to human safety associated with coyotes may decrease the public's capacity to tolerate coyote populations inhabiting suburban and urban lands (Howell 1982), as found with urban foxes in Germany (Konig 2007).

Based on the number of conflicts, southern California is the hot-spot for human–coyote interactions and conflicts (White and Gehrt 2009), but other urbanized areas of the United States and Canada have experienced direct and indirect conflicts. Although incidents thus far have occurred less frequently than in southern California (White and Gehrt 2009), interactions and the potential for conflicts appear to be increasing. This concern was expressed in newspaper articles and press releases (Webster 1981, Brenner 1998, Feris 2004, Lang 2005, Foderaro 2007). In California, the varying levels of conflicts have drawn the attention of wildlife professionals interested in identifying indicators that human injury is imminent (Baker and Timm 1998, Timm et al. 2004). This information may be beneficial for other regions of North America that are concerned with human–coyote interactions, and must be further examined for potential to be broadly applicable.

The 7-Step Sequence, Skepticism, and Research Needs

Wildlife professionals investigating human–coyote interactions in California suggested a hypothetical sequence of escalating coyote conflicts that leads to human injury (Baker and Timm 1998, Timm et al. 2004). After conducting a retrospective study of anecdotal records of human–coyote conflicts, they proposed a hypothetical 7-step "predictable sequence" of changing coyote behaviors (Timm et al. 2004:5). The sequence begins with observations of coyotes on streets and in yards during nighttime and progresses through a sequence of escalating interactions to eventual pet attacks and human injury (Baker and Timm 1998). More importantly, the authors further suggest that this sequence can be used to prevent coyote attacks on humans by identifying animals exhibiting behaviors early in the sequence, and removing the problem individuals through lethal means (Baker and Timm 1998, Timm et al. 2004). While the 7-step sequence from California is intuitively attractive and commonly cited by literature about this management issue, rigorous examination has yet to demonstrate the reliability of these warning signs as predictors of imminent coyote attacks on humans.

Unfortunately, retrospectively investigating previous interactions may lead to erroneous conclusions and a false-positive confirmation of the sequence to reliably forecast escalating risks. When retrospectively investigating coyote attacks on people, early interactions in the sequence described by Timm et al. (2004) may have previously occurred. However, what should be questioned is whether these early interactions reliably forecast the escalation of conflicts and human risks with certainty. If the hypothetical sequence of changing coyote behaviors is a strong predictor of future events, then initial interactions should consistently forecast coyote attacks on pets and humans. While various conflict interactions have been described in publications, no empirical evidence supporting the progression of the hypothetical sequence has been published. Further investigation is needed to test the hypothesis proposed by Timm et al. (2004) before adopting this idea into urban coyote management programs.

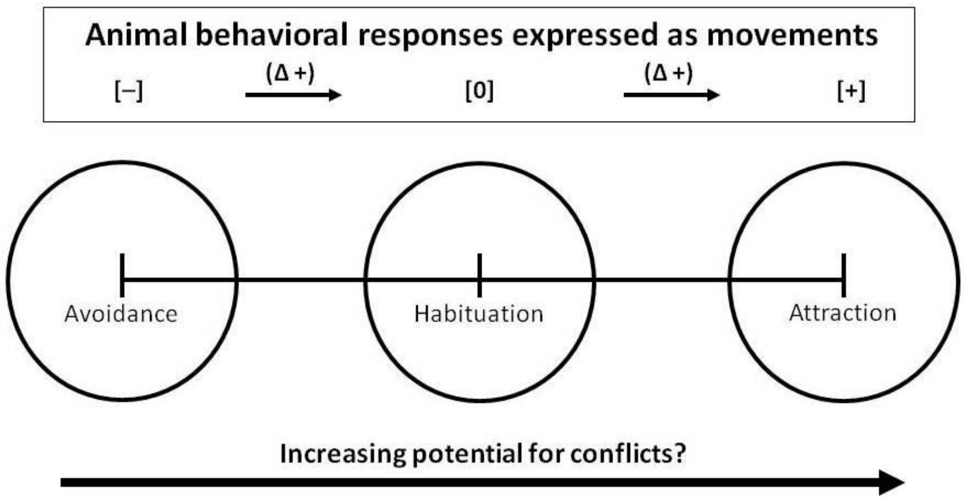
Detailed examination of coyote behavioral ecology is necessary to determine whether individual coyotes progress through the hypothesized sequence of behavioral changes proposed by Timm et al. (2004). If coyotes do progressively change behaviors, then wildlife managers may proactively monitor for precursory interactions and target individual coyotes for management intervention. Alternatively, if human–coyote conflicts are more incidental and sporadic (i.e., less predictable), then wildlife professionals should explore alternative interventions to prevent negative impacts.

Conceptualization and Research Focus

Wildlife species exhibit situational responses to elements of their environment (Whittaker and Knight 1998). These responses have been categorized into 3 general behaviors: avoidance, habituation, and attraction (Whittaker and Knight 1998). Each of these behaviors, expressed as animal movements, exists along a continuum ranging from negative to neutral, and to positive responses to stimuli (Figure 1.1a). This simplistic linear conceptualization suggests that an animal, changing from avoidance to habitation, and to attraction, transitions through positive net changes in behavioral responses (*or states*) to the stimuli. Additionally, human risks may increase with each successive transition due to decreased distance (*or increased association*) between humans and wildlife, suggesting an increased potential for conflict (Figure 1.1a). While these generalizations are a simplistic model of animal behavior, expression may be more complex, and involve either habituation or attraction, or a simultaneous combination of both behaviors (i.e., food conditioned and habituated animals, Hopkins et al. 2010). Attraction or habituation may equally expose humans to potential risks (Figure 1.1b). Discriminating between the types of behaviors and specific human–wildlife conflicts is necessary to respond with effective management intervention techniques (Whittaker and Knight 1998, Hopkins et al. 2010). Gaining a better understanding of animal behaviors involved in human–wildlife interactions is necessary to reduce conflicts and improve wildlife management (Hopkins et al. 2010).

Determining appropriate management responses to conflicts is necessary to improve and refine wildlife management. For example, if an animal exhibits avoidance behavior, then management intervention is likely unnecessary. At the extreme, if an animal has attacked or injured a human, then it is highly likely that the offending animal will be targeted for lethal removal (Wittmann et al. 1998). While these two areas of the conceptual model are relatively well understood, there is a gap in our understanding of how to manage animals that do not exhibit avoidance behavior, yet have not acted aggressively towards humans (Figure 1.1b). It may be possible to target these individuals with non-lethal management interventions to prevent potential human safety risks. Researching the efficacy of behavioral modification strategies in urban areas by examining animal behavior and potentially testing aversive conditioning techniques is of great and immediate value for urban wildlife management (Bounds and Shaw 1994, Lukasik and Alexander 2011). This area requires additional research.

a.



b.

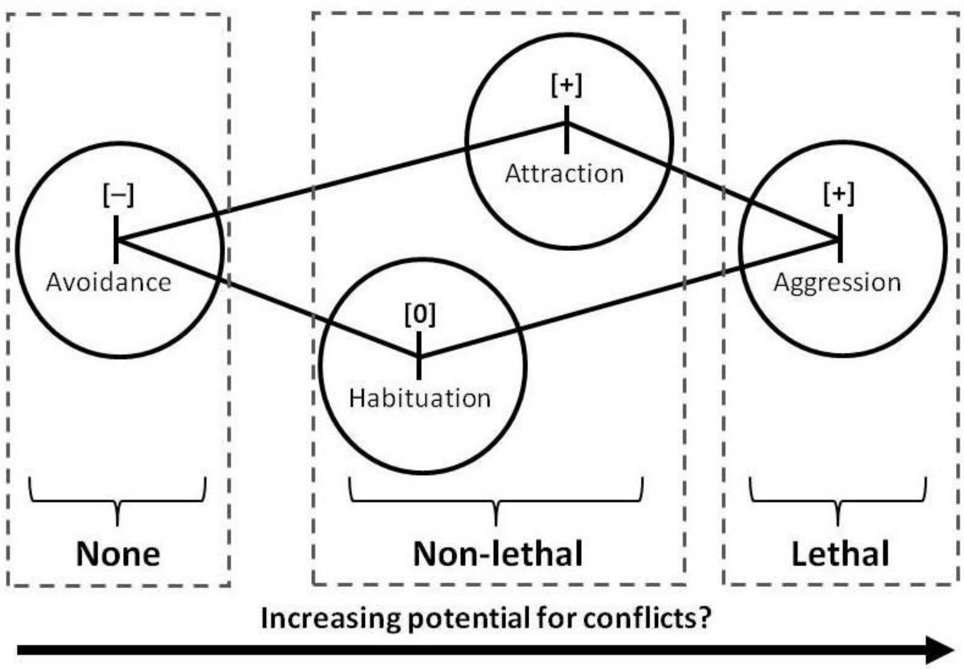


Figure 1.1. The spatial expression of generalized animal behavior spans a continuum of negative, neutral, and positive movements in response to stimuli (a); however, the behaviors may be expressed in a nonlinear sequence (b). Concern exists that decreased distances between humans and coyotes may increase the potential for conflicts through animal aggression or attack. Further research is necessary to guide intervention techniques

Wildlife Management Concerns in New York State

In New York State, the Department of Environmental Conservation (NYSDEC) perceived an increase in the types of human–coyote interactions reported by Timm et al. (2004) (Ferris 2004, Lang 2005, NYSDEC 2005). As a result, NYSDEC became interested in conducting a situation analysis of coyote behavioral ecology and interactions with humans (integrated with a human dimensions study; *see* Hudenko et al. 2008*a*, *b*, *c*, *d*) to better understand the complex relationship of humans and coyotes in suburban and urban landscapes of New York State (NYSDEC 2005). While similar ecological research has been conducted elsewhere in the United States and Canada, (Quinn 1997, Grinder and Krausman 1999, Riley et al. 2003, Bogan 2004, Way et al. 2004, Gehrt et al. 2009), this study was motivated because of the recent range expansion of coyotes through much of New York State during the 20th century (Severinghaus 1974, Fener et al. 2005), and arrival in many suburbs (Webster 1981, Brenner 1998). Moreover, additional concern resulted because northeastern coyotes are larger than their Southwestern counterparts (Thurber and Peterson 1991, Gompper 2002*b*). Their larger size may make northeastern coyotes a greater human safety risk. NYSDEC was also interested in exploring strategies for non-lethal behavioral modification by identifying problem-causing coyotes and field-testing aversive conditioning techniques as potential alternative management options prior to lethal removal. To conduct this investigation, NYSDEC partnered with the Department of Natural Resources at Cornell University for a 2-phase, integrated project of behavioral ecology research (Lang 2005; Table 1.1), and human dimensions research (see Wieczorek Hudenko 2008:56 for the human dimensions research objectives).

Table 1.1. Research phases and corresponding objectives for a study of coyote behavioral ecology and human interactions conducted by New York State Department of Environmental Conservation and the Department of Natural Resources, Cornell University in Westchester County, New York, USA, during 2005–2010.

Coyote ecology and management research phase and specific objectives:
Phase 1 — Coyote behavioral ecology research in a suburban landscape:
1. Evaluate coyote territory size and defense
2. Assess group social structure, including behavior of breeding pairs and juveniles
3. Monitor dependence on anthropogenic food sources (e.g., garbage, pets, handouts)
4. Ascertain what circumstances cause changes in coyote behavior in human-altered landscapes
5. Evaluate coyote interactions with deer herds and feral or free roaming cats
6. Assess growing tolerance to humans, and if human avoidance can be reinforced
Phase 2 — Investigation of management techniques for problem coyotes:
1. Test aversive conditioning techniques (e.g., rubber buckshot, thiabendazole) to modify aggressive coyote behaviors
2. Test hazing and non-lethal control on coyotes prior to attacks on pets
3. Test lethal control of a pack member or removal of pups to modify coyote behaviors following coyote attacks on pets
4. Test lethal removal by trapping or shooting of persistent aggressive coyotes that show no fear of humans

SCOPE OF THE DISSERTATION

This dissertation investigates the premise that coyotes are increasingly interacting with people in residential and urban areas, a situation that may lead to increased potential for conflicts. Also, interactions may occur disproportionately greater than expected in suburban or urban areas than in less developed landscapes;

that this is a suburban coyote management issue. The occurrence of some coyote behaviors may lead to elevated human–coyote conflicts, causing increased risks to human interests and safety (Carbyn 1989, Baker and Timm 1998, Timm et al. 2004). Wildlife professionals have suggested that these behavioral changes can be identified and used for management intervention (Timm et al. 2004). Based on the hypothetical sequence of changing behaviors, research was planned to investigate whether animals exhibiting behaviors early in the sequence described by Baker and Timm (1998) could be targeted for non-lethal management interventions. Behavior modification, such as aversive conditioning through conditioned taste aversion, seeks to prevent conflicts from continuing or escalating, and may be a valuable management option (Gustavson and Garcia 1974, Gustavson et al. 1974, Conover et al. 1977, Cornell and Cornely 1979, Burns 1983). Therefore, the validity of the hypothetical sequence of changing behaviors requires further scrutiny to determine whether precursory behaviors are reliable cues for preemptive management intervention.

This original research was conducted for the dual purpose of: 1) gaining a better understanding of the ecology of coyotes inhabiting urban landscapes, and how their behaviors may lead to situations requiring management intervention, and 2) testing the efficacy of potential management actions (i.e., behavioral modification through aversive conditioning) to minimize and prevent conflicts. The dissertation addresses 3 primary questions:

1) What insight can be learned from understanding how coyotes are interacting with people for cases when people are motivated to report their experiences to wildlife professionals?
2) What is the spatial ecology and behavior of coyotes inhabiting areas where human–coyote interactions are becoming a concern?

3) Are coyotes eating foods that might lead to conflicts with humans in areas where human–coyote interactions are becoming a concern?

The organization of this dissertation proceeds sequentially by first establishing the management issue and identifying gaps in basic and applied knowledge that are necessary for informed adaptive impact management. This is accomplished by reviewing primary literature and published hypotheses regarding human–coyote interactions with emphasis on issues occurring within suburban and urban landscapes (*see above*). Additional concerns reported in grey literature and popular media (Søndergaard et al. 2003) help illustrate issues regarding human–coyote interactions, and demonstrate the relevance and timeliness of this research. The dissertation progresses by investigating human–coyote incident reports, follows with a review of animal behavior and field investigations of spatial ecology and diet use, and concludes with final remarks and suggestions for future research.

Chapter 2: Public Reports of Human–Coyote Interactions: Theoretical Limits and Utility for Wildlife Management.— Interactions between humans and wildlife can motivate stakeholders to report the incidents to wildlife authorities. This chapter delves into human–coyote interactions reported to NYSDEC, and to an alternate Internet-based, incident reporting system. The investigation examines both spatial and temporal trends of reporting, compares between 2 monitoring programs, and describes specific attributes of varying levels of sightings and interactions. Few studies have examined stakeholder reports of human–coyote interactions (Farrar 2007, Lukasik and Alexander 2011). Previous studies have been conducted retrospectively (Howell 1982, Carbyn 1989, Bounds and Shaw 1994, Baker and Timm 1998, Timm et al. 2004, White and Gehrt 2009). Therefore, this chapter provides the first investigation of a statewide program designed to monitor reported interactions between humans and coyotes, and helps to frame the management issue under investigation.

Chapter 3: Coyote Spatial Ecology, Behavior and Human Interactions in Suburban New York.— To gain insight into human–coyote interactions and test hypotheses derived from published literature and previous chapters, I investigate the spatial ecology of coyotes living in a heterogeneous urbanized landscape. This applied research targets areas that initially exhibited high reporting rates of human–coyote conflicts. With field assistance, I captured and radio tracked coyotes from this area to understand 'nuisance' or 'problem' behaviors of coyotes that are suggested to occur prior to human and pet attacks. Emboldened coyotes were targeted in an effort to test the efficacy of behavior modification as a management tool to prevent elevated conflicts and risks to humans. Towards this objective, I propose a conceptual model of coyote behaviors that may lead to human interactions and conflicts as a means to guide expectations for behavioral modification.

Chapter 4: Coyote Diet Use within a Suburban Landscape Gradient North of New York City.— Anthropogenic food subsidies can influence coyote population density and is suggested as an important factor in human–coyote interactions and conflicts. In Chapter 4, I investigate coyote use of human and wild sources of foods along a suburban–urban landscape gradient in Westchester County, New York. This research was motivated by hypotheses generated from the literature and initial findings from the preceding chapters. Residential areas may provide important food resources (e.g., pets, bird seed, compost and discarded human foods) for coyotes that are efficient to obtain. This may create interactions and conflicts between humans and coyotes. Other studies that examine coyote diets along urban gradients typically sample a limited number (<5) of sites for comparison (i.e., a highly urban area compared with a low density residential area). This study makes greater use of the landscape by sampling 31 sites throughout the study area. This research fills an important knowledge gap and improves our understanding of how coyotes live in a heterogeneous urban landscape.

Chapter 5: Management Implications and Concluding Remarks.— This chapter is the culmination of the dissertation and offers a synthesis of conclusions of the information gained by this research. Based on the findings, I suggest further refinement and future research endeavors on this particular topic that may also be extended to the general study of human–wildlife interactions.

REFERENCES

Baker, R. O. and R. M Timm. 1989. Management of conflicts between urban coyotes and humans in Southern California. Proceedings of the Vertebrate Pest Conference 18:299–312.

Bekoff, M. 1977. *Canis latrans*. Mammalian Species 79:1–9.

Beschta, R. L., and W. J. Ripple. 2010. Recovering riparian plan communities with wolves in Northern Yellowstone, U.S.A. Restoration Ecology 18:380–389.

Brenner, E. 1998. Growing numbers of coyotes lead to traps and fear for pets. The New York Times. 11 October 1998; section 14WC:1.

Baruch-Mordo, S., S. W. Breck, and D. M. Theabold. 2008. Spatiotemporal distribution of black bear–human conflicts in Colorado, USA. Journal of Wildlife Management 72:1853–1862.

Bogan, D. A. 2004. Eastern coyote home range, habitat selection and survival in the Albany pine bush landscape. Thesis, State University of New York, University at Albany, Albany, New York, USA.

Bounds, D. L., and W. W. Shaw. 1994. Managing coyotes in U.S. National Parks: human–coyote interactions. Natural Areas Journal 14:280–284.

Bruggers, R. L. 2009. Setting research priorities at Wildlife Services' National Wildlife Research Center. Human–Wildlife Conflicts 3:161–164.

Burns, R. J. 1983. Coyote predation aversion with lithium chloride: management implications and comments. Wildlife Society Bulletin 11:128–133.

Carbyn, L. N. 1989. Coyote attacks on children in Western North America. Wildlife Society Bulletin 17:444–446.

Carrillo, C. D., J. Schmidt, and D. Bergman. 2007. Management of urban coyotes and attacks in Green Valley, Pima County, Arizona. Proceedings of the Wildlife Damage Management Conference 12:323–331.

Caudell, J. N. 2007. In the news: coyote attacks child in New Jersey suburb. Human–Wildlife Conflicts 1:132–134.

Caudell, J. N. 2010. In the news: coyotes kill hiker in Nova Scotia. Human–Wildlife Interactions 4:4–6.

Chang, H. H., M. Eidson, C Noonan-Toly, C. V. Trimarchi, R. Rudd, B. J. Wallace, P. F. Smith, and D. L. Morse. 2002. Public health impact of reemergence of rabies, New York. Emerging Infectious Diseases 8:909–913.

Christensen, N. L., A. M. Bartuska, J. H. Brown, S. Carpenter, C. D'Antonio, R. Francis, J. F. Franklin, J. A MacMahon, R. F. Noss, D. J. Parsons, C. H. Peterson. M. G. Turner, and R. G. Woodmansee. 1996. The report of the Ecological Society of America committee on the scientific basis for ecosystem management. Ecological Applications 6:665–691.

Conover, M. R., J. G. Francik, and D. E. Miller. 1977. An experimental evaluation of aversive conditioning for controlling coyote predation. Journal of Wildlife Management 41:775–779.

Cornell, D., and J. E. Cornely. 1979. Aversive conditioning of campground coyotes in Joshua Tree National Monument. Wildlife Society Bulletin 7:129–131.

Crooks, K. R., and M. E. Soulé. 1999. Mesopredator release and avifaunal extinctions in a fragmented system. Nature 400:563–566.

Curtis, P. D., D. A. Bogan, and G. Batcheller. 2007. Suburban coyote management and research needs: a northeast perspective. Proceedings of the Wildlife Damage Management Conference 12:413–417.

Decker, D. J., and L. C. Chase. 1997. Human dimensions of living with wildlife—a management challenge for the 21st century. Wildlife Society Bulletin 25:788–795.

Don Carlos, A. W., A. D. Bright, T. L. Teel, and J. J. Vaske. 2009. Human–black bear conflict in urban areas: an integrated approach to management response. Human Dimensions of Wildlife 14:174–184.

Farrar, R. O. 2007. Assessing the impacts of urban coyote on people and pets in Austin, Travis County, Texas. Proceedings of the Wildlife Damage Management Conference 12:334–341.

Fener, H. M., J. R. Ginsberg, E. W. Sanderson, and M. E. Gompper. 2005. Chronology of range expansion of the coyote, *Canis latrans*, in New York. Canadian Field-Naturalist 119:1–5.

Ferris, M. 2004. Sightings of coyotes spread south. The New York Times. 2 May 2004; Section 14WC:5.

Foderaro, L. W. 2007. Unwelcome neighbors tracked in Westchester. The New York Times. 3 July 2007; Section B:5.

Gehrt, S. D. 2006. Urban coyote ecology and management: the Cook County, Illinois, coyote project. Ohio State University Extension Bulletin 929, Columbus, Ohio, USA.

Gehrt, S. D., C. Anchor, and L. A. White. 2009. Home range and landscape use of coyotes in a metropolitan landscape: conflict or coexistence? Journal of Mammalogy 90:1045–1057.

Gompper, M. E. 2002*a*. Top carnivores in the suburbs? Ecological and conservation issues raised by colonization of north-eastern North America by coyotes. Bioscience 52:185–190.

Gompper, M. E. 2002*b*. The ecology of northeast coyotes: current knowledge and priorities for future research. Wildlife Conservation Society Working Paper 17:1–48.

Gompper, M. E., R. M. Goodman, R. W. Kays, J. C. Ray, C. V. Fiorello and S. E. Wade. 2003. A survey of the parasites of coyotes (*Canis latrans*) in New

York based on fecal analysis. Journal of Wildlife Disease 39:712–717.

Grinder, M. I., and P. R. Krausman. 1999. Home range, habitat use, and nocturnal activity of coyotes in an urban environment. Journal of Wildlife Management 65:887–898.

Grumbine, R. E. 1994. What is ecosystem management? Conservation Biology 8:27–38.

Grumbine, R. E. 1997. Reflections on "What is ecosystem management?" Conservation Biology 11:41–47.

Gustavson, C. R., and J. Garcia. 1974. Pulling a gag on the wily coyote. Psychology Today 8:68–72.

Gustavson, C. R., J. Garcia, W. G. Hankins, and K. W. Rusiniak. 1974. Coyote predation control by aversive conditioning. Science 184:581–583.

Hopkins, J. B., III, S. Herrero, R. T. Shideler, K. A. Gunther, C. C Schqartz, and S. T. Kalinowski. 2010. A proposed lexicon of terms and concepts for human–bear management in North America. Ursus 21:154–168.

Howe, E. J., M. E. Obbard, R. Black, and L. L. Wall. 2010. Do public complaints reflect trends in human–bear conflict? Ursus 21:131–142.

Howell, R. G. 1982. The urban coyote problem in Los Angeles County. Proceedings of the Vertebrate Pest Conference 10:21–23.

Huffman, J. E. 2005. Diseases of Coyotes. Pages 272–297 *in* S. K. Majumdar, J. E. Huffman, F. J. Brenner, and A. I. Panah, editors. Wildlife Diseases: Landscape Epidemiology, Spatial Distribution and Utilization of Remote Sensing Technology. Pennsylvania Academy of Science, Easton, PA, USA.

Kelley, T. 2007. New Jersey: Middletown: Child bitten by coyote. The New York Times. <http://query.nytimes.com/gst/fullpage.html?res=990CE7DF1630F930A1 5756C0A9619C8B63&ref=coyotes> accessed June 22, 2011.

Krebs, J. W., S. M. Williams, J. S. Smith, C. E. Rupprecht, and J. E. Childs. 2003. Rabies among infrequently reported mammalian carnivores in the United States, 1960–2000. Journal of Wildlife Diseases 39:253–261.

Kretser, H. E., P. J. Sullivan, and B. A. Knuth. 2008. Housing density as an indicator of spatial patterns of reported human–wildlife interactions in Northern New York. Landscape and Urban Planning 84:282–292.

Konig, A. 2007. Fears, attitudes and opinions of suburban residents with regards to their urban foxes. European Journal of Wildlife Research 54:101–109.

Lang, S. S. 2005. Why are coyotes getting more aggressive? Cornell five-year study intends to find out. Cornell University News Service. <http://www.news.cornell.edu/stories/May05/ coyotes.study.ssl.html> accessed July 15, 2010.

Lukasik, V. M., and S. M. Alexander. 2011. Human–coyote interactions in Calgary, Alberta. Human–Dimensions of Wildlife 16:114–127.

Markovchich-Nicholls, L., H. M. Regan, D. H. Deutschman, A. Widyanata, B Martin, L Noreke, and T. A. Hunt. 2008. Relationships between human disturbance and wildlife land use in urban habitat fragments. Conservation Biology 22:99–109.

Messmer, T. A. 2009. Human–wildlife conflicts: emerging challenges and opportunities. Human–Wildlife Conflicts 3:10–17.

New York State Department of Environmental Conservation (NYSDEC). 2005. New York State's Coyote Incident Standard Operating Procedures. Bureau of Wildlife, Division of Fish, Wildlife & Marine Resources, New York State Department of Environmental Conservation, Albany, New York, USA.

Prugh, L. R., C. J. Stoner, C. W. Epps, W. T. Bean, W. J. Ripple, A. S. Laliberte, and J. S. Brashares. 2009. The rise of the mesopredator. BioScience 59:779–791.

Quinn, T. 1997. Coyote (*Canis latrans*) habitat selection in urban areas of western Washington via analysis of routine movements. Northwest Science 71:289–297.

Riley, S. J., D. J. Decker, L. H. Carpenter, J. F. Organ, W. F. Siemer, G. F. Mattfeld, and G. Parsons. 2002. The essence of wildlife management. Wildlife Society Bulletin 30:585–593.

Riley, S. J., W. F. Siemer, D. J. Decker, L. H. Carpenter, J. F. Organ, L. T. Berchielli. 2003. Adaptive impact management: an integrative approach to wildlife management. Human Dimensions of Wildlife 8:81–95.

Riley, S. P. D., R. M. Sauvajot, T. K. Fuller, E. C. York, D. A. Kamradt, C. Bromley, and R. K. Wayne. 2003. Effects of urbanization and habitat fragmentation on bobcats and coyotes in southern California. Conservation Biology 17:566–576.

Ripple, W. J., and R. L. Beschta. 2004. Wolves and the ecology of fear: can predation risk structure ecosystems? BioScience 54:755–766.

Schmitz, O. J., P. A. Hambäck, and A. P. Beckerman. 2000. Trophic cascades in terrestrial systems: a review of the effects of carnivore removals on plants. The American Naturalist 155:141–153.

Siemer W. F., H Wieczorek Hudenko, and D. J. Decker. 2007. Coyote management in residential areas: human dimensions research needs. Proceedings of the Wildlife Damage Management Conference 12:421–430.

Severinghaus, C. W. 1974. Notes on the history of wild canids in New York. New York Fish and Game Journal 21:117–125.

Smith, D. W., R. O. Peterson, D. B. Houston. 2003. Yellowstone after wolves. BioScience 53:330–340.

Søndergaard, T. F., J. Anderson, and B. Hjørland. 2003. Documents and the communication of scientific and scholarly information: revising and updating the NUISIST model. Journal of Documentation 59:278–320.

Thurber, J. M., and R. O. Peterson. 1991. Changes in body size associated with range expansion in the coyote (*Canis latrans*). Journal of Mammalogy 72:750–755.

Timm, R. M., R. O. Baker, J. R. Bennett, and C. C. Coolahan. 2004. Coyotes attacks: an increasing suburban problem. Proceedings of the Vertebrate Pest Conference 21:47–57.

Trout, J. M., M. Santin, and R. Fayer. 2006. Giardia and cryptosporidium species and genotypes in coyotes (*Canis latrans*). Journal of Zoo and Wildlife Medicine 37:141–144.

Way, J. G., I. M. Ortega, and E. G. Strauss. 2004. Movement and activity patterns of eastern coyotes in a coastal, suburban environment. Northeastern Naturalist 11:237–254.

Webster, B. 1981. Coyotes arrive in the northeast after an evolutionary trek across the (*Incomplete title on record*). The New York Times. 3 March 1981; Section C:1.

White, L. A., and S. D. Gehrt. 2009. Coyote attacks on humans in the United States and Canada. Human Dimensions of Wildlife 14:419–432.

Whittaker, D., and R. L. Knight. 1998. Understanding wildlife responses to humans. Wildlife Society Bulletin 26:312–317.

Wieczorek Hudenko, H. 2008. Exploring attitudes and experiences associated with human–coyote relationships in suburban New York. Thesis, Cornell University, Ithaca, New York, USA.

Wieczorek Hudenko, H., D. J. Decker, and W. F. Siemer. 2008*a*. Stakeholder insights into the human–coyote interface in Westchester County, New York. Human Dimensions Research Unit, Cornell University 08-1, Ithaca, New

York, USA

Wieczorek Hudenko, H., D. J. Decker, and W. F. Siemer. 2008*b*. Living with coyotes in suburban areas: insights from two New York State counties. Cornell University Human Dimensions Research Unit HDRU Series No. 08-8, Ithaca, New York, USA

Wieczorek Hudenko, H., D. J. Decker, and W. F. Siemer. 2008*c*. Humans and coyotes in suburbia: can experience lead to sustainable coexistence? Cornell University Human Dimensions Research Unit HDRU Series No. 08-9, Ithaca, New York, USA

Wieczorek Hudenko, H., D. J. Decker, and W. F. Siemer. 2008*d*. Reliance on informants in wildlife management situation analysis—shortcut or shortcoming? Human Dimensions of Wildlife 13:459–470.

Wittmann, K., J. J. Vaske, M. J. Manfredo, H. C. Zinn. 1998. Standards for lethal response to problem urban wildlife. Human Dimensions of Wildlife 3:29–48.

CHAPTER 2

PUBLIC REPORTED HUMAN–COYOTE INTERACTIONS: THEORETICAL LIMITS AND UTILITY FOR WILDLIFE MANAGEMENT

Human development causes fragmentation of natural ecosystems which facilitates interactions between people and wildlife and may increase the potential for conflict (Decker and Chase 1997, Kretser et al. 2008). Subsequently, wildlife professionals recommend monitoring human–wildlife interactions for spatial and temporal patterns to guide appropriate management actions and inform policy formulation in support of public safety and environmental conservation (Decker and Chase 1997, Timm et al. 2004, Baruch-Mordo 2008, White and Gehrt 2009, Lukasik and Alexander 2011, Merkle et al. 2011). The occurrence of recovering and expanding wildlife species such as fisher (*Martes pennanti*), black bear (*Ursus americanus*) and cougars (*Puma concolor*) in urbanized lands can lead to conflicts with people and pose new challenges for wildlife management (Carey 2006, Markovchich-Nicholls et al. 2008, Zezima 2008, Don Carlos et al. 2009). Coyotes (*Canis latrans*), for example, are now common in many suburban and urban areas of North America (Gompper 2002*a*, *b*) and generate elevated public concern (Wieczorek Hudenko et al. 2008*a*, *b*) and uncertainty for wildlife professionals regarding the associated interactions, risks, and potential for conflict (Gompper 2002*a*, Curtis et al. 2007, Siemer et al. 2007).

Coyotes have dramatically expanded their range throughout North America and are increasingly common in urbanized lands (Parker 1995, Gompper 2002*a, b*; Prugh et al. 2009). In New York, coyotes spread rapidly across the state within a 40-year period (Severinghaus 1976, Fener 2005), carry with them introgressed wolf genetics (Kays et al. 2009), and exhibit larger body sizes than their southwestern counterparts (Gompper 2002b, Thurber and Peterson 1991). This is a management concern because across the species' range, coyotes interact with people and may cause conflicts (Howell 1982, Carbyn 1989, Bounds and Shaw 1994, Quinn 1995, Baker and Timm 1998, Timm et al. 2004, Farrar 2007, White and Gehrt 2009, Weckel et al. 2010, Lukasik and Alexander 2011). Recent work suggests that suburban human–coyote conflicts are an increasing issue in the southwestern U.S. (Baker and Timm 1998, Timm et al. 2004). It is unclear how and where northeastern coyote populations interact with people and generate potential for conflicts (Gompper 2002*a*).

In New York State, the Department of Environmental Conservation (NYSDEC) discerned an increasing number of telephone calls pertaining to alarming human–coyote interactions in urbanized areas. As suggested in Baker and Timm (1998) and Timm et al. (2004), NYSDEC implemented a standardized database to record public reports of human–coyote interactions (*or incident reports*) to monitor this issue and to guide management decisions (NYSDEC 2005). Additionally, initial monitoring indicated a spike in the number of reported human–coyote interactions following a press release announcing a joint effort by NYSDEC and Cornell University to study the issue of human–coyote interactions (Lang 2005; Figure 2.1). While I did not investigate the effect of media on reporting rates, this coincidence highlighted the potential to study the occurrence of other human–coyote interactions that might not be reported to NYSDEC, and a need to evaluate alternative ways to collect incident reports and compare between methods. Previous research has been limited to retrospective investigations of human–coyote interactions (Baker and Timm 1998, Timm et al. 2004, White and Gehrt 2009). Only two studies have investigated systematically-collected reports of human–coyote incidents occurring within the metropolitan areas of Austin, Texas (Farrar 2007) and Calgary, Alberta, Canada

(Lukasik and Alexander 2011). Additionally, interest exists in creating a standardized database for all urban areas in North America to monitor human–coyote interactions, and other wildlife conflicts, as a potentially valuable indicator of human–coyote incidents (Baker and Timm 1998, Timm et al. 2004, Baruch-Mordo et al. 2008, White and Gehrt 2009, Lukasik and Alexander 2011). No study has evaluated a statewide dataset of systematically recorded human–coyote incident reports, which would be timely and important for urban wildlife management by a state wildlife agency.

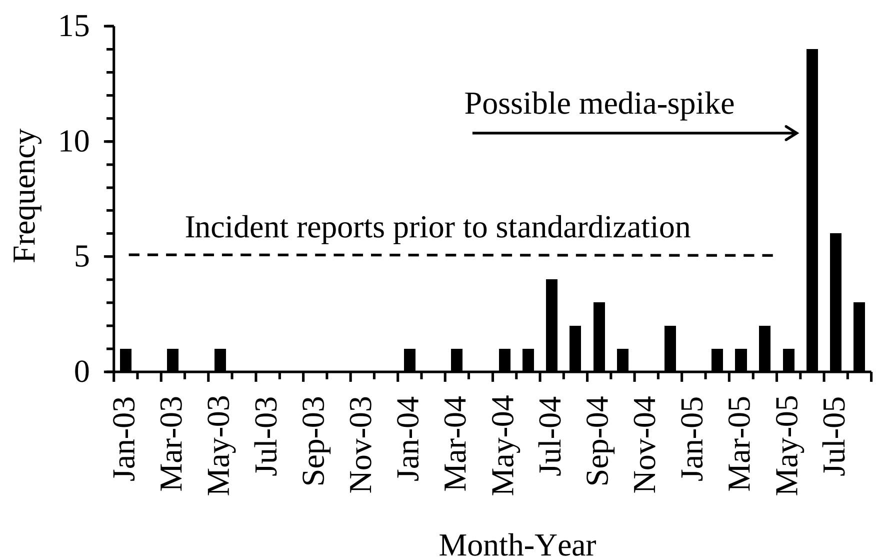


Figure 2.1. Preliminary coyote incident reports noted prior to data collection (January 2003–April 2005) and initial coyote incident report data (May 2005–August 2005) for the lower Hudson Valley, New York, USA. A press release in May 2005 announced the New York State Department of Environmental Conservation (NYSDEC) monitoring efforts. Data provided by NYSDEC.

In this analysis, I examined reported human–coyote interactions from 2 novel datasets collected by different techniques. I conducted this investigation to describe the types of human–coyote interactions occurring throughout New York State, and to investigate whether an alternative method used to collect incident reports within a focal area (i.e., Westchester County) yielded different frequencies of reported interactions. Motivated by recent studies (Baruch-Mordo et al. 2008, Kretser et al. 2008, Lukasik and Alexander 2011), I investigated the spatial distribution of incident reports to gain a better understanding of reported human–coyote interactions, and test for hot-spot areas that may require targeted wildlife management intervention. I discuss the findings and the utility of these data in relation to published studies on stakeholder insights of human interactions with coyotes in Westchester County (Weckel et al. 2010, Wieczorek Hudenko et al. 2008*a*, *b*, *c*) and other published literature.

Specifically, my objectives were to characterize the types of reported human–coyote interactions and determine whether generalized report ratings varied among study years and seasons for statewide and county data. I characterized all statewide incident reports by attributes, and then summarize the most-frequently-reported conditions for attributes that describe each of 4 report ratings. I compared 2 independent collection methods to test whether frequency of generalized report ratings varied by method. Lastly, I investigated the spatial distribution of coyote incident reports for an association with human population size and spatial autocorrelation with neighboring counties to identify hot-spots of elevated reporting of human–coyote interactions and conflicts.

STUDY AREA

The study area encompassed 55 contiguous counties of New York State. Seven counties (including 5 coextensive boroughs) forming Long Island and New York City were excluded from this study because coyotes were not established in these areas. In total, the study area was 122,029 km^2 with a population of approximately 8,214,266 people (U.S. Census Bureau 2008). Counties ranged in human population size from a minimum of 5,379 people in Hamilton County of the central Adirondack region, to a maximum of 950,265 in Erie County in western New

York. Westchester County was selected as a focal area for comparing an alternative collection method because of concern by NYSDEC staff that this area would soon require management intervention. Westchester County (n = 923,459) represented the second most populated county in the study area.

METHODS

Data Collection

I used 2 independent datasets collected by different methods to gain insight into the scope and intensity of reported human–coyote interactions and reporting rates, and to improve my understanding of the dispersion of stakeholder reporting. NYSDEC provided the coyote incident report (CIR) dataset which contained unsolicited reports of human–coyote interactions across New York State. Initial monitoring of the CIR database suggested that other interactions may occur that are not reported to NYSDEC. This hypothesis arose based on a spike in reporting (Figure 2.1) that followed a press release announcing a joint study between NYSDEC and Cornell University (Lang 2005). Therefore, an alternative dataset was developed for comparison with data collected by NYSDEC. This alternative dataset recorded semi-solicited reports using an Internet reporting form (Coyote study web site reports [CWR]). While I did not outright solicit reports, a mechanism was offered for stakeholders to report their interactions when they visited the research project's web site (http://www.nycoyote.org).

Coyote incident reports.— NYSDEC initiated a standardized CIR database to track and monitor reported sightings and interactions with emphasis on negative coyote behaviors. Standardized recording began May 2005 and is ongoing (NYSDEC 2005). The start date led to a staggered study year design and provided 4 12-month study years spanning 1 May$_{(yr)}$–30 April$_{(yr+1)}$. NYSDEC staff conducted all CIR collections. At the time of the telephone call, NYSDEC staff spoke with each caller to address their concerns, gain insight into the motivation of the reporter, and to categorize the coyote interaction (NYSDEC 2005). Each report was recorded on a standardized incident reporting form having 46 attribute categories with nominal, ordinal and continuous values. Additionally, 4 anthropogenic food sources identified by Timm et al. (2004) as possible attractants were listed on the report form for staff to determine whether any were in the vicinity of the interactions. At the completion of the telephone call, the report taker assigned the incident report to 1 of 4 generalized category ratings established by NYSDEC (2005):

- Category 4 – A coyote has been observed near people or their homes.
- Category 3 – A coyote is observed in the same setting repeatedly.
- Category 2 – A coyote has threatened, attacked, or killed a pet.
- Category 1 – A coyote has threatened or attacked a person. A coyote has been observed in or around child play areas, school yards, or parks midday.

Coyote study web reports.— I developed an Internet-based system for web site visitors to report their sightings and interactions with coyotes specific to Westchester County. The report form presented 14 questions regarding the situational attributes of the sightings and interactions. While report collection began in May 2006, actual dates of interactions spanned from January 2006 to the conclusion of the study in December 2008. I reviewed the attributes for each report and assigned a category rating based on NYSDEC standard operating procedures for CIR (NYSDEC 2005).

Analysis of Statewide Patterns

I investigated potential changes in frequencies of categorized report ratings across New York State among 4 study years. Specifically, I examined the total number of reports received each year, and the proportion of reports by category rating to test the predictions that reporting would increase over time (study years); and to test whether the types of reported interactions shifted from lower interaction ratings (i.e., category 3 and category 4 sightings) towards more elevated interactions (i.e., category 1 or category 2) as suggested by Timm et al. (2004).

I also tested the predictions that: (1) reported coyote–dog interactions might peak during the breeding season due to increased territoriality by coyotes, (2) human–coyote conflicts (category 1) might peak during summer when people are more active or recreating outdoors (Quinn 1995, White and Gehrt 2009), and (3) that non-confrontational sightings (category 3 and 4 reports) would increase during the dispersal season as a result of pups becoming more independent and conspicuous prior to dispersing from natal territories. To examine whether these patterns occurred during the year, I pooled reports by categorical ratings across years and biological seasons. Biological seasons were adapted from Laundré and Keller (1981) and partitioned the year into 3 equal periods defined as breeding (January–April), pup-rearing (May–August) and dispersal (September–December) seasons. Additionally, I visually examined within-year variation by month for CIR pooled across study years.

General interactions.— The categorical rating system facilitated rapid monitoring and assessment of reports, yet obscured details. Therefore I examined important attributes in detail to gain greater insight into the reported human–coyote interactions. I examined the age of humans involved in interactions among adults (≥16 years) and children (≤15 years). I classified incident reports by time of day and tested the reporting frequencies between daytime (6:00 AM through 5:59 PM) and nighttime (6:00 PM through 5:59 AM). Stakeholders identified the frequency that coyotes were observed during the 3 months prior to filing reports as either never (no coyotes observed), few times (1–3 coyote observations), or common (≥4 coyote observations). NYSDEC categorized the incident location as residential yards, farms, along streets, school yards, parks, trails, near children play areas, or other. When appropriate, interaction distances were estimated and assigned as either being ≤45.72 m (50 yards) or >45.72 m. I examined the frequency of potential food attractants reported in the vicinity of interactions. Additionally, I examined the reported behaviors of coyotes towards humans (non-fearful, approached or followed, threatened, chased, or attacked) and how humans responded to the presence of coyotes (none or evasive, threatened, or killed coyotes) as recorded by NYSDEC.

Dogs at risk.— Coyotes are known to attack domestic dogs (*Canis lupus familiaris*) and have injured humans during the confrontations (Baker and Timm 1998, Timm et al. 2004). To gain insight into dog–coyote interactions, I examined the frequency and the reported mass (kg) of domestic dogs exposed to 4 escalating categories of coyote aggression (e.g., approached, chased, attacked or injured, and killed). For this analysis, I only used dog mass once, assigned to the most elevated reported dog–coyote interaction category. I reported median mass for each category of coyote aggression as a measure of central tendency to identify the typical dog (by mass) involved with increasing levels of coyote aggression. I did not track dog breeds due to the large number of potential breeds and individual variation of mass. I assumed mass was a good determinant for intensity of dog–coyote interactions.

Reporting Trends by Category Rating

To gain insight into the typical conditions reported for each category rating, I summarized reports to describe the most common (i.e., greatest frequency) response for relevant attributes. Attributes with unidentified (null) responses were not reported, as only positive responses were used. As a cautionary note for this analysis, the particular combination of attributes reported per category rating may not have occurred together for each incident report, and only represent a summary of the most frequently reported descriptive attributes (*various combinations may have occurred*).

Comparison of Report Collection Methods

I compared CIR and CWR collection methods based on categorical ratings of reports generated within Westchester County. All reports that originated outside of Westchester County were excluded. I based the comparison on the NYSDEC categorical ratings system because this reflected the detailed attributes of interactions and the generalized datasets made for a more concise comparison. Reporting detailed attributes of each dataset for this comparison would be unnecessarily redundant.

Statistical Analyses

Data for the analyses were typically categorical frequencies. I used all reports with sufficient information for the analyses, including a limited number of multiple reports from individuals. When appropriate, I tested the comparisons with chi-square (χ^2) contingency tests in JMP 7.0 (SAS Institute, Inc., Cary NC) and binomial tests in R (R Development Core Team, Vienna, Austria). I examined the total CIR reporting per study year using standard linear regression in R for increasing, stable or decreasing reporting rates (β_1). I tested for differences in dog mass per escalating coyote aggression using ANOVA (JMP 7.0). I did not use odds ratios to examine variation in reporting between category ratings because of issues with non-probability convenience sampling. Inferences based on these data do not extend to true population differences, nor do they indicate true risks associated with coyote encounters. Therefore, I did not conduct this standard analysis to avoid confusion between the descriptive results and true risks of encounters with coyotes. Inferences should not be made to human–coyote interactions as a rule, and should be framed among incidents that were reported. I considered all tests as statistically significant with $P < 0.05$. Because human–coyote interactions occurred under various conditions and situations, I report the sample size for each analysis.

Statewide Spatial Analysis

Wildlife professionals have recommended collecting standardized information of reported coyote aggression and attacks as a means to monitor and identify areas exhibiting potential changes in coyote behavior and elevated interactions that may lead to human safety risks (Baker and Timm 1998, Timm et al. 2004). This premise implies a spatial component by suggesting that identifying areas with unusually high levels of reported wildlife interactions could guide management interventions to reduce associated risks of human–coyote interactions. The standardized CIR dataset provided an opportunity to investigate the apparent spatial nature of reported human–coyote interactions across New York State (Figure 2.6).

Several analyses are available to study the distribution of spatial data (Bivand et al. 2008). Recent studies examined the spatial nature of human–wildlife interactions based on point pattern analyses (Baruch-Mordo et al. 2008, Kretser et al. 2008). Baruch-Mordo et al. (2008) explored human–bear (*Ursus americanus*) conflicts using the Getis-Ord statistic (Getis and Ord 1992) to investigate hot-spot clustering of human–bear conflicts as a means to guide targeted management interventions for specific types of conflicts. Their analyses estimated and mapped Getis-Ord cluster values for locations of 3 types of conflicts (e.g., agricultural, human interactions, and vehicle–bear collisions) and then compared the degree of overlap of cluster values with related land-use practices that lead to the generation of the types of interactions. They found the degree of clustering was positively and linearly related to the density of land-use practices that generate the interactions and conflicts. Kretser et al. (2008) used the K-function to investigate spatial patterning of human–wildlife interactions, and bivariate K-function to examine the spatial relationship of reported wildlife interactions with housing density. Kretser et al. (2008) suggested a potential non-linear relationship of human–wildlife interactions across a range of housing densities based on evidence of reported human–wildlife interactions clustering more in intermediate housing densities (i.e., exurban and suburban developments). Each study used a point process framework to study how human–wildlife interactions were distributed across the landscape to better inform management decisions and land-use practices.

Investigating incident reports for clustering, complete spatial randomness, or uniform distributions ignores an important variable related to the generation of the incident reports. The probability of a human–wildlife interaction being reported is based on the proportion of people experiencing an interaction conditioned on the proportion of people that report the event (i.e., conditional probability, Ott and Longnecker 2001). The proportion of people that do not report an interaction is not quantified by unsolicited incident reports. Therefore, the total number of human–wildlife interactions is not reflected by incident reports and remained unknown. This may bias any spatial investigation that does not account for this conditional probability. However, the number of incident reports and human population size were known for a given area. Furthermore, when examining the distribution of events in space researchers should simultaneously account for the variable that may generate the events (such as the dispersion of houses, Kretser et al. 2008). Therefore, I selected human population size as a potential independent explanatory variable for the apparent spatial pattern of human–coyote interactions across New York State.

I investigated the spatial nature of statewide reporting rates at the county level using a regression-based, irregular lattice approach following the analyses of Bivand et al. (2008). The analysis spanned 55 New York State counties known to have coyotes present, which formed the irregular lattice. I aggregated by county both the cumulative CIR data for all study years as the dependent variable (Figure 2.7), and human population size as the independent variable. I did not examine the spatial distribution of reports at the scale of town, or by location point patterns (e.g., Bivariate K-function), due to relatively small sample size across the entire state study area.

No other predictor variables were used for this analysis given the issue of conditional probability of reporting a coyote incident (above), and the use of count data for both the dependent and independent variables. I avoided regressing count data (CIR) on percentage of land cover type. Early examination of potential independent variables revealed that human population size was correlated with human land-use practices (e.g., percent urban or suburban lands, road density, and housing density). Therefore, human population size reflected these variables yet provided a more suitable measure for comparison.

I conducted the analyses with program R (R Development Core Team, Vienna, Austria), and used Moran's I, with a queen contiguity neighborhood and binary weighting for all spatial autocorrelation tests (Bivand et al. 2008). I used Moran's I to test if CIR values and counties were clustered or dispersed. The queen contiguity established a neighborhood network that connected all neighboring counties of each county. I assumed that reporting may be potentially influenced by all neighboring counties for a county in question. I used binary spatial weighting to weight all neighboring counties equally. When test results are statistically significant ($P < 0.05$), positive Moran's I values indicate clustering of counties with similar values, and negative Moran's I values indicate dispersed counties and values.

I tested both CIR and human population aggregated by New York State counties for spatial autocorrelation. Having found no support of global spatial autocorrelation (see results), I continued my investigation and estimated the expected reporting rate trend (β_1) using standard linear regression (Bivand et al. 2008). I removed the reporting rate (trend) and examined the residuals to identify counties, in particular Westchester County, exhibiting elevated reporting rates. As a cautionary measure, I tested the residuals for autocorrelation with Moran's I. Lastly, I plotted for visual comparison and discussion the CIR by x, y coordinates, aggregated CIR data by county, and residual reporting rates by county. Regressing incident reports on human population, I tested the null hypotheses (h_0) of no linear association against 2 alternative hypotheses: (h_1) CIR are linearly and positively associated with human population size, and (h_2) CIR are nonlinearly and positively related to human population size (i.e., lower reporting rates in low populated counties with abrupt and disproportionately higher reporting rates in suburban and urbanized counties).

RESULTS

Statewide patterns.— The NYSDEC Coyote Incident Report (CIR) database contained 450 reports of human–coyote interactions, of which 447 had sufficient information for inclusion in the statewide summary and analyses. The number of incident reports per study year dropped consecutively by 7.9%, 17.2% and 30.2% (Table 2.1) which demonstrated diminished incident reporting ($\beta_1 = -21.7$, $r^2 = 0.93$, $F_{1,2} = 42.69$, $P = 0.02$). However, the proportion of report categories remained consistent among study years ($\chi_6{}^2 = 7.786$, $P = 0.5559$). Half (50.1%) of the CIR reports occurred during the pup-rearing seasons with the remaining number of reports split equally among the breeding seasons (24.8%) and dispersal seasons (25.1%; Table 2.2). Report categories remained proportionately consistent among biological seasons ($\chi_6{}^2 = 5.218$, $P = 0.5161$). Reporting peaked in May and subsequently decreased throughout the remainder of the calendar year. Two minor peaks occurred in January during the breeding season and in October prior to dispersal (Figure 2.2).

Table 2.1. Human–coyote incident reports and percentage of categorical ratings by study year (May yr_t to April yr_{t+1}) reported across New York, USA, May 2005–April 2009. Categorical ratings are 1) Reports of coyotes threatening or attacking people, 2) Reports of coyotes threatening, attacking or killing pets, 3) Reports of coyotes sighted repeatedly, typically in the same setting, 4) Reports of first time sightings of coyotes.

Study year	Total reports (*n*)	Percent of reports by categorical rating			
		1	2	3	4
May 2005–April 2006	139	2.9	30.9	28.1	38.1
May 2006–April 2007	128	6.3	39.1	17.2	37.5
May 2007–April 2008	106	4.7	32.1	23.6	39.6
May 2008–April 2009	74	2.7	32.4	21.6	43.2
Total	447	4.3	33.8	22.8	39.1

Table 2.2. Cumulative human–coyote incident reports and percentage of categorical ratings by biological seasons reported across New York, USA, May 2005–April 2009. Biological seasons are defined as Breeding (January–April), Pup-rearing (May–August), Dispersal (September–December). Categorical ratings are 1) Reports of coyotes threatening or attacking people, 2) Reports of coyotes threatening, attacking or killing pets, 3) Reports of coyotes sighted repeatedly, typically in the same setting, 4) Reports of first time sightings of coyotes.

Biological season	Total Reports (*n*)	Percent of reports by categorical rating			
		1	2	3	4
Breeding	111	2.7	27.0	26.1	44.1
Pup-rearing	224	4.5	37.5	21.4	36.6
Dispersal	112	5.4	33.0	22.3	39.3

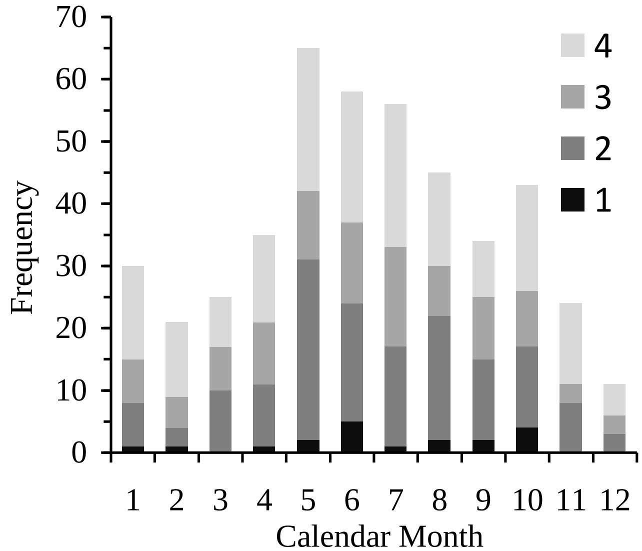


Figure 2.2. Cumulative frequency of coyote incident reports (n = 447) by categorical rating reported by month for the duration of a 4-year monitoring period in New York, USA, May 2005–April 2009. Categorical ratings are 1) Reports of coyotes threatening or attacking people, 2) Reports of coyotes threatening, attacking or killing pets, 3) Reports of coyotes sighted repeatedly, typically in the same setting, 4) Reports of first time sightings of coyotes.

NYSDEC classified 19 (4.3%) incident reports as category 1, an interaction involving a person being threatened or attacked by a coyote. Only 1 incident was reported at a school yard, and did not involve children. During the study period, no human was bitten by a coyote. Three people reported being attacked, although it is difficult to determine whether physical contact was made during the incidents. Interactions with pets (category 2) were reported 7.9 times more than interactions with people (category 1), and first time sightings (category 4) were reported 1.7 times more than repeated observations (category 3; Table 2.1).

General interactions.— Overall, human–coyote interactions reported to NYSDEC occurred in numerous situations, therefore categorization of key attributes to describe the incidents helped characterize the events and led to the identification of important reporting trends. The number of coyotes involved was reported in 91.8% (n

= 413) of incidents, of which 66.6% (n = 275) typically involved 1 coyote. Two coyotes were reported in 15.3% of reports, and greater numbers of coyotes were less common (≤6.3%; Figure 2.3). The number of coyotes involved were not identified for 7.6% (n = 37) of CIR reports.

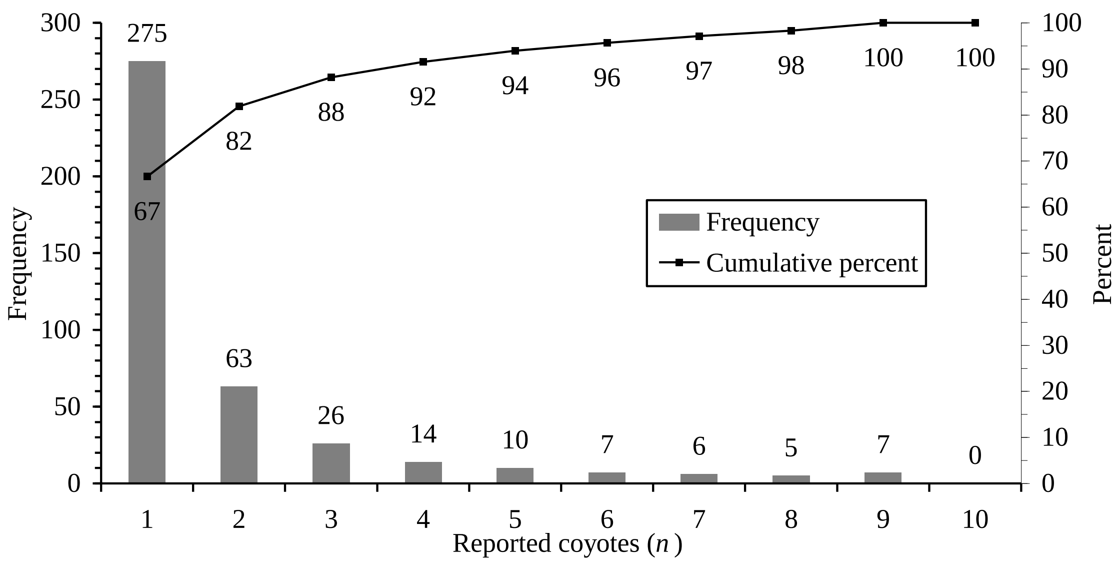


Figure 2.3. Frequency (bars) and cumulative percent distribution (line) of the number of coyotes described per incident reported to New York State Department of Environmental Conservation, New York, USA, May 2005–April 2009.

People indicated that coyotes behaved as non-fearful in 30.0% of all reports. Additionally, coyotes reportedly approached or followed a human in 9.4% of cases, threatened a human in 3.6% of cases, chased a human in 1.6% of cases, and attacked 3 people (0.7% of cases). Of all 447 reports, people either did not respond or acted evasively to the presence of coyotes in 50.1% of cases, while few responded aggressively by threatening coyotes (25.7%), and very few people killed coyotes (0.9%) during the interaction.

Adults (88.2%) were reported as involved in 7.5 times more (Z = 9.92, P < 0.001) interactions with coyotes than children (11.8%) for cases that specified age of the person involved in the interactions (n = 169). This trend remained relatively consistent for reports by categorical ratings ($\chi_3^2 = 6.744$, $P = 0.0805$). While human–coyote interactions occurred throughout the 24-hr day (n = 344), slightly more interactions were reported for daytime (54.9%) than nighttime (45.1%), but this was not significant ($Z = 1.83$, $P = 0.075$). Prior to the reported incident, people indicated they had observed coyotes (n = 393) as common (30.8%), few times (40.2%), or never (29.0%). Most reported interactions (n = 447) occurred in residential yards (69.8%); few occurred at farms (11.4%), along streets (2.5%), school yards (2.0%), parks (1.6%), trails (1.1%), near children play areas (0.7%), and miscellaneous other locations (5.4%). The distance between human and coyote (n = 324) was reported more frequently ($Z = 9.89$, $P < 0.001$) when coyotes were observed ≤45.72 m (50 yards; 77.5% of cases) than at distances >45.72 m (22.5% of cases). Human sources of food (e.g., bird feeders, pet food, garbage and compost) were identified as possible attractants in fewer than 10.0% of all reported interactions.

Dogs at risk.— Incident reports commonly involved domestic dogs, as dog–coyote interactions accounted for the largest proportion of category 2 reports, and were identified in other incident categories. For all (n = 477) reports, 26.6% (n = 119) indicated a dog was present at the time of the interaction. Coyotes reportedly approached 49 dogs, chased 10 dogs, attacked or injured 33 dogs, and killed 20 dogs.

The mass of domestic dogs was reported for 16.3% (n = 73) of reports which allowed the analysis of the association of dog size (kg) involved with increasing levels of aggressive coyote behavior (Figure 2.4). Coyotes approached dogs of all sizes (median = 20.4 kg (45 lbs), n = 32), yet interactions terminated in chasing of larger dogs (median = 29.5 kg (65 lbs), n = 7). Medium-sized dogs tended to more often be attacked or injured (median = 20.0 kg (44 lbs), n = 19) while small dogs (median = 4.5 kg (10 lbs), n = 15) were often reportedly killed by coyotes ($F_{3, 69} = 6.735$, P =

0.0005). A 10-year-old dog weighing 41 kg was reported as killed by an unreported number of coyotes. This incident was an exceptional outlier.

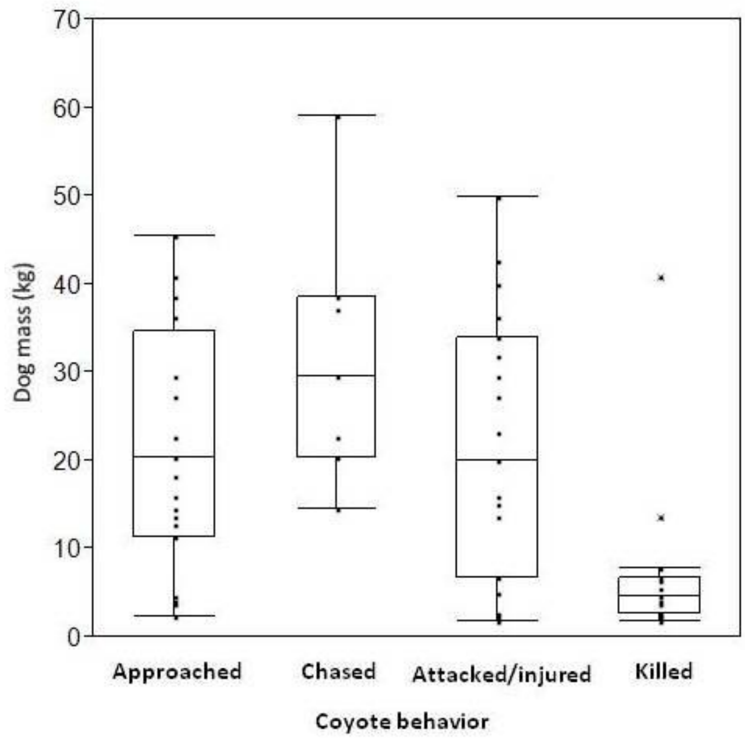


Figure 2.4. Association between dog mass (kg) and the highest level of aggressive behavior exhibited by coyotes (*n* = 73) reported across New York, USA, to New York State Department of Environmental Conservation, May 2005–April 2009.

Reporting Trends by Category Rating

Category 1.— The majority of the reports (*n* = 19) categorized as a coyote threatening or attacking a human involved adults (78.9%) and interactions occurred both day (46.7%) and night (53.3%). The majority of these reports indicated coyotes were common (47.4%), being observed ≥4 times within the past 3 months. Most reports stated that interactions occurred in residential yards (57.9%), and that coyotes were observed ≤45.72 m from people (68.4% of reports). The majority of reports characterized coyote behaviors as threatening (63.2%). If a pet was present, it was typically a dog (31.6%), while on a leash (21.1%). When a pet in general was involved, the majority of reports indicated that coyotes approached pets (15.8%), though coyotes also chased pets (10.5%) or attacked and injured pets (10.5%). Overall, the majority of people (42.1%) did not react or acted evasively (i.e., avoided) to the coyote; fewer people attempted to threaten the coyote (36.8%).

Category 2.— Coyote–pet incident reports (n = 151) occurred both day (43.6%) and night (56.4%). The majority of these reports indicated coyotes were observed commonly (≥4 times; 32.5%), or a few times (1–3 times; 31.1%) during the preceding 3 months. Most incidents occurred in residential yards (66.9%), with coyotes reportedly observed at distances ≤45.72 m (34.4%). The majority of pet interaction reports indicated coyotes were non-fearful (23.2%) and typically involved dogs (51.7%) as opposed to cats (25.8%). Pets in general were unsupervised (35.8%) at the time of the incident. People reported (or suspected) their pets were killed in 34.4% of pet interactions with coyotes, followed by attacked and injured (26.5%), and pets approached by coyotes (21.2%). Similar proportions of people responded to pet–coyote interactions by threatening the coyote (38.4%) or by not reacting to or evading the coyote (35.1%).

Category 3.— Coyotes were observed repeatedly in the same area for 22.8% (n = 102) of reports, and these were non-confrontational interactions (e.g., not category 1 or 2 reports). Coyotes were observed day (55.1%) and night (44.9%), and were reported as common (≥4 observations; 47.1%) or observed a few times (1–3 observations, 40.2%) in the 3 months prior to filing reports. Coyotes were observed typically in residential yards (70.6%) at distances ≤45.72 m (50 yards, 71.6%) by adults (39.2%). Coyotes were reported behaving as non-fearful (47.1%), and people typically did not react to or evaded the coyote (50.0%).

Category 4.— The largest proportion of reports (n = 143) received a category 4 rating for first-time sightings of a coyote. People reported more ($Z = 3.60$, $P \leq 0.001$) first-time sightings for daytime (65.0%) than nighttime (35.0%), however the overall Chi-square test among all categories was not significant (see above). The majority indicated they had not observed coyotes (39.4%), or had observed coyotes 1–3 times (38.9%) in the past 3 months. It is unclear whether these observations occurred in the same setting (suggesting a category 3 rating), or among different locations. Most reports occurred in residential yards (73.1%), while an adult was present (40.0%). Coyotes were typically reported ≤45.72 m (50 yards, 64.6%) from people and behaved as non-fearful (23.4%). The majority of people did not react to or evaded the coyote (64.0%).

Coyote Study Web Reports

The Coyote Study Web Report (CWR) database received 236 total reports of interactions and sightings of coyotes of which 180 (76.3%) reports originated from Westchester County, the focal study area. Other reports (n = 56) originated nearby yet outside of Westchester County, and were discarded from further county-level analyses. The proportions of report categories remained consistent among years (χ_6^2 = 3.815, P = 0.7017) although the number of reports fluctuated slightly with the lowest reporting occurring in the last year of data collection (Table 2.3).

Comparison of Report Collection Methods

Considering data generated from Westchester County, the CIR database received 45 incident reports in 48 months, and the CWR received 180 reports in 36 months (Table 2.4). Adjusting for study period length, the CWR database received 5.5 times more reports than the CIR database. The frequency of incident report ratings were not proportionate between databases (χ_3^2 = 28.721, $P \leq 0.001$). Both databases received approximately equal numbers of category 1 and category 2 reports

(Table 2.4). However, CWR received 4.27 times more category 3 reports and 9.13 times more category 4 reports than the CIR database. Little overlap between the two datasets existed as only 1 person from the county filed reports to both. Repeated reporting was less common for CIR database than the CWR database. One person reported to the CIR database 2 separate interactions involving pets (i.e., category 2), while 8 people reported to the CWR database 21 reports which were assigned category 3 or category 4 ratings.

Table 2.3. Coyote website incident reports and percentage of categorical ratings by year reported for Westchester County, New York, USA, January 2006–December 2009. Categorical ratings are 1) Reports of coyotes threatening or attacking people, 2) Reports of coyotes threatening, attacking or killing pets, 3) Reports of coyotes sighted repeatedly, typically in the same setting, 4) Reports of first time sightings of coyotes.

		Percent of reports by categorical rating			
Study year	Total reports (*n*)	1	2	3	4
2006	60	0	5.0	23.3	71.7
2007	74	1.4	6.8	13.5	78.4
2008	46	0	4.3	17.4	78.3
Total	180	0.6	5.6	17.8	76.1

Table 2.4. New York State Department of Environmental Conservation coyote incident reports (CIR), May 2005–April 2009 and Coyote Study Web Reports (CWR), May 2006–December 2008, originated from Westchester County, New York, USA. Categorical ratings are 1) Reports of coyotes threatening or attacking people, 2) Reports of coyotes threatening, attacking or killing pets, 3) Reports of coyotes sighted repeatedly, typically in the same setting, 4) Reports of first time sightings of coyotes.

	Categorical Rating *n* (%)				
Database	1	2	3	4	Total
CIR	1 (2.2)	14 (31.1)	10 (22.2)	20 (44.4)	45 (100.0)
CWR	1 (0.6)	10 (5.6)	32 (17.8)	137 (76.1)	180 (100.0)
Corrected magnitude[i]	1.33	0.95	4.27	9.13	5.33

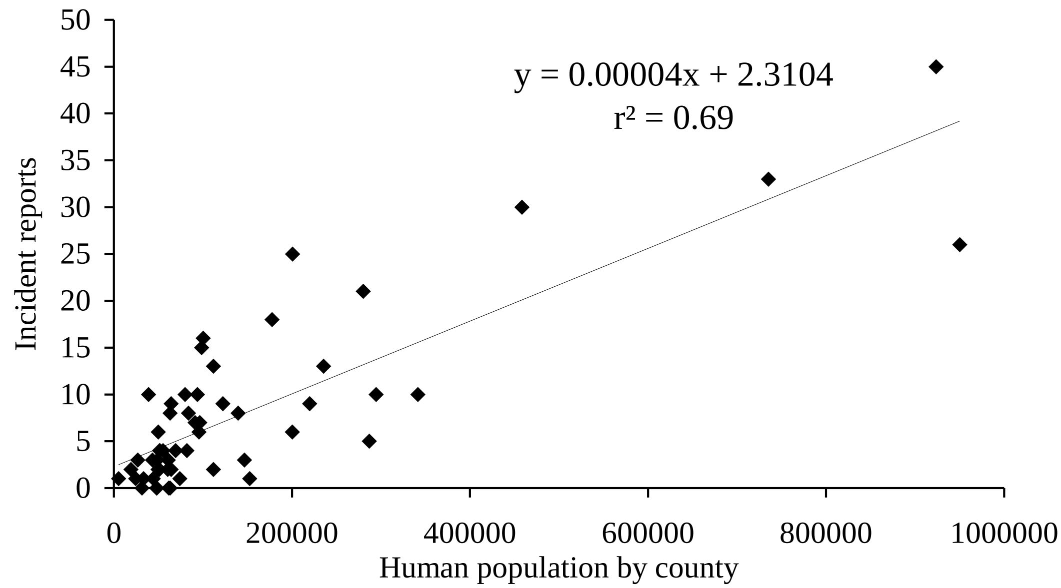
[i] Corrected magnitude = (CIR/4 years) / (CWR/3 years)

Statewide Spatial Analysis

Using Moran's I, I did not detect spatial correlation among incident reports (Moran's I = –0.0845, P = 0.5337) or human population (Moran's I = 0.3474, P = 0.3641). I found evidence in support of h_1 that the number of reported human–coyote interactions was linearly and positively associated with human population size (r^2 = 0.691, $F_{1, 53}$ = 118.4, $P \leq 0.0001$; Coyote Incident Reports = 2.310 + 0.00003883 * County Population Size). The assumptions of least squares regression were not violated as the residuals were normally distributed (G-test, P = 0.069), and the assumption of linearity was met given the high r^2 value (Figure 2.5). After removing the expected reporting rate (trend) by county population, I did not find support that the residuals exhibited significant autocorrelation (Moran's I = 0.6601, P = 0.2546). Modeling of spatial autocorrelation among neighboring counties was not required.

Examining the residuals, I found that reporting rates for two counties fell outside of the 95% confidence interval for fitted values (Figure 2.5b). Saratoga County (residual = 14.9) and Erie County (residual = –13.2) deviated the greatest from the expected reporting rate. The residual value for Westchester County (residual = 6.84) was not significantly above the expected reporting rate.

a.



b.

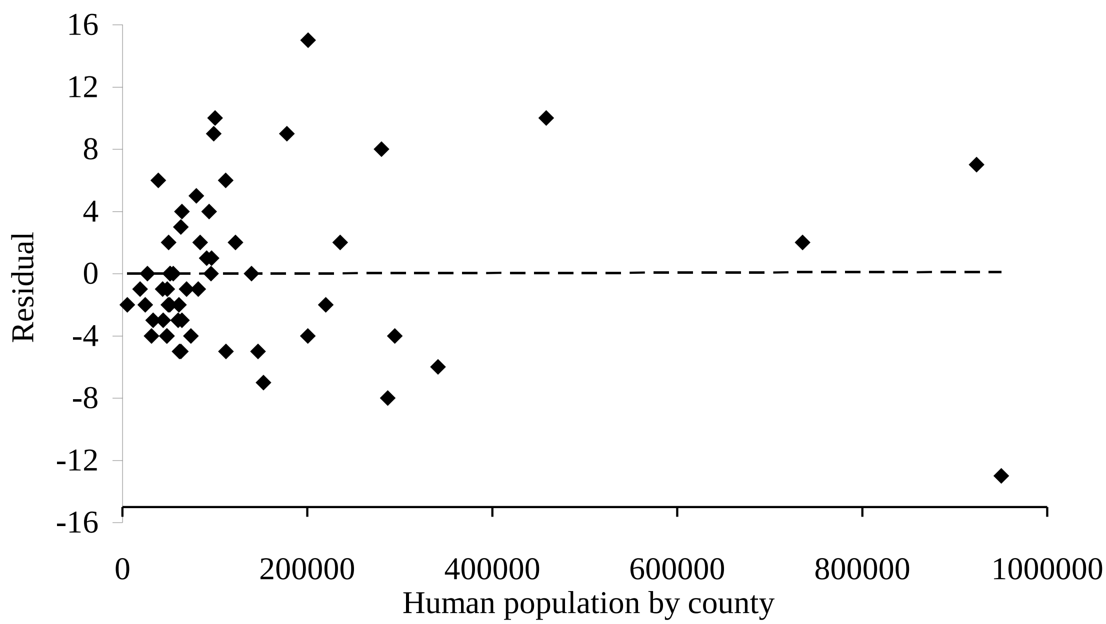


Figure 2.5. Association between the cumulative human–coyote incident reports and human population size for 55 counties of New York, USA, collected May 2005–April 2009, with (a) the fitted values and predicted reporting rate (trend) and (b) the residual values deviating from the predicted reporting rate (trend removed).

DISCUSSION

This study is the first examination of systematically-collected, human–coyote interactions across a state in the United States. Similar studies have examined incident report data within the metropolitan areas of cities (Farrar 2007, Lukasik and Alexander 2011), while related studies retrospectively examined information gleaned from unintentional or disparate sources (i.e., newspaper articles or miscellaneous public records) not intended specifically for wildlife management research (Howell 1982, Carbyn 1989, Baker and Timm 1998,Timm et al. 2004, White and Gehrt 2009). Research has described coyote attacks on humans across North America (White and Gehrt 2009), estimated the likelihood of experiencing a human–coyote interaction (i.e., sighting) in a suburban county of New York (Weckel et al. 2010), and examined stakeholder insights and perceptions of human–coyote interactions (Hudenko et al. 2008*a*, *b*, *c*). My research builds on this literature by providing direct insight into the spatial and temporal occurrence of human–coyote interactions that motivated stakeholders to report observations and seek information or management assistance from a state wildlife agency.

Human–wildlife interactions are anticipated to increase in frequency, and wildlife professionals are interested in creating a standardized database of human interactions with coyotes and other wildlife species (see Baker and Timm 1998, Timm et al. 2004, Baruch-Mordo et al. 2008, White and Gehrt 2009, Lukasik and Alexander 2011). As such, this research report is timely and valuable for urban wildlife managers by providing a comprehensive and objective analysis of the spatial and temporal variation of incident reporting, and theoretical limits and utility for wildlife management.

Reported Interactions

Statewide patterns.— I found the number of CIR decreased over study years, while report categories remained consistently proportionate over study years and biological seasons. This was directly opposite my expectations because, based on hypotheses of Baker and Timm (1998) and Timm et al. (2004), I predicted the number of reports would increase and categories would shift towards more frequent reporting of conflict interactions. Future research may address concerns of variation in recording incidents, and variation in reporting rates that may be influenced by media reports or other unidentified factors. Although not considered in this analysis, future monitoring efforts should consider the potential influence of inconsistent recording of wildlife incident reports when many individuals are involved in recording reports.

The frequency of reporting varied within the year, as half of the CIR occurred during the pup-rearing biological season which corresponds to summer months. This result was similar to White and Gehrt (2009), as they observed more coyote attacks on people during summer months, and suggested this is perhaps due to increased human outdoor activity (Quinn 1995). Interestingly, Lukasik and Alexander (2011) found reporting rates were lowest for sightings yet slightly elevated for conflict interactions during pup-rearing season. It is difficult to determine why this pattern occurred since, based on my results, it appears that sightings and conflicts are correspondingly reported greater during pup-rearing season, and in similar proportions throughout the remainder of the year. In addition to peak reporting during pup-rearing season (May), I noted minor reporting increases during October and January, perhaps correlating with coyote dispersal and breeding season, respectively. In New York State, it is likely coyote biology and behavior combined with increased human outdoor-activity explains within-year variation of reported human–coyote interactions. However, it is difficult to determine why reporting diminished over study years yet the proportions of report categories remained consistent.

NYSDEC received disproportionate numbers of reports by categories with more reports received for lower interaction levels (i.e., category 3 and 4) than elevated interactions (i.e., category 1 and 2). NYSDEC categorized the greatest proportion of reports as category 4, first time sightings, while pet–coyote interactions accounted for the second most reported interaction, followed by repeated sightings. Human–coyote conflicts accounted for only 4.3% of CIR across New York State and accounted for few incident reports within Westchester County for both (CIR and CWR) independent collection methods.

General interactions.— CIR indicated most coyote interactions occurred in residential yards, and seldom along residential streets, school yards, recreational parks, natural area trails or children's play areas. Unsolicited reports of coyote interactions may be systematically biased towards elevated reporting for interactions in residential yards. Based on human perception and acceptance, stakeholders expressed they would be increasingly concerned if coyotes were observed closer to their backyards than in other community areas (Wieczorek Hudenko et al. 2008*b*). Sightings of coyotes are common in residential yards near natural areas (Quinn 1995, Weckel et al. 2010, Lukasik and Alexander 2011). Interestingly, stakeholders in Austin, Texas, often perceived coyote behavior as aggressive, yet systematic investigation suggested fewer coyotes exhibited aggressive behaviors (Farrar 2007). This further demonstrates evidence of some stakeholders having low tolerance or understanding of coyotes in residential settings, as found by Wieczorek Hudenko et al. (2008*b*). This concern of proximity and low tolerance may influence residents to report coyote sightings that occur in their yards more than distant sightings away from residences. In fact, 78% of CIR indicated that coyotes were observed ≤45.72 m from people. Stakeholder reporting of coyote sightings does not accurately describe coyote space use patterns

(Quinn 1995). Therefore, field investigations are necessary to gain insight into coyote spatial ecology and behavior, and use of residential and human-activity areas.

Pet–coyote interactions accounted for the largest proportion of heightened interactions, beyond general coyote sightings, and may have the potential to put more people at risk of injury than direct coyote aggression towards humans. Indeed, as White and Gehrt (2009) point out, Timm et al. (2004) loosely defined coyote attacks on humans by including in their accounts any incident in which coyotes first attacked a pet that resulted with an intervening pet owner being bitten or scratched. Interestingly, I found in most incident reports that people typically evaded (or avoided) or acted non-confrontationally towards coyotes. However, when a pet was involved, pet owners were more likely to intervene and threaten or chase away the coyote. People intervening in pet–coyote interactions may be at risk of possible injury, and this could be more likely for owners of small dogs.

Dogs at risk.— I found evidence suggesting that risks to dogs interacting with coyotes increased with decreasing dog-mass. By examining the mass of dogs involved in elevated coyote aggression, I found that dogs <9 kg (20 lbs.) are most at risk of being killed by coyotes. Dogs of various mass were approached or even attacked, however these interactions were more likely to end at chasing for larger dogs of approximately 30 kg (65 lbs). While these weight relationships may seem intuitive, this is the best approximation yet of coyote-related risks to dogs of various masses. This information may improve our understanding of interactions with coyotes and help to prevent human and pet injuries.

Theoretical Limits

Comparison of Report Collection Methods.— Based on a possible media-spike in reporting rates at the onset of a suburban coyote study in New York (Lang 2005), I examined the potential for an alternative reporting mechanism for coyote sightings and interactions. As predicted, the CWR database received more reports than the CIR database with little overlap in reporting. Reporting rates by category for NYSDEC CIR data were different than CWR; this is likely an important consideration for wildlife managers. General sightings (category 3 and 4) were reported more frequently to CWR than CIR, yet accounted for proportionately more observational reports than elevated interaction reports (category 1 and 2) for both datasets. The raw number of elevated interactions was approximately equal for both datasets, yet proportionately less common for CWR data from Westchester County. This suggests that elevated interactions are less frequent in Westchester County than would otherwise be determined by CIR alone.

Although not directly comparable, the CWR more closely agree with results from a random sample of stakeholders (Wieczorek Hudenko et al. 2008*b*) in that both patterns decreased from a greater frequency of general sightings (or awareness of coyotes) to few elevated interactions (or problems) with coyotes. Lukasik and Alexander (2001) similarly found sightings accounted for 89% of all incident reports in Calgary, Canada, and Farrar (2007) found non-conflict interactions accounted for 91% of incident reports in Austin, Texas. Further investigation on motivations of stakeholders to report their interactions to various professionals is needed to understand wildlife stakeholder acceptance and capacity (Wieczorek Hudenko et al. 2008*b*).

As my comparative analysis of CWR and CIR suggests, a differential in likelihood to report interactions of varying intensities may exist. This may be further confounded by accessibility to file the report (i.e., finding a specific agency phone number versus finding a readily accessible web-site report form). Although the total number of human–coyote interactions is not estimable by incident reports, the comparison of both methods, and lack of overlap in reporting between methods, confirm that many more sightings and general interactions occur than are reported to NYSDEC. This highlights the need to maintain an accurate assessment of quality information collected by robust sampling methods. Therefore, if assessing the scope and magnitude of human–coyote interactions is a desirable objective for wildlife professionals, then efforts should be made to collect sightings through multiple sources for a more complete understanding (Wieczorek Hudenko et al. 2008*c*). An Internet-based method could provide a useful tool for this enabling objective. However, while specialized incident monitoring strategies in Austin, Texas; Calgary, Canada; and CWR in Westchester County, New York all converge towards similar findings, random sampling strategies of stakeholders (i.e., Wieczorek Hudenko et al. *a*, *b*) are likely the best methods to avoid indeterminable levels of bias that may occur when monitoring incident reports of human–coyote interactions. Most importantly, random sampling strategies can provide insight into human–coyote interaction rates by determining the proportion of stakeholders who do not experience interactions and conflicts with coyotes, which monitoring incident reports at any spatial scale or level of intensity cannot provide. Robust sampling strategies (e.g., public surveys) are necessary when accurate (precise and unbiased) assessments about wildlife management issues are needed (Wieczorek Hudenko et al. 2008*c*).

Statewide Spatial Analyses.— Much concern exists that human–coyote interactions are an increasing suburban or urban issue, and this topic has gained increasing attention as apparent from published research (Howell 1982, Quinn 1995, Baker and Timm 1998, Gompper 2002a, Timm et al. 2004, Farrar 2007, Wieczorek Hudenko et al. 2008*a*, *b*, *c*, Gehrt et al. 2009, White and Gehrt 2009, Weckel et al. 2010, Lukasik and Alexander 2011). The occurrence of coyotes in residential and suburban areas may be relatively new for many metropolitan areas. However I found that incident reporting across New York State, at the county scale, is linearly related to human population size. Based on the association of CIR to human population size, I did not find evidence that human–coyote interactions are limited to suburban and urban counties.

Researchers have examined the spatial distribution of human–wildlife interactions, finding important spatial clustering of interactions (Baruch-Mordo et al. 2008, Kretser et al. 2008, Lukasik and Alexander 2011). Human–bear conflicts clustered in areas of related land-use practices (Baruch-Mordo et al. 2008). Because clustered interactions were associated with related land-use practices (e.g., agricultural conflicts clustered in dense areas of practicing agriculture), the researchers suggested the need for targeted management interventions (Baruch-Mordo et al. 2008). Their results are not dissimilar to my findings, yet may lead to entirely different conclusions. This highlighted the need to investigate further the underlying process of reporting human–wildlife interactions.

In this example, I investigated the association of CIR with human population size. For an incident report to occur, it is necessary for a person to experience an interaction with a coyote, and to report the interaction to an agency. The number of human–wildlife interactions that are not reported to an agency remain unknown. Therefore, the probability of interactions and the total number of incidents cannot be estimated by incident reports. However the number of reported incidents and human population size was measurable and explored for spatial patterns to further understand how to manage human–coyote interactions.

I found no evidence of hot-spots, or clusters of counties, with elevated reporting across New York State, with perhaps one exception (i.e., Saratoga County). Because incident reporting was proportionately and linearly related with human population size (h_1), further investigation of spatial point processes was not needed for this statewide analysis scale. Further cluster analyses at this scale would track the dispersion of the human population, and not be informative about the occurrence of coyote interactions. However, if this initial examination found hot-spots of reporting identified by a non-linear (e.g., sigmoidal curve) relationship of incident reports with human population size (e.g., h_2: low incident rate for low populated areas abruptly, and non-linearly increasing for highly populated areas), then perhaps further spatial statistical examinations might identify an important process not yet explained, or support the need for targeted management interventions as found by Baruch-Mordo et al. (2008).

Visually examining the dispersion, or pattern, of CIR data alone suggests that incident reports cluster in certain areas of New York (Figure 2.6). Aggregating incident reports by county further exemplifies the appearance of hot-spot counties. Indeed, simply monitoring counties for raw counts of incident reports suggests 6 New York State counties have elevated reporting rates (Figure 2.7). However, further analyses are needed to account for the process that gives rise to this pattern. Through my spatial analyses, I removed the expected reporting rate (trend) and examined the residuals (Figure 2.8), which represent deviations away from the expected reporting rate. Extreme deviations from the mean reporting rate represent counties with elevated or depressed reporting rates. My analysis found Saratoga County to have the highest reporting rate and Erie County to have the lowest reporting rate based on human population size. Westchester County exhibited relatively normal (expected) reporting rates. Based on finding a linear relationship between incident reporting and human population size, I did not find strong evidence for a targeted management intervention for any particular county in New York State. However, targeted management may be required at a finer scale such as town-level or more localized areas (coyote home range).

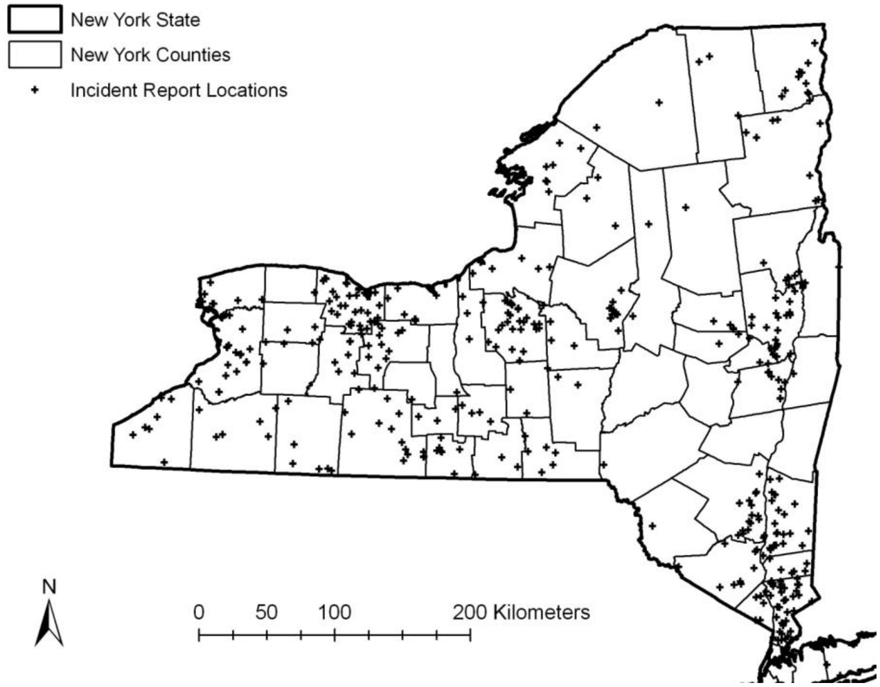


Figure 2.6. Map of the dispersion of human–coyote interactions reported to New York State Department of Environmental Conservation across 55 counties of New York, USA, May 2005–April 2009.

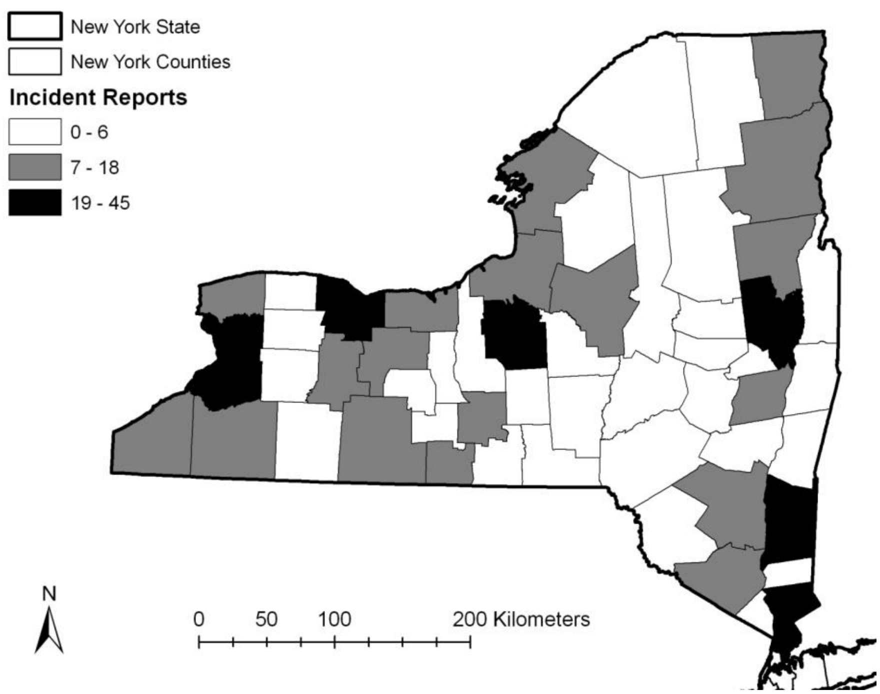


Figure 2.7. Map of human–coyote interaction reports aggregated by 55 counties of New York, USA, May 2005–April 2009.

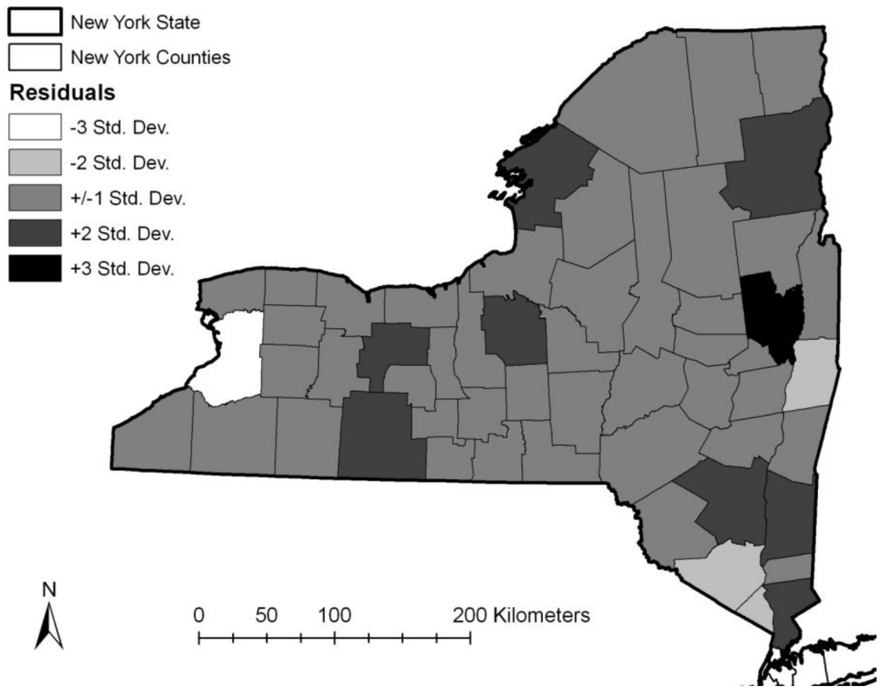


Figure 2.8. Map of the residual values deviating from the predicted reporting rates based on coyote incident reports regressed on human population size for 55 counties of New York, USA, May 2005–April 2009.

In consideration of the spatial scale of analysis, insufficient interactions were reported to investigate the spatial occurrence of human–coyote interactions at a town or finer resolution. Both Baruch-Mordo et al. (2008) and Kretser et al. (2008) utilized datasets containing 2,405 and 2,234 incident reports, respectively, representing approximately 5 times more reports than the CIR database. Data for these studies were collected over several years and represent areas of chronic human–wildlife interactions. Their analyses do not forecast actual interactions of individual animals, but identify areas where interactions have occurred and may continue, such as potential areas of human–coyote interactions in Westchester County (Weckel et al. 2010). Based on these specific analyses, human–coyote interactions can be expected to be reported in proportion to the human population size for each county across New

York State. Localized studies may find patterns of human–coyote sightings and conflicts occurring where dense human-populated areas border riparian, shrub or natural areas (Quinn 1995, Weckel et al. 2010, Lukasik and Alexander 2011).

MANAGEMENT IMPLICATIONS

Public sighting reports seem an attractive means to collect information about wildlife populations, animal behaviors, and human–wildlife interactions. These types of reports can be quite numerous and appear superficially as a robust sampling strategy. However, monitoring unsolicited incident reports of human–coyote interactions was not a robust method to accurately index the frequency of human interactions and conflicts with coyotes. Without periodic random sampling of stakeholders, it is difficult to identify and adjust for potential biases in reporting such as interactions proximate to residential yards, people, and pets. However, benefits exist to systematically collecting unsolicited stakeholder reports of interactions with coyotes. While not fully representative of all human–coyote interactions, these reports may lend direct insight into the types of interactions with coyotes that motivated stakeholders to report their experiences to a state wildlife agency. Perhaps clarity exists by illustrating a helpful graphing analogy, in that these data help define the x-axis of conflicts that occur, but do not reliably indicate the frequency plotted on the y-axis. Random sampling is necessary to estimate true frequencies of occurrence.

Examining CIR, I found frequent reports of dog–coyote interactions, general interactions near or in residential yards, and in close proximity to people and pets. These interactions may increase during summer months when people are active outdoors and coyotes are provisioning pups. Public education may be necessary to inform stakeholders of these risks, and to inform how to respond when a coyote is sighted. Perhaps most importantly, I identified a potential insertion point for management intervention as people typically avoided confrontation with a coyote by either not responding, or avoiding the animal. Few people threatened coyotes. Wildlife professionals may encourage stakeholders to take more proactive steps in curbing aggressive coyote behaviors through hazing and chasing coyotes away from residential yards or the presence of humans. While this need not be a blanket management recommendation, it certainly may be encouraged in localized areas where coyote sightings appear to be recurring or increasing. However, further research is needed to test the efficacy of this recommendation, as current levels of conflict interactions are low (Farrar 2007, Wieczorek Hudenko et al. 2008*a*, *b*, Lukasik and Alexander 2011). Additionally, current levels of human interference with coyotes may be sufficient to limit localized coyote aggression towards people (Wieczorek Hudenko et al. 2008*b*).

It should be noted that due to the theoretical and probabilistic constraints of coyote incident reports, it is unlikely to provide insight into broad-scale changes in animal trends or success of localized management interventions in a neighborhood, as these reports do not reflect true behavior of animals and wildlife populations. These data appear to be influenced by complex human behaviors influencing where or whether to report or not to report (Howe et al. 2010). While sightings and non-conflict interactions are important to maintain a clear perspective, conflict interactions are most important to wildlife professionals interested in alleviating risk to people and should be the focus of any broad-scale efforts to monitor human–coyote interactions. Perhaps the greatest benefit of systematically recording stakeholder reports is the equitable treatment of all stakeholders across New York State, ensuring that each person is treated fairly and their concerns appropriately addressed (G. R. Batcheller, New York State Department of Environmental Conservation, personal communication) which is supported by my spatial analyses.

REFERENCES

Baker, R. O., and R. M Timm. 1998. Management of conflicts between urban coyotes and humans in Southern California. Proceedings of the Vertebrate Pest Conference 18:299–312.

Baruch-Mordo, S., S. W. Breck, and D. M. Theabold. 2008. Spatiotemporal distribution of black bear–human conflicts in Colorado, USA. Journal of Wildlife Management 72:1853–1862.

Bivand, R. S., E. J. Pebesma, V. Gómez-Rubio. 2008. Applied spatial data analysis with R. Springer, New York, New York, USA.

Bounds, D. L., and W. W. Shaw. 1994. Managing coyotes in U.S. National Parks: human–coyote interactions. Natural Areas Journal 14:280–284.

Carbyn, L. N., 1989. Coyote attacks on children in western North America. Wildlife Society Bulletin 17:444–446

Carey, J. 2006. Wildlife in the concrete jungle. National Wildlife 44:31–37.

Curtis, P. D., D. A. Bogan, and G. Batcheller. 2007. Suburban coyote management and research needs: a northeast perspective. Proceedings of the Wildlife Damage Management Conference 12:413–417.

Decker, D. J., and L. C. Chase. 1997. Human dimensions of living with wildlife—a management challenge for the 21st century. Wildlife Society Bulletin 25:788–795.

Don Carlos, A. W., A. D. Bright, T. L. Teel, and J. J. Vaske. 2009. Human–black bear conflict in urban areas: an integrated approach to management response. Human Dimensions of Wildlife 14:174–184.

Farrar, R. O. 2007. Assessing the impacts of urban coyote on people and pets in Austin, Travis County, Texas. Proceedings of the Wildlife Damage Management Conference 12:334–341.

Fener, H. M., J. R. Ginsberg, E. W. Sanderson, and M. E. Gompper. 2005. Chronology of range expansion of the coyote, *Canis latrans*, in New York. Canadian Field-Naturalist 119:1–5.

Gehrt, S. D., C. Anchor, and L. A. White. 2009. Home range and landscape use of coyotes in a metropolitan landscape: conflict or coexistence? Journal of Mammalogy 90:1045–1057.

Getis, A., and J. K. Ord. 1992. The analysis of spatial association by use of distance statistics. Geographical Analysis 24:189–206.

Gompper, M. E. 2002a. Top carnivores in the suburbs? Ecological and conservation issues raised by colonization of north-eastern North America by coyotes. Bioscience 52:185–190.

Gompper, M. E. 2002b. The ecology of northeast coyotes: current knowledge and priorities for future research. Wildlife Conservation Society Working Paper 17:1–48.

Howe, E. J., M. E. Obbard, R. Black, and L. L. Wall. 2010. Do public complaints reflect trends in human–bear conflict? Ursus 21:131–142.

Howell, R. G. 1982. The urban coyote problem in Los Angeles County. Proceedings of the Vertebrate Pest Conference 10:21–23.

Kays, R., A. Curtis, and J. J. Kirchman. 2009. Rapid adaptive evolution of northeastern coyotes via hybridization with wolves. Biology Letters 6:89–93.

Kretser, H. E., P. J. Sullivan, and B. A. Knuth. 2008. Housing density as an indicator of spatial patterns of reported human–wildlife interactions in Northern New York. Landscape and Urban Planning 84:282–292.

Lang, S. S. 2005. Why are coyotes getting more aggressive? Cornell five-year study intends to find out. Cornell University News Service. <http://www.news. cornell.edu/stories/May05/ coyotes.study.ssl.html> accessed July 15, 2010.

Laundré, J. W., and B. L. Keller. 1981. Home range use by coyotes in Idaho. Animal Behavior 29:449–461.

Lukasik, V. M., and S. M. Alexander. 2011. Human–coyote interactions in Calgary, Alberta. Human Dimensions of Wildlife 16:114–127.

Markovchich-Nicholls, L., H. M. Regan, D. H. Deutschman, A. Widyanata, B Martin, L Noreke, and T. A. Hunt. 2008. Relationships between human disturbance and wildlife land use in urban habitat fragments. Conservation Biology 22:99–109.

Merkle, J. A., P. R. Krausman, N. J. Decesare, and J. J. Jonkel. 2011. Predicting spatial distribution of human–black bear interactions in urban areas. Journal of Wildlife Management 75:1121–1127.

New York State Department of Environmental Conservation (NYSDEC). 2005. New York State's coyote incident standard operating procedures. Bureau of Wildlife, Division of Fish, Wildlife & Marine Resources, New York State Department of Environmental Conservation, Albany, New York, USA.

Ott, R. L., and M. Longnecker. 2001. An introduction to statistical methods and data analysis. Fifth edition. Duxbury, Pacific Grove, California, USA.

Prugh, L. R., C. J. Stoner, C. W. Epps, W. T. Bean, W. J. Ripple, A. S. Laliberte, and J. S. Brashares. 2009. The rise of the mesopredator. BioScience 59:779–791.

Parker, G. R. 1995. Eastern coyote. Nimbus, Halifax, Nova Scotia, Canada.

Quinn, T. 1995. Using public sighting information to investigate coyote use of urban habitat. Journal of Wildlife Management 59:238–245.

Severinghaus, C. W. 1974. Notes on the history of wild canids in New York. New York Fish and Game Journal 21:117–125.

Siemer W. F., H. Wieczorek Hudenko, and D. J. Decker. 2007. Coyote management in residential area: human dimensions research needs. Proceedings of the

Wildlife Damage Management Conference 12:421–430.

Thurber, J. M., and R. O. Peterson. 1991. Changes in body size associated with range expansion in the coyote (*Canis latrans*). Journal of Mammalogy 72:750–755.

Timm, R. M., R. O. Baker, J. R. Bennett, and C. C. Coolahan. 2004. Coyotes attacks: an increasing suburban problem. Transactions of the North American Wildlife and Natural Resources Conference 69:67–88.

U.S. Census Bureau. 2008. <http://www.census.gov/geo/www/ua/ua_2k.html>. Accessed 5 October 2009.

Weckel, M. E., D. Mack, C. Nagy, R. Christie, and A. Wincorn. 2010. Using citizen science to map human–coyote interaction in suburban New York, USA. Journal of Wildlife Management 74:1163–1171.

White, L. A., and S. D. Gehrt. 2009. Coyote attacks on humans in the United States and Canada. Human Dimensions of Wildlife 14:419–432.

Wieczorek Hudenko, H., D. J. Decker, and W. F. Siemer. 2008*a*. Living with coyotes in suburban areas: insights from two New York State counties. Cornell University Human Dimensions Research Unit HDRU Series No. 08-8, Ithaca, New York, USA.

Wieczorek Hudenko, H., D. J. Decker, and W. F. Siemer. 2008*b*. Humans and coyotes in suburbia: can experience lead to sustainable coexistence? Cornell University Human Dimensions Research Unit HDRU Series No. 08-9, Ithaca, New York, USA.

Wieczorek Hudenko, H., D. J. Decker, and W. F. Siemer. 2008*c*. Reliance on informants in wildlife management situation analysis—shortcut or shortcoming? Human Dimensions of Wildlife 13:459–470.

Zezima, K. 2008. A fierce predator makes a home in the suburbs. The New York Times. 10 June 2008; Section F:4.

CHAPTER 3

COYOTE SPATIAL ECOLOGY, BEHAVIOR AND HUMAN INTERACTIONS IN SUBURBAN NEW YORK

Understanding coyote (*Canis latrans*) spatial ecology and related behaviors that lead to conflicts with humans is necessary to guide an informed management response to growing concerns of human–coyote interactions. Negative human–coyote interactions, if allowed to persist, may escalate to severe conflicts (Baker and Timm 1998, Timm et al. 2004, Lukasik and Alexander 2011). Examining the spatial ecology and behavior of coyotes can provide important perspective on the scale and magnitude of the issue by quantifying the frequency, intensity, and duration of human–coyote conflicts. Furthermore, studying a sample of individually-identifiable coyotes can provide additional perspective on population parameters (White and Garrott 1990, Manly et al. 2002), and the prevalence of problem individuals within a study area. Gaining this level of understanding may improve coyote management, and methods for reducing conflicts.

Human–coyote interactions occur in many areas throughout North America (Cornell and Cornely 1979, Carbyn 1989, Bounds and Shaw 1994, Quinn 1995, Hsu and Hallagan 1996, White and Gehrt 2009, Lukasik and Alexander 2011). In recent years, greater attention has been given to human–coyote conflicts occurring in urban lands. Researchers have studied coyote spatial ecology (Grinder and Krausman 2001, Way et al. 2002, Quinn 1997, Riley et al. 2003, Gehrt et al. 2009, Grubbs and Krausman 2009), interactions with humans (Farrar 2007, Weckel et al. 2009, White and Gehrt 2009, Lukasik and Alexander 2011, *see* Chapter 2), and the human dimensions of coyotes in suburban lands (Wieczorek Hudenko et al. 2008*a*, *b*, *c*) among other aspects of coyote ecology and management. While many studies aim to better understand aspects of human–coyote interactions, few field studies have explicitly tested the efficacy of non-lethal management options. Bounds and Shaw (1994) noted that wildlife managers prescribe actions to curb animal behaviors without knowing whether such recommendations are effective at alleviating conflicts. Although many potential non-lethal management options exist, few have been empirically tested to determine whether these alternative interventions achieve the desired outcome of minimizing conflicts (Knowlton et al. 1999, and Mitchell et al. 2004). Consequently, wildlife managers continue to have few proven, non-lethal options to manage human–coyote interactions in suburban lands. Examining the efficacy of behavioral modification strategies in urban areas by studying coyote behavior is of great and immediate value for urban wildlife management (Bounds and Shaw 1994, Lukasik and Alexander 2011).

Human–coyote interactions and conflicts are diverse (*see* Chapter 2) which makes developing management strategies difficult. Interactions and conflicts include general sightings of coyotes, stakeholder concern of sightings or fear of coyotes (Wieczorek Hudenko et al. 2008*a*, *b*), coyotes injuring and killing pets (Farrar 2007), and the perceived and objective risk of human injury (Howell 1982, Carbyn 1998, Bounds and Shaw 1994, Wieczorek Hudenko et al. 2008*a*, White and Gehrt 2009). Human deaths from coyote attacks are extremely rare throughout North America, as only 2 people (1 child and 1 adult) are known to have been killed as a result of coyote attacks (Howell 1982, Caudell 2010). Because there are multiple coincident types of human–coyote conflicts, it is plausible to describe the issue as a syndrome, or suburban coyote syndrome.

Wildlife professionals contending with diverse human–wildlife conflicts seek effective management alternatives in addition to lethal methods (Cornell and Cornely

1979, Bounds and Shaw 1994, Worcester and Boelens 2007, Lukasik and Alexander 2011). This, in part, is in response to changing stakeholder attitudes that favor the use of non-lethal methods (e.g., animal behavior modification) or highly-selective lethal methods for resolving conflicts (Arthur 1981, Reiter et al. 1999). However, it is essential to recognize that non-lethal methods require a level of specificity in application beyond non-selective and selective lethal management. By definition, non-selective lethal methods target any animal within a treatment area, whereas selective lethal methods target specific individuals involved in conflicts. In contrast, non-lethal management methods target specific conflict behaviors of individuals within a treatment area. To develop such specialized methods, it is necessary to thoroughly understand animal behaviors and associated conditions that lead to human–wildlife conflicts. This requires using consistent and appropriate terminology to describe animal behaviors, which may be latent and difficult to identify (Whittaker and Knight 1998, Knight 2009, Hopkins et al. 2010), and to correctly classify these behaviors into an ethogram for quantitative research (MacNulty et al. 2007). While classification might be difficult, developing a conceptual model would be instrumental for investigating human–coyote interactions and conflicts by framing the issue, organizing potential animal behaviors (Whittaker and Knight 1998, Goodenough et al. 2001, MacNulty et al. 2007), supporting consistent terminology (Hopkins et al. 2010), and focusing subsequent research efforts.

Coyotes recently expanded their species range throughout the northeastern USA (Severinghaus 1974, Parker 1995, Fener et al. 2005). Coyote populations spread across most of New York State by the mid 1970's (Severinghaus 1974, Fener et al. 2005) and apparent population growth has continued to extend the species range into suburban and urban lands, generating public attention (Webster 1981, Ferris 2004, Foderaro 2007). Currently, few studies have examined coyote spatial ecology and interactions with humans in New York (Kendrot 1998, Bogan 2004) and northeastern USA (Person and Hirth 1991; Way et al. 2002, 2004). Additionally, northeastern coyotes exhibit larger body sizes than their southwestern counterparts (Gompper 2002, Thurber and Peterson 1991) and may pose greater risks to human safety. Therefore, current research is needed to provide information about coyote ecology within this region (Gompper 2002), and to gain insight into the prevalence of coyote conflicts in urbanized landscapes.

Apparent increases in human–coyote conflicts motivated the New York State Department of Environmental Conservation (NYSDEC) to investigate coyote spatial ecology and behavior to understand the complex relationship between humans and coyotes in suburban landscapes, and to explore non-lethal management options to resolve conflicts (NYSDEC 2005). The research objectives of this study were to improve understanding of the current spatial ecology of coyotes inhabiting a targeted area within New York State, and examine how coyote space use and behavior may generate interactions with humans and increase the potential for conflicts. I conducted this research to identify opportunities to field-test non-lethal management intervention through animal behavioral modification (e.g., aversive conditioning through hazing or conditioned taste aversion). Towards this end, I developed a conceptual model of coyote behaviors that may lead to human interactions. I used the model to frame expectations of conflicts, as a means to identify when initiating aversive conditioning trials may be possible (below). To accomplish this, I studied a sample of radio-marked coyotes to determine the prevalence of problematic animals (or behaviors), and to reveal potential behavioral pathways that may lead to conflicts with human interests. I relate the conceptual model of interactions and conflicts with the findings of the field investigation and discuss issues of attempting to field-test behavior modification strategies.

CONCEPTUAL MODEL OF THE SUBURBAN COYOTE SYNDROME

Conceptualizing and understanding the behavioral processes that lead to patterns of human–coyote conflicts is important for wildlife professionals to develop and test methods for non-lethal modification of animal behaviors. Researchers have begun to examine patterns of conflicts (Carbyn 1989, Bounds and Shaw 1994, Baker and Timm 1998, Timm et al. 2004, Farrar 2007, White and Gehrt 2009, Lukasik and Alexander 2011). Yet few coyote studies explicitly discuss animal behaviors and behavioral pathways that lead to conflicts. Developing a conceptual model using clear and consistent terminology is necessary to improve communication and understanding of animal behaviors that lead to wildlife management issues (Whittaker and Knight 1998, Hopkins et al. 2010), such as human–coyote conflicts, and is fundamental when researching selective non-lethal management options to advance wildlife management and conservation. Specifying a conceptual model facilitates prediction, hypothesis formulation, discussion and eventual refinement of the model and understanding of animal behaviors related to human–wildlife conflicts (Whittaker and Knight 1989, Goodenough et al. 2001).

Animal behavioral responses to humans have been classified into 3 general categories: avoidance, habituation, and attraction (Whittaker and Knight 1998). These 3 behavioral responses to humans are expressed in a continuum of positive (attraction), neutral (habituation) and negative (avoidance) animal movements (Whittaker and Knight 1998; Figure 1.1). While habituation and attraction are different behaviors and movement responses, the spatial expression of both behaviors may lead to coyote association with people and human–developed lands. Subsequently, both behaviors may increase potential for animal aggression and attack. However, other animal behaviors may not fit squarely within these 3 categories, yet still emerge to generate conflict interactions. For example, a coyote that typically exhibits avoidance behavior by evading humans may exhibit territorial defense towards domestic dogs (*Canis lupus familiaris*), perhaps even in the presence of humans (Baker and Timm 1998, Timm et al. 2004, Farrar 2007, *see* Chapter 2). Therefore, additional animal behavioral responses should be incorporated into a conceptual model of human–coyote interactions and escalating risks to human interests and safety.

Wildlife professionals have proposed a hypothetical 7-step "predictable sequence" of escalating human–coyote interactions (Baker and Timm 1998, and Timm et al. 2004), yet do not sufficiently discuss animal behaviors that may generate these interactions. Further research is necessary to better understand how coyote behaviors change. For example, unanswered questions remain regarding whether animals persist in elevated behavioral states (or chronic tendencies), or express behaviors as situation-specific responses (or incidental events) (Whitaker and Knight 1998). General models should incorporate the dynamics of complex behaviors to improve management of human–wildlife conflicts. Here, I build on this idea using a conceptual model of behavioral state and transitions similar to Mattson et al. (2011) to represent a hypothetical process leading to human–wildlife conflicts. This model exhibits multiple pathways of state and transitions to represent changing animal behaviors that lead to interactions and conflicts (Figure 3.1), while accommodating for animals that may exhibit behavioral events or tendencies (Whittaker and Knight 1998). Insight into latent animal behaviors represented by this model may be gained from actively monitoring animal space use (e.g., home range behavior) which is a spatial manifestation of behavior (Burt 1943, Börger 2008). Home ranges are conceptually defined as the area used for common activities (behaviors) to satisfy biological needs (Burt 1943) during a specified time period (White and Garrott 1990), and have an estimable probability of occurrence for an animal (Kerohan et al. 2001). The degree to which coyotes use human-developed lands and interact with humans can be measured spatially and temporally through radio-telemetry and direct observation.

Avoidance.— This behavior is expressed by animals repeatedly evading human interactions (Whittaker and Knight 1998, Knight 2009), or using areas away from human-activity centers. Generally, coyotes exhibit apparent avoidance behavior and tend to live primarily in natural areas (Quinn 1997, Grinder and Krausman 2001, Riley et al. 2003, Bogan 2004, Gehrt et al. 2009). Studies also reveal that coyotes inhabiting urban landscapes are typically active during nighttime (Quinn 1997, Grinder and Krausman 2001, Riley et al. 2003, Bogan 2004, Gehrt et al. 2009, Grubbs and Krausman 2009), although decreased persecution may relax nocturnal tendencies of coyotes (Kitchen et al. 2000). Relative avoidance may be inferred by differential habitat use and selection studies (Manly et al. 2002). Coyote avoidance of human interactions is the desired behavioral state for coyote management (Figure 3.1).

Habitation.— Often the focus on animal behaviors related to human–coyote issues is simplified or singularly identified as habituation (*see* Howell 1982, Carbyn 1989, Baker and Timm 1998, Timm et al. 2004, Kloppers et al. 2005, Timm and Baker 2007, White and Gehrt 2009, Geist 2008, Geist 2011*a*, *b,* Rogers and Mansfield 2011). Additionally, habitation can be misused and should not be confused with the term habitual (Whitaker and Knight 1998), or food attraction (i.e., incorrectly stated as "food habituated," see Hopkins et al. 2010). For example, Timm and Baker (2007:274) state "Habituation begins when animals tolerate humans at a distance, and can progress in some instances to "taming," that is, conditioning an animal through positive reinforcement such as food." This usage generalizes a specific behavior to describe other complex behaviors (e.g., taming, tolerance and food conditioning) and may be incorrect when describing management issues (Whitaker and Knight 1998, Knight 2009, Hopkins et al. 2010). This seemingly simple semantic distinction may be very important because ambiguous usage may impede progress in understanding human–wildlife interactions and advancements in wildlife management (Whittaker and Knight 1998, Hopkins et al. 2010, Rogers and Mansfield 2011).

Habituation is defined as the waning of response to a stimulus (Whittaker and Knight 1989, Alcock 1998, Hopkins et al. 2010). By definition, habituation describes a specific behavioral tendency in which animals decreasingly respond, or cease to respond, to a stimulus (i.e., humans). Habituation is a neutral interaction. The animal neither leaves nor approaches; it simply fails to respond with an overt behavior (Whittaker and Knight 1998). While wildlife habituation can provide benefits such as wildlife viewing opportunities, it also can lead to human–wildlife conflicts (Knight 2009). Habituation occurring in conflict interactions may require different intervention approaches than say food-attracted or food conditioned animals.

Attraction.— There are numerous potential coyote attractants in human-developed lands, such as sources of food (Fedriani et al. 2001), water (Grinder and Krausman 2001, Timm et al. 2004, Grubbs and Krausman 2009), and shelter (Way 2009). Food attraction is an important management concern (Cornell and Cornely 1979, Carbyn 1989, Bounds and Shaw 1994). Sources of potential food attraction can subsidize coyote populations and increase their numbers (Fedriani et al. 2001). People intentionally or unintentionally leave exposed food sources for coyotes (Cornell and Cornely 1979, Bounds and Shaw 1994). Coyotes may become conditioned to seek anthropogenic food sources, and through associative learning (Goodenough et al. 2001), may associate people with food. Food-conditioned coyotes may also habituate to people, resulting in animals that are both food-conditioned and habituated (Hopkins et al. 2010).

Competition.— Wild canids such as wolves (*Canis lupus*) and coyotes may act aggressively towards domestic dogs (*Canis lupus familiaris*) (Baker and Timm 1998, Timm et al. 2004, Farrar 2007, Edge et al. 2011, Chapter 2). This behavior may be invoked by territorial wild canids that act competitively with other conspecifics (Okoniewski 1982, Gese 2001). Coyote aggression towards dogs is reported more frequently than objective risks to humans (Fararr 2007, Lukasik and Alexander 2011, Chapter 2), yet may put people at risk of injury when coyotes attack domestic dogs and pet owners intervene.

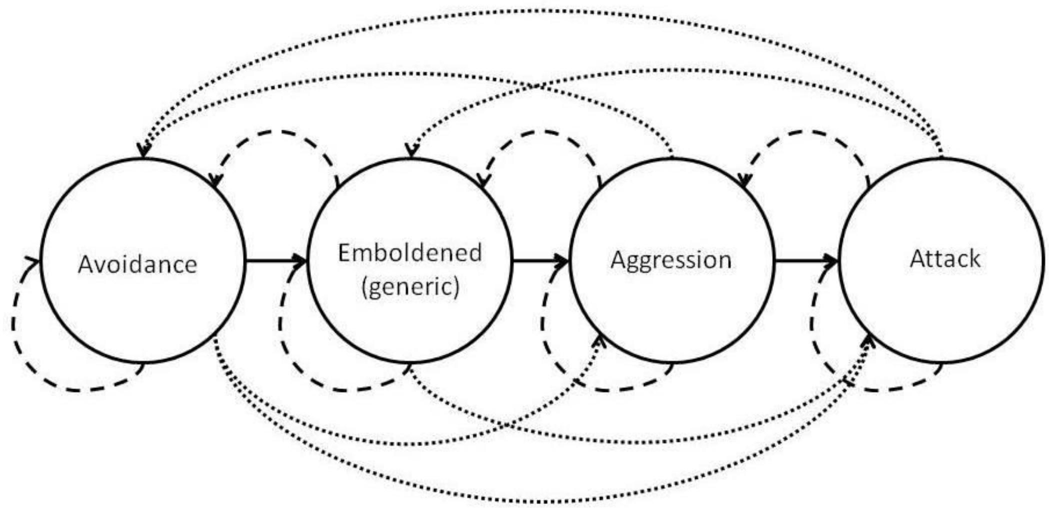
Emboldened Wildlife.— There are multiple potential causes of human–coyote conflicts (*see above*). Upon sighting a coyote, it may be difficult to determine whether an animal is simply habituated and non-responsive to humans, or food-attracted and likely to approach in quest of food, or behaving territorially and about to chase or attack a domestic dog. Therefore, I suggest emboldened be used as a generic term for wildlife management, in lieu of generalizing habituation, to describe events when animals do not evade human interactions as a result of an unidentifiable latent behavior (e.g., attraction, habituation, or competition). Emboldened is a term currently interspersed throughout wildlife management literature (e.g., NYSDEC 2005, Farrar 2007). There is precedence for usage, and it should be easy to incorporate the term into the emerging lexicon of human–wildlife management (Hopkins et al. 2010). However, if the specific animal behavior can be identified, then it is strongly recommended to describe the management situation with the greatest specificity, and avoid generalized terms.

Aggression.— The general management concern is that emboldened animals are associated with increased potential for conflicts and aggression. Outward aggression is a step beyond emboldened behaviors (i.e., habituation and attraction). Animals engaged in predation sequences (MacNulty et al. 2007) are aggressive. Conversely, an animal can act aggressively in an avoidance situation. That is, it is possible an animal may appear aggressive, yet be responding to a perceived threat while in defense of a den. Aggression is the communication through display of pending risk of physical conflict.

Attack.— Coyote attacks on humans are infrequent (see Chapter 1, Chapter 2). Many severe attacks are directed towards young children (Carbyn 1989, White and Gehrt 2009). While coyote attacks are possible, attack behavior is costly to the animal exhibiting the behavior, and is not likely to be maintained as a behavioral state, but as a briefly expressed behavior. This raises the question of whether the same animal will demonstrate attack behavior as an isolated event, or a chronic tendency.

Transitions.— Concern exists that emboldened animal behaviors, if allowed to persist, will lead to increased potential for elevated conflict interactions. This suggests transitions among escalating behaviors. Many of these behaviors are latent, and only quantifiable by the degree of outward expression (Whittaker and Knight 1998), making quantification difficult. Furthermore, apparent expression or transition between behavioral states may not follow a linear sequence from avoidance through attack, such as the appearance of an unprovoked attack. Therefore additional transitions should be considered among behavioral states that bridge between avoidance and more elevated behaviors (Figure 3.1). Animals may not persist in elevated behavioral states, thus reverting to lower behaviors. Field research is needed to understand the progression of individual animals through the sequence of escalating behaviors. If an animal displays emboldened behavior, it may be desirable to promote animal avoidance through non-lethal, behavioral modification. Many wildlife professionals seek to prevent the persistence of conflicts through management interventions, aiming to alter the behavioral state or tendency of wild animals by increasing the potential for animal behavior transitions to revert to lesser interaction levels, or avoidance (Gustavson et al. 1974, Conover et al. 1977, Cornell and Cornely 1979, Robel et al. 1981, Andelt 1999, Bromley and Gese 2001, Kloppers et al. 2005).

a.



b.

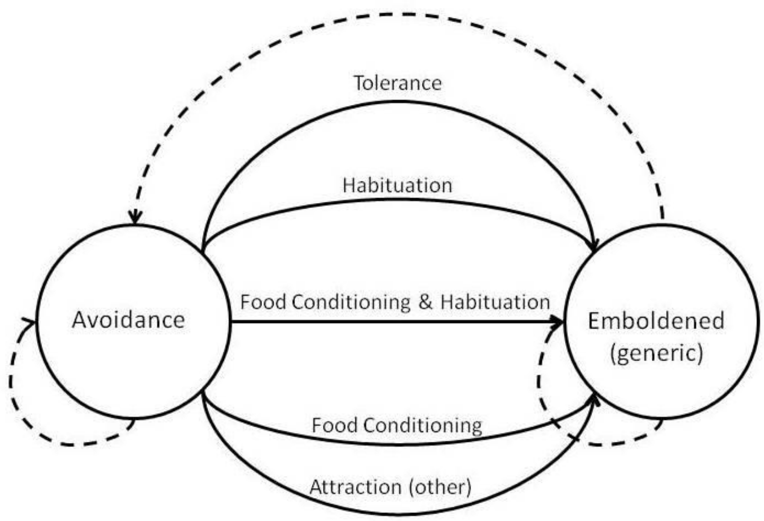


Figure 3.1. The conceptual model of coyote behavioral changes leading to conflicts with respect to humans and pets (a). Emboldened coyotes may result from multiple coyote behavioral responses (b). Solid lines represent transitions to behaviors with increasing risks to people and pets. Dashed lines represent maintenance of behavior tendency, or reverting from behavior events to less risky behaviors. Dotted lines represent alternative behavioral pathways, such as a diseased animal rapidly transitioning from avoidance to aggression or attack, or a territorially defensive animal quickly reverting to avoidance after an incident.

Expectations for Field-Testing Aversive Conditioning

Wildlife professionals seek to promote coyote avoidance of people and human-developed lands to decrease interactions and minimize potential for conflicts. The coyote behavioral state of avoidance is the desired treatment effect when testing aversive conditioning. Therefore, coyotes that avoid conflicts with humans are unsuitable candidates for field-testing aversive conditioning, as this is the desired end. Relative avoidance is estimated by coyotes selecting for natural habitats, and avoiding human interactions by selecting against human-developed lands.

Emboldened coyotes are expected to be conspicuous by remaining active in residential areas during nighttime or daytime, and to interact with people and pets, or seek anthropogenic sources of food. Emboldened coyotes may be identified as animals exhibiting increased use of residential and suburban lands, either in proportion to available or selecting for human-developed lands. Emboldened coyotes involved in conflicts are suitable candidates for field-testing aversive conditioning methods in an attempt to promote avoidance behavior. Specific aversive conditioning methods should attempt to curb conflict behaviors. For example, a coyote attracted to human sources of food may be observed in residential areas near people when seeking food, and may be identified for conditioned taste aversion. Habituated animals may be identified from conspicuous movement patterns in residential areas and targeted for hazing trials. Therefore, I investigated the ability to identify emboldened coyotes through radio tracking and visual observations by researchers and stakeholders to identify the specific conflict behavior to field-test aversive conditioning.

Testing behavioral modification strategies on highly aggressive coyotes or those that have attacked pets or people was beyond the scope of this research project. The current practice is to prescribe lethal management of any coyote that may be involved in aggression or attacks on people and pets (NYSDEC 2005). However, it was necessary to incorporate these behavioral interactions to complete the conceptual model and frame the objective of this research.

STUDY AREA

I selected Westchester County, New York, to study coyote spatial ecology based on concerns expressed by NYSDEC wildlife managers that human–coyote interactions reported by stakeholders from this region indicated an increasing potential for human injury. NYSDEC identified this county as being of greatest concern among all counties across New York State. Within the county, I selected 4 towns as focal areas for intensive field study. I targeted Greenburgh and Mt. Pleasant in the southern region, and Somers and Yorktown in northern Westchester County (Figure 3.2). The towns provided a comparison between paired-towns in the heavily populated southern region and a less populated northern region of the county (Table 3.1). Furthermore, I focused the initial field research in areas where past human–coyote conflicts had occurred within the towns.

I considered the animals captured for live-study (see below) as a representative sample of the coyotes existing in the study towns. That is, I could not limit coyote capture to a specific demographic of the population, and thus studied all animals captured during trapping sessions. In addition to coyotes, Westchester County has other resident carnivores such as the gray fox (*Urocyon cinereoargenteus*), red fox (*Vulpes vulpes*), black bear (*Ursus americanus*), fisher (*Martes pennanti*), and bobcat (*Lynx rufus*). However, their abundance is unknown, and some species are suspected as being uncommon in the county.

Westchester County is located adjacent to and north of New York City. The county is bounded by the Hudson River Estuary to the west, Putnam County, New York, to the north and Connecticut to the east. The annual mean daily temperatures range from −3.9 °C in January to 22.8 °C during summer months (NOAA 2009).

Daylight hours range from 9 hours 10 minutes at the winter solstice to 15 hours 10 minutes on the summer solstice (NOAA 2009). Monthly precipitation averages 10.8 cm ± 1.2 S.D. (NOAA 2009). Precipitation varies seasonally between snow and occasional icing during winter, and rain occurring throughout all seasons. Frequent freezing nights and thawing days with mean high temperatures above freezing occur during winter months.

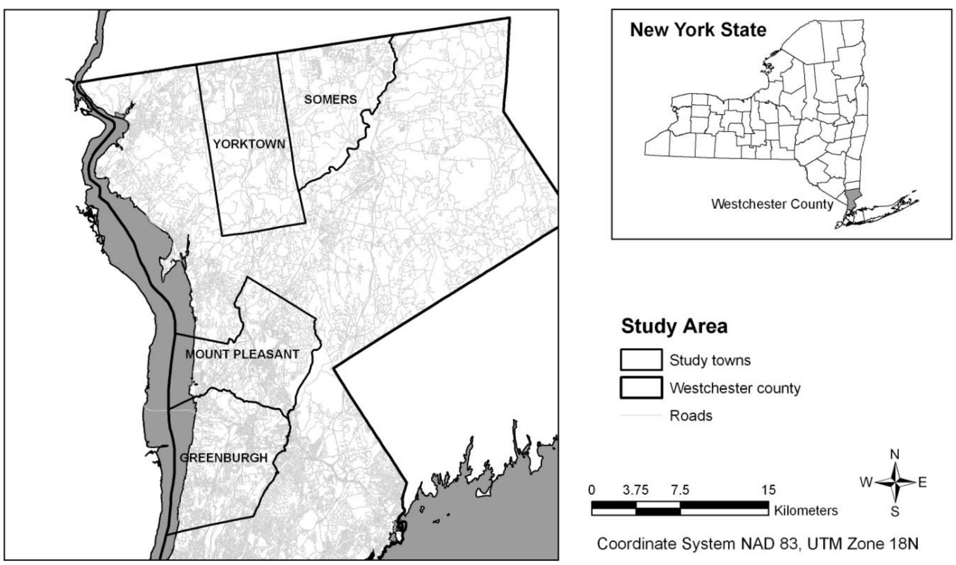


Figure 3.2. Spatial ecology and behavior of coyotes (*Canis latrans*) was studied in Westchester County, New York, USA, the full extent of the study area during 2006–2008. Coyotes were captured within the 4 study towns though home ranges overlapped areas outside of the focal towns.

Westchester County has an estimated 923,459 residents (U.S. Census Bureau 2008). The U.S. Census Bureau defines an urban area as having a population of ≥50,000 people, or an area with a human density ≥386 people/km^2 (≥1,000 people/mile^2), and urban clusters as areas with surrounding densities of 193 people/km^2 (≥500 people/mile^2; U.S. Census Bureau 2008**)**. As such, Westchester County's human population (750 people/km^2) surpasses the U.S. Census Bureau's definition of urban area (U.S. Census Bureau 2008). However, the southern region is more densely populated than the northern part of the county (Table 3.1).

I used a simplified version of the National Land Cover Database (2006) to classify the habitat and land cover of the study area. Of the initial 20 categories for the statewide land cover data, I consolidated the 14 categories that occur in Westchester County into 6 generalized categories used for subsequent resource use and selection analyses (Table 3.1; APPENDIX A).

Table 3.1. Land-use metrics for study towns in Westchester County, New York, USA, during 2006–2008.

		Study Towns			
		Southern County		Northern County	
Metric	Westchester county	Greenburgh	Mt. Pleasant	Yorktown	Somers
Land area (km^2)	1,232.0	93.1	84.9	102.2	83.2
Total Road Length	7,348.0	754.0	623.0	481.0	325.0
Road density (km/km^2)	5.96	8.10	7.34	4.71	3.91
Land cover type (%)					
Water & wetlands	11.5	15.9	16.4	9.2	9.0
Developed, open space	23.1	34.0	28.3	24.6	15.7
Developed, low intensity	10.1	17.2	10.1	8.1	6.2
Developed, medium–high intensity	9.6	14.4	9.1	4.7	2.2
Forest	41.7	18.2	32.3	49.3	55.5
Crops & shrub	4.0	0.4	3.8	4.1	11.3
Urbanized area	Yes	Yes	<	<	<
Urban clusters	>	>	Yes	Yes	Yes
Population[1]	923,459	86,764	43,221	18,346	36,318
Population Density (per km^2)	750[2]	932[2]	509	179.5	436.5
Housing Density	349,445	34,084	13,985	12,852	7,098

[1] Data from the US Census Bureau, 2000 Census

[2] US Census Bureau defines urbanized areas as having populations of 50,000 people with a density of 386 individuals/km^2, therefore Westchester County and Greenburgh are heavily urban, and Mt. Pleasant, Yorktown and Somers are suburban, with urban clusters.

METHODS

Live Capture and Radio Tracking

Field crews and I captured coyotes for live-study with #3 Victor Soft-catch footholds, Collarum® cable restraints, and standard non-locking, neck-cable restraints (AFWA 2006*a*, *b*, Shivik et al. 2000, Olson and Ticshaefer 2004). I set traps in locations exhibiting coyote activity (i.e., scats, tracks or both) that also minimized the potential to trap domestic animals or conflict with people. I monitored traps a minimum of once per 24-hour period starting approximately 0700 hours. Upon discovery, I removed captured coyotes from traps and physically restrained each using leg hobbles, a muzzle, and a blindfold. I physically restrained coyotes, without chemical immobilization, as the handling procedure was minor (Friend et al. 1994) and of short duration (≤20 minutes). This avoided using a Schedule III controlled substance in a highly human-populated area, and avoided long recovery periods from chemical immobilization. Furthermore, chemical immobilization was unnecessary for researcher safety (Friend et al. 1994) when handling coyotes. I assumed the handling procedure of physically-restrained coyotes was minimally invasive to the animal and their subsequent behaviors, because the most potentially traumatic or behavior-altering aspect involved the capture event, period of restraint, and removal from the trap. I also assumed using physical restraint instead of chemical restraint added little hazing beyond the point of removing the animal from the trap.

All captured coyotes were fitted with either very-high-frequency (VHF) radio-collars (Advanced Telemetry Systems, Isanti, Minnesota) or combination global positioning systems (GPS)/VHF radio-collars (HABIT Research, Victoria, BC, Canada) to locate coyotes at will and track their movements. All coyotes received color-coded and uniquely numbered plastic ear tags (NASCO, Fort Atkinson, Wisconsin) to facilitate field observation by researchers, or potential visual observations made by the general public and reported by phone or email to the study personnel. At the time of capture, I collected morphological measures (i.e., standard mammalian measures and weight), assessed reproductive status, and examined tooth wear to estimate age (Gier 1968). I classified coyotes into 3 age groups (pups, yearlings, and adults) because assessing age by tooth wear is less accurate for older animals (Bowen 1982). I inspected coyotes for any physical condition (e.g., broken or missing limbs or tooth damage) that might correlate with future aberrant behaviors described by the conceptual model (i.e., emboldened, aggressive or attack behaviors). All coyotes were released at the capture site immediately after the handling process. I located all coyotes within 24–48 hours after their release to monitor for capture myopathy, which was not detected. The capture and handling protocol was approved by Cornell University Institutional Animal Care and Use Committee (Protocol #2005-0091).

It is important to note the limitations of an observational study to monitor coyote spatial ecology and behavior. I could not manipulate the factor (or treatment) of interest, being behavioral changes, by food conditioning or habituating coyotes in an urban area. Ethically, this is an issue because it could place people and pets in jeopardy. Therefore, I conducted a comparative observational study between 2 sets of paired towns. Essentially, this set up a before/after/control designed experiment (Ott and Longnecker 2001). Coyotes were captured in paired towns (2 southern and 2 northern towns) for intended comparison among before, after, and control space use measures.

Demographic differences in conflict interactions might occur, such as male coyotes depredating sheep during breeding pup-rearing season (Blejwas et al. 2006). Therefore, I equipped both males and females with tracking collars to investigate demographic differences of coyotes interacting or conflicting with humans.

Monitoring male and female pairs, putative offspring, and resident associates, was biologically and behaviorally necessary to gain insight into understanding the scope of human–coyote interactions and conflicts.

Radio Tracking Sessions.— I tracked the sample of radio-collared coyotes during diurnal (0600–1759 hours) and nocturnal (1800–0559 hours) sessions. I used standard radio triangulation to locate coyotes (White and Garrott 1990), and estimated positions using LOCATE II (Pacer, Truro, Nova Scotia, Canada). I typically used ≥3 bearings to estimate locations, and occasionally used 2 bearings when intersecting at approximately 90° and signal strengths indicated animals were relatively nearby. I assessed the tracking system by taking multiple locations on beacon test collars deployed in natural areas of the study area. Mean (± SD) error between estimated locations and true locations was 121 ± 66 m. I categorized animal activity as active or inactive based on fluctuations of radio signal amplitude (Nams 1989, Theuerkauf and Jedrzejewski 2002). Previous studies in urban areas, and early indications from radio tracking, revealed coyotes were more active during nocturnal than diurnal periods (Atkinson and Shackleton 1991, Grinder and Krausman 2001, Riley et al. 2003, Way 2004, Bogan 2004, Gehrt et al. 2009, Grubbs and Krausman 2009). Therefore, I collected 1 location during diurnal sessions to avoid overrepresentation of resting areas in home range estimates, and collected multiple locations during nocturnal sessions to monitor coyote activity and movements.

Each diurnal session started with a randomly selected individual and then attempted to locate all coyotes systematically, in geographic succession, for a total of 5 sessions per week. For nocturnal sessions, I divided the sample of coyotes into geographic subsets, and systematically located each subset on a sequential basis. During nocturnal sessions I attempted to collect 4–5 locations for each coyote with relocations occurring at ≥1-hr intervals. This scheme produced approximately 5 diurnal locations and 5 nocturnal locations per coyote per week. Systematic tracking with multiple locations per night session were collected to increase the biological and behavioral significance of the spatial analyses (McNay et al. 1994, De Solla et al. 1999, Kernohan et al. 2001), which has been found to produce similar home range estimates to those based on independent locations for coyotes (Gese et al. 1990). Additionally, this sampling scheme for collecting locations was used to attempt to detect and observe any potentially short-lived (behavioral events) or reoccurring (behavioral tendencies) human–coyote interactions resulting from emboldened, aggressive or attack behaviors of coyotes with respect to people and pets. To avoid bias and overrepresentation of any particular home range area, I maintained this sampling strategy for the total monitoring period for each animal, and subsequently estimated annual ranges to increase information and fully incorporate the entire home range behavior of each animal (De Solla et al. 1999).

I recorded all visual observations of marked and unmarked coyotes and their activities or behaviors while conducting field work (Bogan et al. 2009). I obtained coordinates of visual observations using a hand-held GPS receiver, or later by estimating positions using ArcGIS 9.3 geographical information system software (Environmental Systems Research Institute, Redlands, California). Visual- and triangulation-based locations of radio-marked coyotes were used for spatial analyses.

Spatial Ecology and Behavior

Nocturnal movements.— I estimated nocturnal movement rates by calculating the change in location over change in time using successive telemetry locations collected at ≥1-hr and <2-hr intervals. These estimated straight-line movements approximated minimum coyote movement rates as found with wolves (Theuerkauf and Jedrzejewski 2002). I report the range of average movement rates per coyote, and not an average of averages.

Home ranges.— I estimated annual 95% fixed-kernel home ranges and selected the smoothing band (h) distance for the standard bivariate normal (i.e., Gaussian) kernels using least squares cross validation (h_{lscv}) (Worton 1998, Worton 1995, Seamen and Powell 1996, Seamen et al. 1999). I used individual coyotes having ≥30 locations while targeting >50 locations (Gese et al. 1990, Seaman et al. 1999). I did not eliminate potential outlier locations from the spatial analyses because these may account for potential human–coyote interactions (Bogan 2004). Coyote conflicts may occur in the periphery of home ranges in, or nearby, residential areas.

I calculated all home ranges using Home Range Tools extension (Rodgers et al. 2007) for ArcGIS 9.3. I defined the study year as beginning April 1_{yr0} and ending on March 31_{yr+1} of the following calendar year, as this start date coincided with the approximate timing of whelping, and when coyotes were initially radio collared for study. I generated multiple annual home range estimates for animals that survived and were tracked over multiple years. I used all home range estimates for analyses to detect changes in space use and behavior, which was integral for this study. Animals tracked for multiple years are indicated with a, b, or c for successive study years.

Home range complexity.— Fixed-kernel density estimates using h_{lscv} smoothing bands may generate home ranges with multiple disjoined areas (Worton 1995, Seaman and Powell 1996). This may correctly model structure in the data, or may indicate undersmoothing of the underlying distribution of locations (Worton 1995). While other researchers found fixed-kernel density estimates using h_{lscv} undesirable (Riley et al. 2003, Gehrt et al. 2009), I found this as reasonable considering that coyote home ranges were positioned within a heterogeneous landscape which may offer varying degrees of habitat quality among the different land cover types. Fixed-kernel home ranges using h_{lscv} have been found to contour well around location clusters, whereas kernel methods using h_{ref} oversmoothed estimates

(Worton 1995, Seaman and Powell 1996, Gitzen and Millspaugh 2003). Both minimum convex polygon estimates (Mohr 1947, Hayne 1949) and fixed-kernel estimates with h_{ref} smoothing often include large proportions of areas having no locations or empirical evidence of use. I capitalized on the disjoined features because coyotes must commute between distinct areas of concentrated activity, potentially crossing human-developed lands, which may provide opportunity for human–coyote interactions and conflicts. Therefore, I calculated the number of disjoined areas for the 95% isopleths home range to document this condition, which may provide insight into human–coyote interactions as a measure of potential exposure. I assumed that an increasing number of core areas would increase the potential for human–coyote interactions. I also assumed the 95% fixed-kernels with h_{lscv} smoothing provided reasonable estimates of home range probability distributions because they are constrained to where coyotes were detected, while accounting for telemetry location error by incorporating the smoothing parameter over all locations (Millspaugh et al. 2006). Additionally, home-range-based habitat analyses correctly use the animal as the sampling unit, and not relocations (Powell 2000, Millspaugh et al. 2006). If undersmoothing occurred, then home ranges are conservative estimates of space use.

Resource use and selection.— I conducted an analysis of categorical land cover types by comparing used resources and available resources to gain insight into coyote spatial ecology and behavior in the suburban landscape. Because habitat selection may occur at multiple scales, I conducted the investigation at two levels: 2$^{\text{nd}}$ order selection of home range placement within the general study area, and 3$^{\text{rd}}$ order selection of habitat use within the home range (Johnson 1980). This study corresponds with sampling protocol A and design II and III outlined in Manly et al. (2002). That is, individual animals were identified, resource use was considered randomly sampled, and available resources were censused for comparisons (Manly et al. 2002). I measured the proportion of land cover types in ArcGIS 9.3.

To conduct the 2nd order selection analyses, I measured the proportion of the 6 land cover types within home ranges and compared use with the overall proportions of land cover within the Westchester County study area. This corresponds with Design II habitat studies, where individual animals are identified and resource use is measured separately for each, and one set of available resources are measured across the entire study area for comparison (Manly et al. 2002). While the exact composition of resources (land cover types) measured for the study area may not be available to every individual animal, I conducted this analysis to gain a general understanding of where coyotes locate home ranges within Westchester County.

I conducted the 3rd order selection by comparing the habitat use by locations with the available habitat of the home range measured for each individual animal. However, because of errors associated with triangulation, I created buffers around each location to account for imperfect tracking errors, and to account for the influence of neighboring land cover types on animal behavior (Rettie and McLoughlin 1999). I used the radius calculated from the generalized area of the median value of 95% error ellipses estimated for all locations. I used this calculated radius because the 95% error ellipses provide an estimate of overall system precision (Nams and Boutin 1991:175). Therefore, I measured use of the 6 land cover types within a 72-m buffer around locations. I compared the average of each proportion of land cover type measured for each animal's set of locations to the proportion of available land cover types within home ranges. This analysis gave insight into where animals moved within home range distributions.

I tested for differential habitat use at both scales of selection using compositional analysis to determine whether use differed from random use of available land cover types (Aebischer et al. 1993). Compositional analysis is similar to MANOVA, uses the animal as the sampling unit, and accounts for non-independence of proportional use of land cover types. Because of the unit sum constraint that all proportions of a composition sum to 1 (e.g., a home range), use of one cover type influences the use of another cover type (White and Garrott 1990, Aebischer et al. 1993). For example, a cover type used in greater proportion than available may appear to be selected for because another cover type perceived by the researcher as available to the animal was either unavailable or of poor quality, resulting in less use than available. Therefore, the used cover type appears to be selected for in this example.

Compositional analysis works through this issue by comparing the log ratios of the proportional use of resources in comparison to a reference resource against log ratios of available resources (Aebischer et al. 1993). The method calculates the Wilk's lambda statistic, and tests the overall null hypothesis of no selection (H_0: use = available) among the sample population of coyotes. If coyote use of the landscape is selective (reject H_0), then a ranking matrix is calculated to determine the relative selection order of land cover-types. For each scale of selection, I report the overall test for selection and ranking matrices of land cover types. While it may be possible to establish a relative ranking of the selection of land cover types (suggesting relative preference), it is difficult to establish relative preference from this analysis. It remains undetermined whether avoidance of the lowest ranked cover type influences the apparent preference of another land cover type. Therefore, ranks should be interpreted as demonstrating which cover types are used in greater proportion than expected (available) while simultaneously accounting for use of other cover types. Absolute preference may not be determined from these statistical analyses, and may not exist biologically, as coyotes are habitat generalists able to use a wide range of habitats in many biomes across the species range. Caution should be used when interpreting results of selection studies (White and Garrott 1990).

Examining habitat selection for a sample population of animals may obscure individual variation of selectivity. Individual variation in selection may average out or cancel the estimated population's selectivity of a resource when some animals 'select' for a resource and other animals 'avoid' a particular resource. Therefore, I examined variation in how animals responded to the land cover types using Eigenanalysis at the 2^{nd} and 3^{rd} orders of selection (Calenge and Dufour 2006). This analysis is based on Manly's selectivity ratios (Manly et al. 2002) by comparing used and available resources of categorical variables, and is similar to factor analysis or principal component analysis (PCA), which reduces the dimensionality of correlated variables to few independent and important factors that represent most of the original data structure. Eigenanalysis maximizes the difference between used and available habitat on the first factorial axis. The method may reveal important variation of the sample population in the form of continuous variation or distinct grouping of differences in how individuals use the landscape (Calenge and Dufour 2006). I used package adehabitat (Calenge 2006) in R (R Development Core Team, Vienna, Austria) to conduct compositional analyses and eigenanalysis.

I report mean values with standard deviation (SD) or ranges where appropriate for sample sizes for all spatial measurements (e.g., movement rates, home ranges, home range complexity and habitat analyses). I relate the visual observations of coyotes and empirical results from radio-tracking with the conceptual model, and discuss these results to shed light on expectations for conflicts and important limiting issues of field testing behavioral modification strategies.

RESULTS

Live Capture and Radio Tracking

I captured coyotes in Westchester County, New York, and equipped 30 individuals of various ages with VHF tracking collars and 8 adults with combination GPS/VHF collars (Table 3.2). Half (n = 4) of the GPS/VHF tracking collars failed to produce usable data due to equipment failure from a suspected combination of design flaws and programming errors in the data collection protocol routines. The remaining 4 GPS/VHF collars produced data for <50% of the expected 12-month operational lifespan of the devices. During this time, the GPS/VHF collars collected location data at a rate of approximately 0.33 to 0.5 of the intended rate of 24-hourly locations per day. Due to the technological failures and introduced erroneous data during data transmissions for downloads, I discarded these data to prevent unidentifiable errors in the analyses and focus the remainder of this paper on data collected from the coyotes equipped with VHF tracking collars.

Table 3.2. Sex and age groups of radio- and GPS-tracked coyotes in Westchester County, New York, USA, during March 2006–December 2008.

	Radio		GPS		Total
Age group	F	M	F	M	All
Adult	5	9	5	3	22
Juvenile	6	1	0	0	7
Pup	4	5	0	0	9
Total	15	15	5	3	38

Monitoring the VHF-collared coyotes, I collected a total of 3,277 locations. Eight coyotes died or disappeared before sufficient locations ($n \geq 30$) were collected for home range and subsequent analyses. The remaining 22 coyotes used for analyses each had ≥30 locations for a total of 3,214 locations. These coyotes were tracked an average of 425 days, ranging from a minimum of 79 days to a maximum of 999 days.

While conducting the tracking sessions and other field work, field crews observed tagged coyotes on 10 occasions and untagged coyotes on 17 occasions throughout the course of the study in Westchester County (see Bogan et al. 2009).

Spatial Ecology and Behavior

Average nocturnal movement rates per coyote ranged from a minimum of 96 m/hr to a high of 1,086 m/hr. The shortest estimated single movement rate measured between successive locations for all coyotes was 4 m/hr suggesting no movement between locations. The greatest estimated single movement rate was 4,988 m/hr, although the actual movement was calculated as 1,829 m between successive locations taken at 0.4 hours. This triangulation was taken less than the standard minimum 1-hr interval because signal fluctuation indicated great activity. The next greatest estimated movement rate (3,592 m/hr) was for a male coyote that maintained a large home range and exhibited the greatest average movement rate.

I measured 34 annual home ranges for 22 individual animals because some coyotes lived for multiple study years. The 95% fixed-kernel home ranges averaged 5.67 ± 3.25 (SD) km^2. The smallest estimated home range was 1.25 km^2 and the largest was 13.94 km^2. The number of disjoined areas that composed the 95% fixed-kernel home ranges of individual coyotes ranged between 1 contiguous area to 18 discrete areas. The average number of core areas was 5.5 ± 4.2 SD.

Second-order use and selection.— On average, 95% fixed-kernel home ranges for coyotes included forest land cover (51.9%) in greater proportion than all other cover types. Developed, open space (26.0%) was the second largest proportion. Coyote home ranges contained developed, low intensity (8.2%), developed, medium–high intensity (5.7%), shrub & crop (5.1%), while water & wetlands (3.2%) were the smallest proportionate use. Although habitat use appeared to be influenced by the proportion of available land cover types, habitat selection was non-random (Wilk's lambda, $\Lambda = 0.1686$, $P < 0.001$), and animals were selective when locating a home range within Westchester County (Figure 3.3).

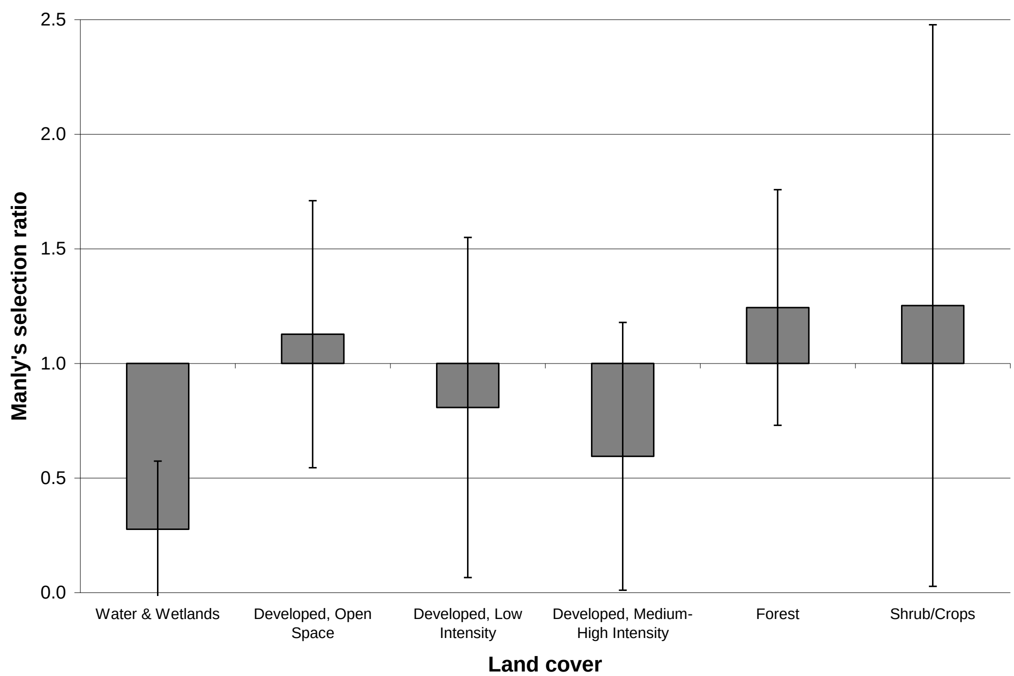


Figure 3.3. Second-order selection (*home ranges within the study area*): Manly's selection ratios comparing the proportional cover types used within 95% fixed-kernel home ranges (use) compared with the proportional land cover types available within the study area (available) of Westchester County, New York, USA, during 2006–2008.

Habitat-ranking matrices ranked forest and developed and open space similarly, yet forest was selected significantly greater than all other land cover types (Table 3.3). Coyotes selected for developed, open space similarly to shrub and crop lands, yet significantly more than all remaining land cover types. Developed, low intensity was selected more than developed medium–high intensity and water & wetlands. Water & wetlands were selected the least within the county, which was also confirmed by eigenanalysis (Figure 3.4). Eigenanalysis revealed variation among coyote selection of forest, open space, and shrub and crop land uses. Two coyotes

(151.996 and 151.123) were associated with developed open space and developed, low intensity lands in southern Westchester County. Their use of the landscape remained relatively consistent among study years (e.g., a, b, c; Figure 3.4). Most other coyotes selected forest, and shrub and crop land cover types (Figure 3.4). Overall, coyotes tended to avoid locating home ranges in water and wetlands; and developed, medium–high intensity lands.

Table 3.3. Second-order selection (*home ranges within the study area*): simplified ranking matrices of compositional analysis for coyote habitat selection based on comparison of proportional land cover types used within 95% fixed-kernel home ranges compared with the proportional land cover types available within the Westchester County study area, New York, USA, 2006–2008. Positive signs indicate use greater than available and negative signs indicate use less than available while triple signs represent significant deviation from random with $P < 0.05$.

Land cover type	Land cover type: Developed, medium–high intensity	Developed, low intensity	Developed, open space	Forest	Shrub & crops	Water & wetlands	Rank
Developed, medium–high intensity	0	− − −	− − −	− − −	−	+	1
Developed, low intensity	+ + +	0	− − −	− − −	+	+ + +	3
Developed, open space	+ + +	+ + +	0	−	+	+ + +	4
Forest	+ + +	+ + +	+	0	+ + +	+ + +	5
Shrub & crops	+	−	−	− − −	0	+ + +	2
Water & wetlands	−	− − −	− − −	− − −	− − −	0	0

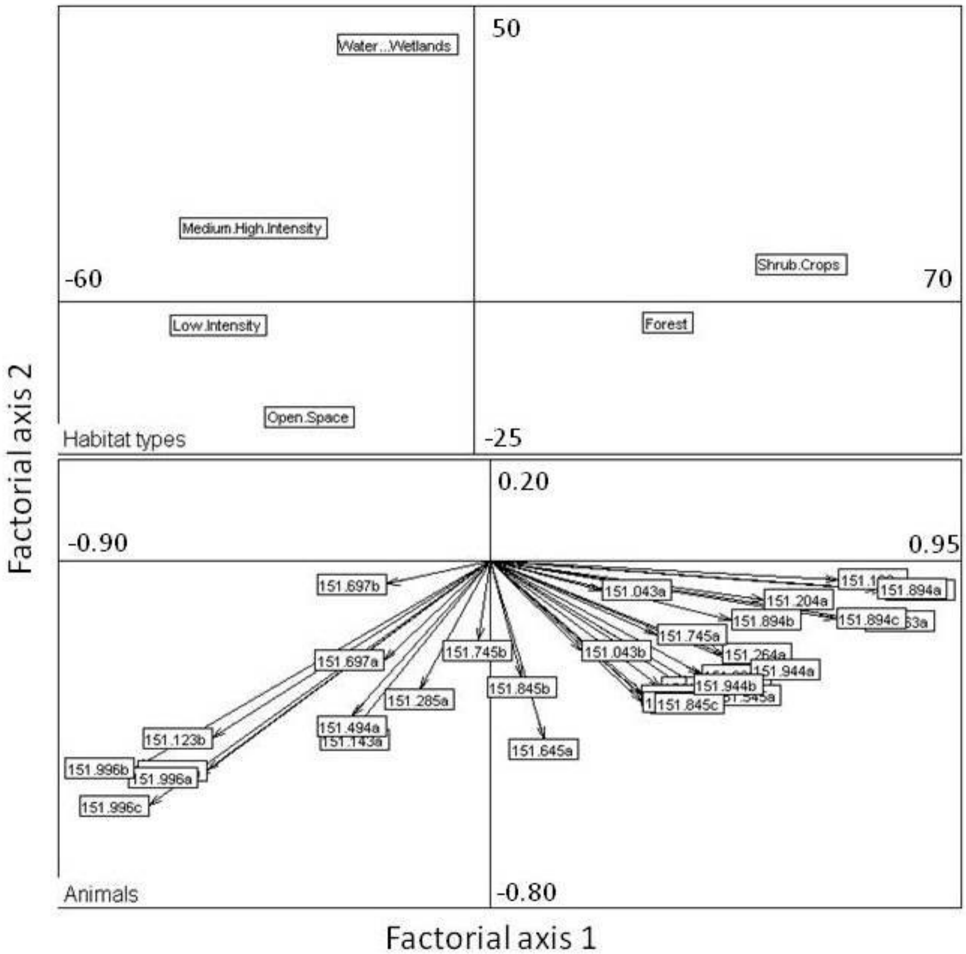


Figure 3.4. Eigenanalysis of selection ratios for comparison of proportional land cover types used within 95% fixed-kernel home ranges compared with the proportional land cover types available within the study area in Westchester County, New York, USA, during 2006–2008.

Third-order use and selection.— Coyote use of land cover within home ranges centered more on natural areas (56.6%) and on developed, open space (22.9%). Shrub and crops (6.9%), developed, low intensity (5.7%), water and wetlands (4.3%) and developed, medium–high intensity (3.7%) were also used within home ranges. Habitat selection was non-random, as coyotes were selective when using available land cover types (Wilk's lambda, $\Lambda = 0.30352$, $P < 0.002$). Within home ranges, coyotes selected for water and wetlands, forest, and shrub and crop lands similarly (Figure 3.5), and in greater proportion than all other available land cover types (Table 3.4). Developed, open space was selected intermediately in relation to all other land cover types. Developed, medium–high intensity, and developed, low intensity lands were selected least in proportion to availability of land cover.

Table 3.4. Third-order selection (*locations within home ranges*): simplified ranking matrices of compositional analysis for coyote habitat selection based the comparison of the proportional land cover types used within 72-m buffered locations compared with the proportional land cover types available within 95% fixed-kernel home ranges from Westchester County, New York, USA, 2006–2008. Positive signs indicate use greater than available and negative signs indicate use less than available while triple signs represent significant deviation from random with $P < 0.05$.

Land cover type	Land cover type						
	Developed, medium–high intensity	Developed, low intensity	Developed, open space	Forest	Shrub & crops	Water & wetlands	Rank
Developed, medium–high intensity	0	–	– – –	– – –	– – –	– – –	0
Developed, low intensity	+	0	– – –	– – –	– – –	– – –	1
Developed, open space	+ + +	+ + +	0	– – –	– – –	– – –	2
Forest	+ + +	+ + +	+ + +	0	+	–	4
Shrub & crops	+ + +	+ + +	+ + +	–	0	–	3
Water & wetlands	+ + +	+ + +	+ + +	+	+	0	5

Eigenanalysis indicated that most coyotes selected for forest lands (Figure 3.6), and revealed variation in Manly's selection ratios (Figure 3.5). Some coyotes also selected for shrub and crop lands, while others selected for water and wetlands when available (Figure 3.6). At this analysis scale, wetlands contributed most to water and wetlands land-cover category within coyote home ranges. Eigenanalysis revealed variation in how certain coyotes used home ranges over multiple study years (Figure 3.4). Coyote 151.745 (male) demonstrated selection for water and wetlands in year a, that decreased in study year b. Coyote 151.894 (female) increased use of shrub and crop lands throughout study years a, b, and c (Figure 3.6). Female coyote 151.845 increase use of developed, medium–high intensity lands during the second study year (b), compared to the first (a) and last (c) study year.

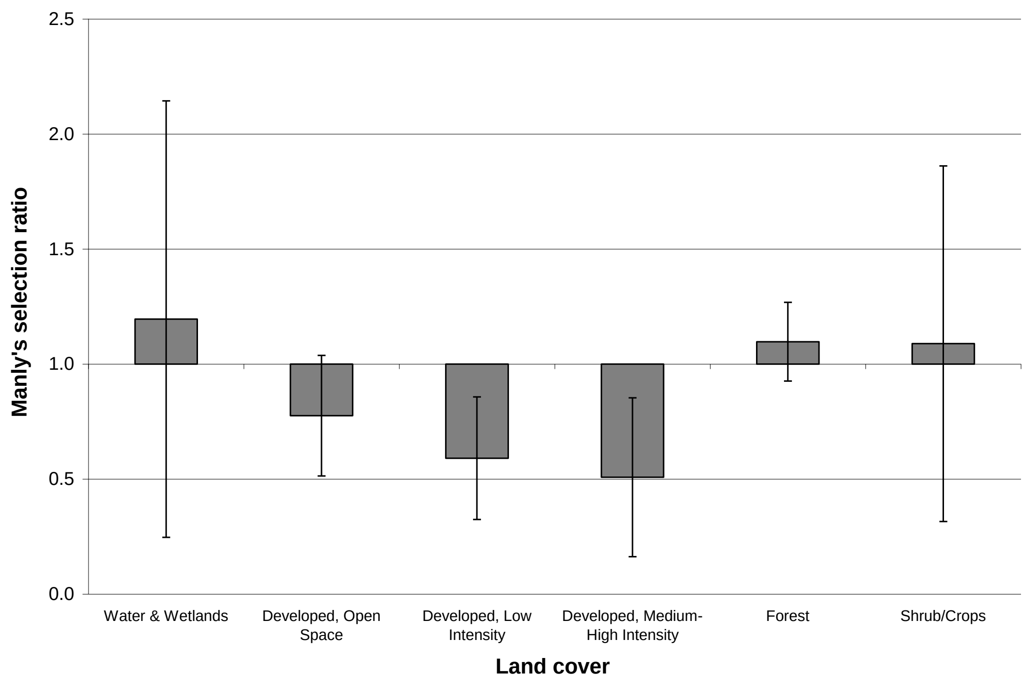


Figure 3.5. Third-order selection (*locations within home ranges*): Manly's selection ratios comparing the proportional land cover types used within 72-m buffered locations (use) compared with the proportional land cover types available within 95% fixed-kernel home ranges (available) in Westchester County, New York, USA, during 2006–2008.

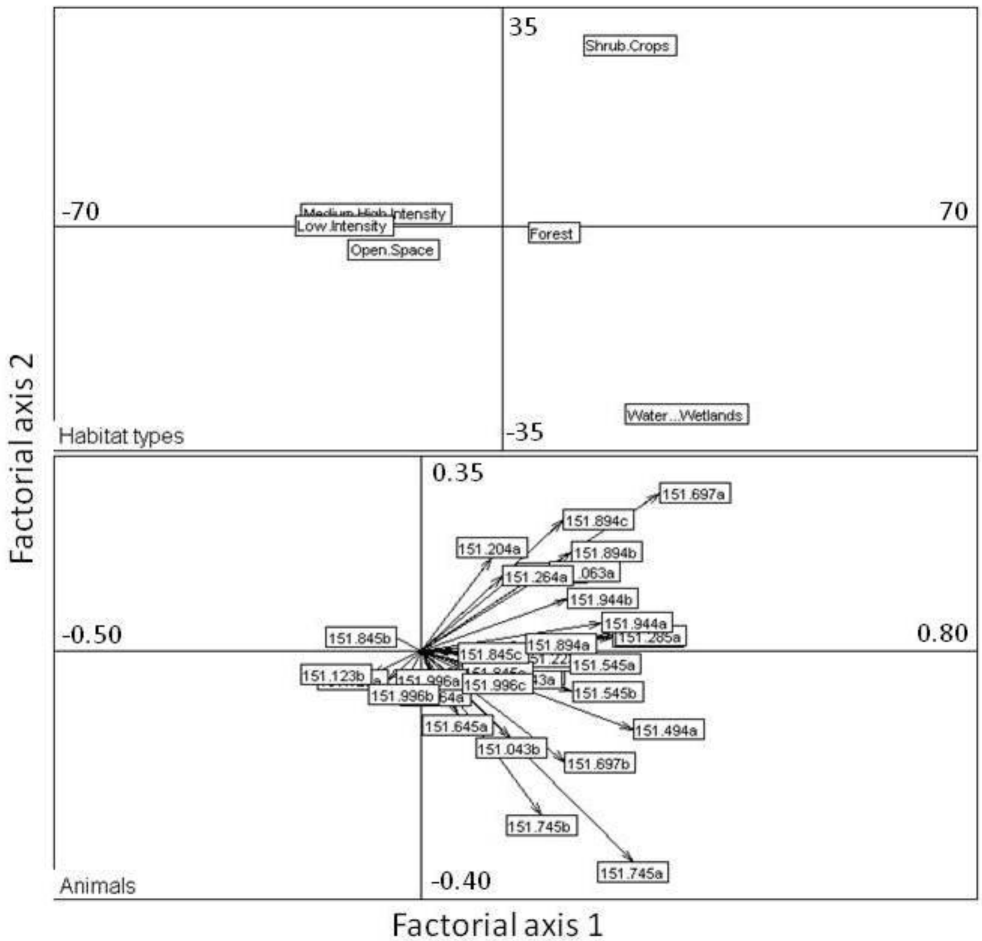


Figure 3.6. Eigenanalysis of selection ratios for comparison of proportional land cover types used within 72-m buffered locations compared with the proportional land cover types available within 95% fixed-kernel home ranges in Westchester County, New York, USA, during 2006–2008.

During the course of the study, I found no indication of coyotes exhibiting chronic tendencies of emboldened behaviors with the exception of 1 coyote. Coyote 151.845b was observed by field researchers to repeatedly use a residential neighborhood during a 4-week period, which occurred during breeding season (January 2008). Residents reported that the coyote was observed near dogs kept outside, often in backyards. Additionally, residents reported the female coyote did not attack, nor injure any dogs. The reports and tracking data indicate this was a short-lived tendency, and persisted for approximately 4 weeks. Coyotes demonstrated apparent avoidance behavior (29 to 30/30 coyotes). Only one (1/30 coyotes) indicated emboldened behavior, and no individuals appeared to act aggressively (0/30 coyotes), or attack humans or pets (0/30 coyotes). No management intervention was implemented on this animal, or any other coyotes due to the limited amount of interactions, and apparent avoidance behavior of coyotes in the urbanized landscape. Therefore, opportunities did not occur to field-test behavioral modification strategies on the sample of coyotes in Westchester County during the study.

DISCUSSION

Developing strategies to manage suburban coyotes is necessary to prevent human–coyote interactions from becoming conflicts. While coyotes that avoid human interactions likely do not require behavioral management intervention, coyotes that attack humans or pets, or otherwise cause damage are typically not tolerated, and may be targeted for lethal removal (Wittmann et al. 1989, NYSDEC 2005). However, a gap exists between animals that avoid humans and require no action, and aggressive animals that attack. Emboldened wildlife may interact with humans in various settings (Carbyn 1989, Bounds and Shaw 1994, White and Gehrt 2009, Chapter 2) and cause stakeholder concern (Wieczorek Hudenko et al. 2008*a*). Also, some suggest that emboldened behaviors (e.g., habituation, attraction, competition) will lead to increasing potential for conflicts (Timm et al. 2004, Geist 2008, Geist 2011*a*, *b;* Farrar 2007, Lukasik and Alexander 2011). There is uncertainty that requires further research to understand behavioral pathways that lead to human–wildlife conflicts in order to address the question: Is aversive conditioning a viable (i.e., efficacious) method to manage emboldened coyotes that may or may not be a risk to human interests and safety? Answering this question will help improve best management practices of urban coyotes.

During 2006–2008, I studied coyotes to improve understanding of human–coyote interactions and conflicts in Westchester County, New York, an area suspected of requiring targeted management intervention. To facilitate this research, I proposed a conceptual model to help frame potential conflict behaviors that might occur, and require intervention. However, I had mixed results when evaluating elements of the conceptual model. While the model may help focus research by aiding in determining what events and behaviors should trigger field trials, no opportunity arose to initiate field-testing of aversive conditioning methods.

Spatial Ecology and Behavior

Studying the spatial ecology and behavior of coyotes is important to understand the types of negative interactions that require management. To meet this objective, I studied a sample of coyotes within 4 towns of Westchester County where past conflicts had occurred.

Overall, coyote home ranges were within minimal and maximal estimates determined by other studies. Gehrt (2007) reviewed 9 studies that reported home range estimates for coyotes living in urbanized landscapes. Excluding one study as a potential outlier (i.e., Way et al. 2002), the overall mean home range area for urban coyote studies was 7.3 km^2 (Gehrt 2007). Coyotes in Westchester County used mean home ranges of 5.67 ± 3.25 (s.d.) km^2. Other studies used different methods to estimate home ranges and caution should be used when making direct comparisons between area estimates. I used methods that may produce conservative estimates of home range area, yet appeared to model coyote spatial behavior reasonably well. I selected the methods to address the specific needs of this research project.

Analysis of resource use and selection for resident coyotes in Westchester County indicated that coyotes tended to select for more natural habitat types while selecting against developed lands. This overall pattern occurred for both analysis scales although slight differences did result. Coyotes appear to be more selective for forest and open space land cover when locating a home range within the study area (second order selection) than when moving throughout their home range (third-order selection). When moving within home ranges, coyotes appear to avoid open space, low intensity and medium–high intensity developed lands. Therefore, it appears that coyotes in Westchester County select home ranges in more natural areas composed of forested, and shrub and crop lands, while avoiding open space, low intensity and medium–high intensity developed lands when moving within established home ranges. It is noteworthy that this pattern occurred despite using conservative estimates of home ranges for the comparative resource selection analyses.

Coyotes did not necessarily prefer forest and other cover selected cover types. Coyotes inhabit a wide range of habitat types, in various ecosystems and biomes, and are considered habitat generalists. The apparent patterns in space use may be driven by coyote avoidance of human-developed areas more than a preference for the specific natural areas in the study area. Coyotes may be able to fulfill their biological needs (e.g., foraging, escape cover, resting cover, denning and reproduction) by using forested, wetlands, shrub and crop areas, and less densely human-developed lands. Human-developed lands may not offer sufficient benefits such as food and cover to outweigh risks of foraging in exposed areas. However, selection against one cover type and selection for another cover type should be considered simultaneously, and not separately, until experimental manipulations of available resources reveal relative preference of habitat types.

Coyotes were primarily nocturnal during the study. Therefore I calculated nocturnal movement rates when coyotes were more active and likely to interact with people and pets. Mean movement rates per coyote varied considerably from 96 m/hr to 1,086 m/hr. Coyotes typically stayed in natural areas during nocturnal tracking sessions, which might explain the limited movement rates. I documented very few movements between disjoined home range areas while coyotes were in residential or other developed lands. These movements were likely rapid, yet did not happen frequently when tracking most coyotes. One male coyote did exhibit greater mean movement rates that may be associated with territorial behavior, as some movements occurred in the periphery of the home range. Territorial movements could lead to conflict interactions between dogs and coyotes during nighttime.

Overall, I found coyotes in Westchester County used home ranges of multiple disjunctive areas, primarily composed of forest and other natural cover types. While coyotes must move throughout the heterogeneous landscape, potentially interacting with humans, I found little empirical evidence of coyotes in situations likely to lead to conflicts. Only 1 coyote demonstrated short-lived interaction tendencies, which persisted for approximately 4 weeks during breeding season. Field crews conducting radio tracking observed a shift in space use by this female coyote (151.845b). During this time, residents reported by phone to project personnel that the coyote was observed moving through neighborhoods, and interacting with pet dogs in backyards. No damage was reported to humans, pets, or other human interests. This behavior was short-lived, and the coyote reverted to typical movement patterns, which was supported by both radio tracking and sighting reports. The simultaneous confirmation by radio tracking and stakeholder sighting reports (Chapter 2) provided additional confirmation that our tracking efforts were appropriate for documenting potential conflicts. All coyotes were fitted with ear tags and this likely cued people to investigate their observations of an ear tagged coyote, and potentially increased the reporting rates. This was the best and only potential opportunity to test aversive conditioning, yet the conflict ended before initiating trials. It is unknown whether any residents attempted to haze and chase away the coyote. The event resolved without any researcher intervention. This is in sharp contrast to claims that conflict behaviors and subsequent interactions persist and continue to intensity, as suggested by Baker and Timm (1998), and Timm et al. (2004).

Conceptualizing the Suburban Coyote Syndrome

I proposed a conceptual model to help frame the management issue under investigation. Early visions of the model were inspired by Whittaker and Knight (1998). The authors provided clarification of 3 general behavioral responses of wildlife (attraction, habituation, and avoidance) to various stimuli. Among other relevant contributions, the authors offered 2 important points. The first relevant point was the clarification and appropriate usage of habituation, and the distinction between attraction and habituation. The second relevant point made in the article illuminated diverging concepts between behavioral events and behavioral tendencies. These points helped shape the conceptual model from spatial expectations (where conflicts might occur) to a more dynamic state–transition model of behavior (how and why conflicts might occur). These points, particularly the generalization of habituation, continue to be argued (*see* Geist 2008, Geist 2011*a*, *b,* Rogers and Mansfield 2011) and researched by professionals (Howell 1982, Carbyn 1989, Baker and Timm 1998, Whittaker and Knight 1998, Timm et al. 2004, Kloppers et al. 2005, Timm and Baker 2007, Knight 2009, White and Gehrt 2009, Gehrt et al. 2009). This highlighted the need to clarify communication and expectations of how human–coyote interactions may develop into conflicts, which is fundamental when investigating opportunities for human dimensions or animal behavioral intervention.

Habituation is a term that is often misused (Whittaker and Knight 1998), or generalized to describe other complex behaviors. Habitation is often referenced to describe the general process of human–coyote (and other wildlife) interactions that includes other important behaviors (i.e., Howell 1982, Carbyn 1998, Baker et al. 1998, Timm et al. 2004, Kloppers et al. 2005, Timm and Baker 2007). Additionally, the term is misused to describe severe coyote conflicts. For example, an article discussing a fatal coyote attack on an adult human suggested that "the coyotes must have been very habituated to people" (Caudell 2010:4). This usage lacks specificity, and suggests that coyotes were very non-responsive, or non-reactionary to the presence of people. Perhaps this is possible, but this behavioral state may not lead to animals attacking and killing a woman. Researchers may confuse terminology using "food habituated" (Hopkins et al. 2010). Habituation is likely used as a convenient way to discuss the issue because there is no other widely accepted or frequently used term to describe this important issue in general terms. Therefore, I suggest using emboldened wildlife to describe conditions when exact behaviors are unidentified.

The above examples from the literature may place too much emphasis on habituation, and divert attention from other issues, such as food conditioning of wildlife. It may be incorrect to focus on habituation as the threshold behavior that leads to conflicts. Lakasik and Alexander (2011:124) discuss habitation and cite research by Grinder and Krausman (1989) that suggest coyotes in Tucson, Arizona, did not habituate to people unless encouraged through food conditioning (meaning food conditioned and habituated, Hopkins et al. 2010). Lukasik and Alexander (2011) suggest that presence of humans alone does not necessarily lead to habitation. Food conditioning seems to be an important factor in generating human–coyote conflicts (Cornell and Cornely 1979, Bounds and Shaw 1994, Grinder and Krausman 1998). These studies support food conditioning being a larger issue than habituation. Coyote use of anthropogenic food resources should be a focus incorporated into future research. It is important to study home range behavior and diet to better understand wildlife ecology (Powell 2000).

I designed the conceptual model by incorporating these important clarifications of the developing lexicon of managing human–wildlife interactions (Whittaker and Knight 1998, Hopkins et al. 2010). Emboldened is a generalizable term, not linked to specific wildlife behaviors, to describe situations when animals do not avoid interactions with humans. Yet the model can still accommodate specific emboldened behaviors (Figure 3.1b) that may persist in behavioral states (tendencies) or support the expression of behaviors in short, situation-specific response events. Additional transitions accommodate sudden conflict interactions such as diseased animals, or unexpected wildlife aggression or attack. Wildlife researchers and professionals may find the conceptual model helpful when developing protocols or research projects to study wildlife interactions and conflicts.

Considerations for field-testing aversive conditioning

During the study in Westchester County, only 1 coyote generated interactions perceived as negative or as a conflict. Few sightings were reported of ear-tagged and radio-collared animals. However, these reports were simply sighting reports and did not express concern. Essentially 29 of the 30 coyotes studied for this research maintained avoidance tendencies. One animal exhibited emboldened behaviors, and no study coyotes behaved aggressively or attacked people and pets. Although speculation, the coyote may have been seeking a mate, as the coyote did not attack or injure dogs. This provided little opportunity to evaluate the conceptual model, and no opportunity to field-test behavioral modification strategies. Interestingly, the 1 case of emboldened behaviors was sustained as a tendency for 4 weeks, and then transitioned back to avoidance behavior. This confirmed the need to incorporate increasing and decreasing behavioral transitions into the conceptual model.

Future research will likely continue to refine this model and our understanding of conflicts and animal behaviors. Considering that coyote spatial ecology studies find evidence of few problematic animals (Gehrt et al. 2009), it may be difficult to field-test strategies for behavioral modification. Research designs will likely consider a before, after, and control framework. However, appropriate controls will be difficult to identify, and short-lived behavioral events may obscure the effects of tests. Appropriate replication may be difficult to achieve. Although avoiding pseudoreplication is typically recommended in radio-telemetry studies, it may be desirable as a type of experimental control for testing aversive conditioning on 1 animal within a social group.

I found that coyotes typically lived in natural lands, attempted to avoid interactions with humans, and potential conflicts such as sightings were brief interactions. Coyotes appear to exhibit situational (event) responses, and not tendencies to continue conflict behaviors.

MANAGEMENT IMPLICATIONS

Managing human–coyote interactions will require many techniques and strategies to contend with objective and perceived risks associated with coyotes inhabiting suburban and urban landscapes. Although most coyotes in this study and others, demonstrate apparent avoidance of human interactions, future research may investigate the efficacy of encouraging people to prevent objective risks by discouraging emboldened coyote behaviors. Additional research may continue to address how to manage emboldened coyotes. However, there may be limited opportunities to field-test methods. When opportunities do arise, it may be difficult to measure an objective, before and after, treatment effect, or have appropriate controls for comparison. Conflict interactions may result from short-lived, situation-specific events in which an animal quickly reverts back to an avoidance state. Field-testing aversive conditioning may lead to type I errors without adequate controls. Human dimensions research will be required to understand how wildlife stakeholder acceptance capacity influences tolerance and identification of objective and perceived risks. The temporal and spatial scale required to observe sufficient coyote conflicts may be greater than what any specialized coyote ecology study can sustain. Wildlife professionals will likely need to use an adaptive impact management strategy to learn through management experimentation. Adaptive impact management may require multiple state cooperators, over decades.

While human–coyote interactions in suburban and urban lands formed the motivation for this study, this conceptual model is likely generalizable to other landscapes and wildlife. Understanding wildlife behaviors that cause conflicts is necessary to appropriately respond with non-lethal and selective lethal strategies that require precise applications to specific individuals. Specifying a conceptual model facilitates the formulation of hypothesis and allows researchers and managers to make predictions for identifying conflicts and anticipate future management decisions. Experience will lead to refining the conceptual model and understanding of animal behaviors related to human–wildlife conflicts.

I found no opportunity to adequately field-test behavioral modification through aversive conditioning. This suggests that human–coyote interactions are infrequent in New York State. However the distinction must be clearly stated that I found no opportunity for researcher intervention. Other factors may be influencing the current status of few negative interactions. Currently, New York State environmental conservation law permits nuisance wildlife control operators (NWCO) to remove coyotes that cause a nuisance or damage. However, very few coyotes are reported to NYSDEC as being taken by NWCOs. Additionally, the current level of stakeholders intervening may be sufficient (Wieczorek Hudenko et al. 2008b). Indeed, approximately 26% of stakeholders that reported an interaction with a coyote to NYSDEC indicated that they attempted to haze or chase away the coyote. Perhaps current management practices and actions taken by stakeholders are sufficient to prevent most conflicts.

REFERENCES

Aebischer, N. J., P. A. Robertson, R. E. Kenward. 1993. Compositional analysis of habitat use from animal radio-tracking data. Ecology 74:1313–1325.

Alcock, J. 1998. Animal Behavior, Sixth Edition. Sinauer Associates, Sunderland, Massachusetts, USA.

Andelt, W. F. 1999. Relative effectiveness of guarding-dog breeds to deter predation on domestic sheep in Colorado. Wildlife Society Bulletin 27:706–714.

Arthur, L. M. 1981. Coyote control: the public response. Journal of Range Management 34:14–15.

Association of Fish and Wildlife Agencies [AFWA]. 2006*a*. Best management practices for trapping in the Eastern United States. pp13.

Association of Fish and Wildlife Agencies [AFWA]. 2006*b*. Best management practices: trapping coyotes in the Eastern United States. pp13.

Atkinson, K. T., and D. M. Shackleton. 1991. Coyote, *Canis latrans*, ecology in a rural–urban environment. Canadian Field-Naturalist 105:49–54.

Baker, R. O., and R. M. Timm. 1998. Management of conflicts between urban coyotes and humans in southern California. Proceedings of the Vertebrate Pest Conference 18:299–312.

Blejwas, K. M., C. L. Williams, G. T. Shin, D. R. McCullough, M. M. Jaeger. 2006. DNA convicts breeding male coyotes of killing sheep. Journal of Wildlife Management 70:1087–1093.

Bogan, D. A. 2004. Eastern coyote home range, habitat selection and survival in the Albany Pine bush landscape. Thesis, State University of New York, University at Albany, Albany, New York, USA.

Bogan, D. A., P. D. Curtis, and G. F. Albers. 2009. Numerically common, functionally rare: difficulties in detecting urban coyotes for population monitoring. Proceedings of the Wildlife Damage Management Conference 13:164–171.

Börger, L., B. D. Dalziel, and J. M. Fryxell. 2008. Are there general mechanisms of animal home range behavior? A review and prospects for future research. Ecological Letters 11:637–650.

Bounds, D. L., and W. W. Shaw. 1994. Managing coyotes in U.S. national parks: human–coyote interactions. Natural Areas Journal 14:280–284.

Bowen, W. D. 1982. Determining age of coyotes, *Canis latrans*, by tooth sections and tooth–wear patterns. Canadian Field-Naturalist 96:339–341.

Bromley, C., and E. M. Gese. 2001. Surgical sterilization as a method of reducing coyote predation on domestic sheep. Journal of Wildlife Management 65:510–519.

Burt, W. H. 1943. Territoriality and home range concepts as applied to mammals. Journal of Mammalogy 24:346–352.

Calenge, C., 2006. The package "adehabitat" for the R software: a tool for the analysis of space and habitat use by animals. Ecological Modelling 197:516–519.

Calenge, C., and A. B. Dufour. 2006. Eigenanalysis of selection ratios from animal radio-tracking data. Ecology 87:2349–2355.

Carbyn, L. N. 1989. Coyote attacks on children in western North America. Wildlife Society Bulletin 17:444–446.

Caudell, J. N. 2010. In the news: coyotes kill hiker in Nova Scotia. Human–Wildlife Interactions 4:4–6.

Conover, M. R., J. G. Francik, and D. E. Miller. 1977. An experimental evaluation of aversive conditioning for controlling coyote predation. Journal of Wildlife Management 41:775–779.

Cornell, D., and J. E. Cornely. 1979. Aversive conditioning of campground coyotes in Joshua Tree National Monument. Wildlife Society Bulletin 7:129–131.

De Solla, S. R., R. Bonduriansky, and R. J. Brooks. 1999. Eliminating autocorrelation reduces biological relevance of home range estimates. Journal of Animal Ecology 68:221–234.

Edge, J. L., D. E. Beyer, Jr., J. L. Belant, M. J. Jordan, and B. J. Roell. 2011. Livestock and domestic dog predations by wolves in Michigan. Human–Wildlife Interactions 5:66–78.

Fararr, R. O. 2007. Assessing the impacts of urban coyote on people and pets in Austin, Travis County, Texas. Proceedings of the Wildlife Damage Management Conference 12:334–341.

Fedriani, J. M., T. K. Fuller, and R. M. Sauvajot. 2001. Does availability of anthropogenic food enhance densities of omnivorous mammals? An example with coyotes in southern California. Ecography 24:325–331.

Fener, H. M., J. R. Ginsberg, E. W. Sanderson, and M. E. Gompper. 2005. Chronology of range expansion of the Coyote, *Canis latrans*, in New York. Canadian Field-Naturalist 119:1–5.

Ferris, M. 2004. Sightings of coyotes spread south. The New York Times. 2 May 2004; section 14WC: 5.

Foderaro, L. W. 2007. Unwelcome neighbors tracked in Westchester. The New York Times. 3 June 2007; section B:5.

Friend, M., D. E. Toweill, R. L. Brownell, Jr., V. F. Nettles, D. S. Davis, and W. J. Foreyt. 1994. Guidelines for the proper care and use of wildlife in field research. Pages 96–105 *in* T. A. Bookhout, Editor. Research and management techniques for wildlife and habitat. Fifth edition. The Wildlife Society, Bethesda, Maryland, USA.

Gehrt, S. D. 2007. Ecology of coyotes in urban landscapes. Proceedings of the Wildlife Damage Management Conference 12:303–311.

Gehrt, S. D., C. Anchor, and L. A. White. 2009. Home range and landscape use of coyotes in a metropolitan landscape: conflict or coexistence? Journal of Mammalogy 90:1045–1057.

Geist, V. 2008. The danger of wolves. The Wildlife Professional 2:34–35.

Geist, V. 2011*a*. Wildlife habituation: advances in understanding and management application. Human–Wildlife Interactions 5:9–12.

Geist, V. 2011*b*. Response to Rogers and Mansfield (2011) and Stringham (2011). Human–Wildlife Interactions 5:192–196.

Gese, E. M. 2001. Territorial defense by coyotes (*Canis latrans*) in Yellowstone National Park, Wyoming: who, how, where, when, and why. Canadian Journal of Zoology 79:980–987.

Gese, E. M., D. E. Andersen, and O. J. Rongstad. 1990. Determining home-range size of resident coyotes from point and sequential locations. Journal of Wildlife Management 54:501–506.

Gier, H. T. 1968. Coyotes in Kansas (revised). Kansas State College Agricultural Experiment Station Bulletin 393, Manhattan, Kansas, USA.

Gitzen, R. A., and J. J. Millspaugh. 2003. Comparison of least-squares cross-validation bandwidth options for kernel home-range estimation. Wildlife Society Bulletin 31:823–831.

Gompper, M. E. 2002. The ecology of northeast coyotes: current knowledge and priorities for future research. Wildlife Conservation Society Working Paper 17:1–48.

Goodenough, J, B. McGuire, R. A. Wallance. 2001. Perspectives on Animal Behavior. Second Edition. Wiley, New York, New York, USA.

Grinder, M. I., and P. R. Krausman. 2001. Home range, habitat use, and nocturnal activity of coyotes in an urban environment. Journal of Wildlife Management 65:887–898.

Grubbs, S. E., and P. R. Krausman. 2009. Use of urban landscape by coyotes. Southwestern Naturalist 54:1–12.

Gustavson, C. R., J. Garcia, W. G. Hankins, and K. W. Rusiniak. 1974. Coyote predation control by aversive conditioning. Science 184:581–583.

Hayne, D. W. 1949. Calculation of size of home range. Journal of Mammalogy 30:1–18.

Hopkins, J. B., III, S. Herrero, R. T. Shideler, K. A. Gunther, C. C Schqartz, and S. T. Kalinowski. 2010. A proposed lexicon of terms and concepts for human–bear management in North America. Ursus 21:154–168.

Howell, R. G. 1982. The urban coyote problem in Los Angeles County. Proceedings of the Vertebrate Pest Conference 10:21–23.

Hsu, S. S., and L. F. Hallagan. 1996. Case report of a coyote attack in Yellowstone National Park. Wilderness and Environmental Medicine 2:170–172.

Johnson, D. H. 1980. The comparison of usage availability measurements for evaluating resource preference. Ecology 61:65–71.

Kendrot, S. R. 1998. The effects of roads and land use on home range use, behavior and mortality of eastern coyotes (*Canis latrans* var.) in northern New York. Thesis, State University of New York College of Environmental Science and Forestry, Syracuse, New York, USA.

Kernohan, B. J., R. A. Gitzen, and J. J. Millspaugh. 2001. Analysis of animal space use and movements. Pages 125–166 *in* J. J. Millspaugh and J. M. Marzluff, editors. Radio tracking and animal populations. Academic, San Diego, California, USA.

Kitchen, A. M., E. M. Gese, and E. R. Schauster. 2000. Changes in coyote activity patterns due to reduced exposure to human persecution. Canadian Journal of Zoology 78:853–857.

Kloppers, E. L., C. Cassady St. Claire, and T. E. Hurd. 2005. Predator-resembling aversive conditioning for managing habituated wildlife. Ecology and Society 10(1): Article 31.

Knight, J. 2009. Making wildlife viewable: habituation and attraction. Society and Animals 17:167–184.

Knowlton, F. F., E. M. Gese, and M. M Jaeger. 1999. Coyote depredation control: an interface between biology and management. Journal of Range Management 52:398–412.

Lukasik, V. M., and S. M. Alexander. 2011. Human–coyote interactions in Calgary, Alberta. Human Dimensions of Wildlife 16:114–127.

MacNulty, D. R., L. D. Mech, and D. W. Smith. 2007. A proposed ethogram of large-carnivore predatory behavior, exemplified by the wolf. Journal of Mammalogy 88:595–605.

Manly, B. F. J., L. L. McDonald, D. L. Thomas, T. L. McDonald, and W. P. Erickson. 2002. Resource selection by animals; statistical design and analysis for field studies, second edition. Kluwer Academic, Norwell, Massachusetts, USA.

Mattson, D., K. Logan, and L. Sweaner. 2011. Factors governing risk of cougar attacks on humans. Human–Wildlife Interactions 5:135–158.

McNay, R. S., J. A. Morgan, F. L. Bunnell. 1994. Characterizing independence of observations in movements of Columbian black-tailed deer. Journal of Wildlife Management 58:422–429.

Millspaugh, J. J., R. M. Nielson, L. McDonald, J. M. Marzluff, R. A. Gitzen, C D. Rittenhouse, M. W. Hubbard, S L. Sheriff. 2006. Analysis of resource selection using utilization distributions. Journal of Wildlife Management 70:384–395.

Mitchell, B. R., M. M. Jaeger, and R. H. Barrett. 2004. Coyote depredation management: current methods and research needs. Wildlife Society Bulletin 32:1209–1218.

Mohr, C. O. 1947. Table of equivalent populations of North American small mammals. American Midland Naturalist 37:223–249.

Nams, V. O. 1989. A technique to determine the behavior of a radio-tagged animal. Canadian Journal of Zoology 67:254–258.

Nams, V. O., and S. Boutin. 1991. What is wrong with error polygons? Journal of Wildlife Management 55:172–176.

New York State Department of Environmental Conservation (NYSDEC). 2005. New York State's Coyote Incident Standard Operating Procedures. Bureau of Wildlife, Division of Fish, Wildlife & Marine Resources, New York State Department of Environmental Conservation, Albany, New York, USA.

National Land Cover Database. 2006. Multi-Resolution Land Characteristics Consortium. <http://www.mrlc.gov/nlcd06_data.php>. Accessed 10 June 2011.

National Oceanic and Atmospheric Administration [NOAA]. 2009. National Ocean and Atmosphere Administration Climate and Weather Information. <http://cdo.ncdc.noaa.gov/climatenormals/clim84/NY/NY309670.txt>. Accessed 2 October 2009.

Okoniewski, J. C. 1982. A fatal encounter between an adult coyote and three conspecifics. Journal of Mammalogy 63:679–680.

Olson, J. F., and R. Tischaefer. 2004. Cable restraints in Wisconsin: a guide to responsible use. Wisconsin Department of Natural Resources. PUB-WM-442-

2004.

Ott, R. L., and M. Longnecker. 2001. An introduction to statistical methods and data analysis. Fifth edition. Duxbury, Pacific Grove, California, USA.

Parker, G. R. 1995. Eastern coyote: the story of its success. Nimbus, Halifax, N. S. Canada.

Person, D. K., and D. H. Hirth. 1991. Home range and habitat use of coyotes in a farm region of Vermont. Journal of Wildlife Management 55:433–441.

Powell, R. A. 2000. Animal home ranges and territories and home range estimators, pp. 65–110 *in* L. Boitani and T. K. Fuller, editors. Research Techniques in Animal Ecology: Controversies and Consequences. Columbia University Press, New York, New York, USA.

Quinn, T. 1995. Using public sighting information to investigate coyote use of urban habitat. Journal of Wildlife Management 59:238–245.

Quinn, T. 1997. Coyote (*Canis latrans*) habitat selection in urban areas of western Washington via analysis of routine movements. Northwest Science 71:289–297.

Reiter D. K., M. W. Brunson, and R. H. Schmidt. 1999. Public attitudes toward wildlife damage management and policy. Wildlife Society Bulletin 27:746–758.

Rettie, W. J., and P. D. McLoughlin. 1999. Overcoming radiotelemetry bias in habitat-selection studies. Canadian Journal of Zoology 77:1175–1184.

Rodgers, A. R., A. P. Carr, H. L. Beyer, L. Smith, and J. G. Kie. 2007. HRT: Home Range Tools for ArcGIS. Version 1.1. Ontario Ministry of Natural Resources, Centre for Northern Forest Ecosystem Research, Thunder Bay, Ontario, Canada.

Rogers, L. L., and S. A. Mansfield. 2011. Misconceptions about black bears: a response to Geist (2011). Human–Wildlife Interactions 5:173–176.

Robel, R. J., A. D. Dayton, R. R. Henderson, R. L. Meduna, and C. W. Spaeth. 1981. Relationships between husbandry methods and sheep losses to canine predators. Journal of Wildlife Management 45:894–911.

Riley, S. P. D., R. M Saubajot, T. K. Fuller, E. C. York, D. A. Kamrant, C. Bromley, and R. K Wayne. 2003. Effects of urbanization and habitat fragmentation on bobcats and coyotes in southern California. Conservation Biology 17:566–576.

Seamen, D. E., J. H. Millspaugh, B. J. Kernohan, G. C. Brundige, K. J. Raedeke, and R. A. Gitzen. 1999. Effects of sample size on kernel home range estimates. Journal of Wildlife Management 63:739–747.

Seamen, D. E., and R. A. Powell. 1996. An evaluation of the accuracy of kernel density estimators for home range analysis. Ecology 77:2075–2085.

Severinghaus, C. W. 1974. Notes on the history of wild canids in New York. New York Fish and Game Journal 21:117–125.

Shivik, J. A., K. S. Gruver, and T. J. DeLiberto. 2000. Preliminary evaluation of new cable restraints to capture coyotes. Wildlife Society Bulletin 28:606–613.

Theuerkauf, J., and W. Jedrzejewski. 2002. Accuracy of radiotelemetry to estimate wolf activity and locations. Journal of Wildlife Management 66:849–864.

Timm, R. M., R. O. Baker, J. R. Bennett, and C. C. Coolahan. 2004. Coyote attacks: an increasing suburban problem. Transactions of the North American Wildlife and Natural Resources Conference 69:67–88.

Timm, R. M., and R. O. Baker. 2007. A history of urban coyote problems. Proceedings of the Wildlife Damage Management Conference 12:272–286.

Thurber, J. M., and R. O. Peterson. 1991. Changes in body size associated with range expansion in the coyote (*Canis latrans*). Journal of Mammalogy 72:750–755.

U.S. Census Bureau. 2008. <http://www.census.gov/geo/www/ua/ua_2k.html>. Accessed 5 October 2009.

Way, J. G., I. M. Ortega, and P. J. Auger. 2002. Eastern coyote home range, territoriality, and sociality on urbanized Cape Cod. Northeast Wildlife 57:1–18.

Way, J. G., I. M. Ortega, and E. G. Strauss. 2004. Movement and activity patterns of eastern coyotes in a coastal, suburban environment. Northeastern Naturalist 11:237–254.

Way, J. G. 2009. Observations of coywolves, *Canis latrans x lycaon*, crossing bridges and using human structures of Cape Cod, Massachusetts. Canadian Field-Naturalist 207:206–209.

Webster, B. 1981. Coyotes arrive in the northeast after an evolutionary trek across the. The New York Times. 3 March 1981; section C:1.

Weckel, M. E., D. Mack, C. Nagy, R. Christie, and A. Wincorn. 2010. Using citizen science to map human–coyote interactions in suburban New York, USA. Journal of Wildlife Management 74:1163–1171.

White, G. C., and R. A. Garrott. 1990. Analysis of wildlife radio-tracking data. Academic Press, San Diego, California, USA.

White, L. A., and S. D. Gehrt. 2009. Coyote attacks on humans in the United States and Canada. Human Dimensions of Wildlife 14:419–432.

Whittaker, D., and R. L. Knight. 1998. Understanding wildlife responses to humans. Wildlife Society Bulletin 26:312–317.

Wieczorek Hudenko, H., D. J. Decker, and W. F. Siemer. 2008*a*. Stakeholder insights into the human–coyote interface in Westchester County, New York. Human Dimensions Research Unit, Cornell University 08-1.

Wieczorek Hudenko, H., W. F. Siemer, and D. J. Decker. 2008*b*. Living with coyotes in suburban areas: insights from two New York State counties. Human Dimensions Research Unit, Cornell University 08-8.

Wieczorek Hudenko, H., W. F. Siemer, and D. J. Decker. 2008*c*. Humans and coyotes in suburbia: can experience lead to sustainable coexistence? Human Dimensions Research Unit, Cornell University 08-9.

Wittmann, K., J. J. Vaske, M. J. Manfredo, and H. C. Zinn. 1998. Standards for lethal response to problem urban wildlife. Human Dimensions of Wildlife 3:29–48.

Worcester, R. E., and R. Boelens. 2007. The co-existing with coyotes program in Vancouver, B.C. Proceedings of the Wildlife Damage Management Conference 12:393–397.

Worton, B. J. 1989. Kernel methods for estimating the utility distribution in home-range studies. Ecology 70:164–168.

Worton, B. J. 1995. Using Monte Carlo simulation to evaluate kernel-based home range estimators. Journal of Wildlife Management 59:794–800.

CHAPTER 4

COYOTE DIET USE WITHIN A SUBURBAN LANDSCAPE GRADIENT NORTH OF NEW YORK CITY

Wildlife use of anthropogenic food subsidies is an important component to food conditioning, a process that drives many human–wildlife interactions and increases potential for conflicts (Cornell and Cornely 1979, Bounds and Shaw 1994, Whittaker and Knight 1998, Don Carlos et al. 2009, Gehrt et al. 2009, White and Gehrt 2009). Food attractants may reinforce animal behaviors by strengthening wildlife association to urbanized areas or encouraging viewable wildlife (Whittaker and Knight 1998, Knight 2009). In urbanized lands, the use of anthropogenic foods can alter animal density and spacing (Fedriani et al. 2001, Prange and Gehrt 2004, Bino et al. 2011). Generalist carnivores that exploit the diversity of food items in urbanized landscapes may exist at higher densities than in areas with less human-development (Fedriani et al. 2001, Prange and Gehrt 2004, Bino et al. 2011) and reduce the space required by animals (Hidalgo-Mihart et al. 2004, Bino et al. 2011). For example, coyotes (*Canis latrans*) have been documented at higher densities in urban areas where they consumed more anthropogenic foods than in less urbanized lands where they had more natural diets (Fedriani et al. 2001). Additionally, coyotes inhabiting a landfill used less space than neighboring coyotes having no association to the landfill (Hidalgo-Mihart et al. 2004). Thus, use of anthropogenic foods may increase animal densities and decrease space use, which for urban areas, could result in increased interaction rates between coyotes and humans.

Coyotes have been documented to use anthropogenic food sources in urban areas in greater proportion than in less intensively develop lands (Quinn 1997, Fedriani et al 2001, Morey et al. 2007, Grigione et al. 2010), and this reliance is suspected of being associated with instances where emboldened individuals apparently lost their fear of humans (Howell 1982, Baker and Timm 1998, Bounds and Shaw 1994, White and Gehrt 2009). Emboldened animals (Chapter 3) may increase human risks and injuries (Howell 1982, Carbyn 1989, Baker and Timm 1998, Bounds and Shaw, 1994). Additionally, other negative impacts may result from coyotes attacking or killing pets (Farrar 2007, Lukasik and Alexander 2011, Chapter 2). Indeed, high levels of anthropogenic foods in coyote diets may be viewed as a warning sign, or precursor, to elevated coyote aggression towards humans, and this may lead to human injuries (Baker and Timm 1998, Lukasik and Alexander 2011). Studying the degree to which coyotes use anthropogenic foods will be helpful for making informed management decisions regarding human–coyote interactions.

Recently, coyotes inhabiting Westchester County, New York, have generated much interest and concern from state wildlife managers, residents and the media (Lang 2005, Curtis et al. 2007, Siemer et al. 2007). This motivated comprehensive research regarding the human dimensions, biology, and ecology of coyotes inhabiting the county (Wieczorek Hudenko et al. 2008*a*, *b*, *d*; Bogan et al. 2009) and potential for human–coyote interactions (Weckel et al. 2010). Although few (4%) stakeholders (n = 1,160) experienced negative or "problem" interactions with coyotes, many (77%) were aware of coyotes in the county and had observed coyotes near their homes (32% of respondents; Wieczorek Hudenko 2008*a, d*). In fact, many interactions reported to the New York State Department of Environmental Conservation (NYSDEC) occur in residential yards (Chapter 2), and sightings were more likely to occur in neighborhoods with increasing proximity to natural areas (Weckel et al. 2010). Coyotes typically used home ranges centered in natural areas, and occasionally used residential lands while switching between disjunctive natural areas within home ranges (Chapter 3). What remains unknown is whether residential lands provide food attractants or food subsidies for coyotes. Furthermore, do coyotes in Westchester County utilize anthropogenic foods? Examining coyote diets from urban areas should reveal use of anthropogenic food items that may be potential drivers of negative human–coyote interactions.

I examined the composition of coyote diets along a suburban-urban gradient to reveal the relationship between anthropogenic foods and human-developed lands to inform potential future wildlife management interventions (e.g., removal of food attractants, feeding bans, pet-safety recommendations). My objective was to examine the composition of coyote diets across a landscape gradient to identify the degree to which coyotes use anthropogenic foods in proportion to natural foods. Information on the diets of coyotes is important to understand their natural history and behavioral ecology, and enhance our understanding of coyote populations inhabiting urbanized lands in the northeastern United States.

STUDY AREA

I conducted the diet study in Westchester County, New York, a mixed urban landscape immediately north of New York City. Westchester County spans 1,232 km^2 and has an estimated 923,459 residents (U.S. Census Bureau 2008). Overall human density in the county was 750 people/km^2 and was classified as urban (U.S. Census Bureau 2008). However, the housing density and developed lands varied among towns. Therefore, I targeted 4 towns within the county for the coyote diet study. In southern Westchester, I selected Greenburgh and Mt. Pleasant with 932 and 509 people/km^2, respectively. In northern Westchester County, I selected Yorktown and Somers, having population densities of 179.5 and 426.5 people/km^2, respectively. While the county is heavily populated, there are dispersed forested lands of mixed deciduous, coniferous, mixed shrub land, woody wetlands covering approximately

52% of the county (Bogan et al. 2009, Chapter 3, APPENDIX A,).

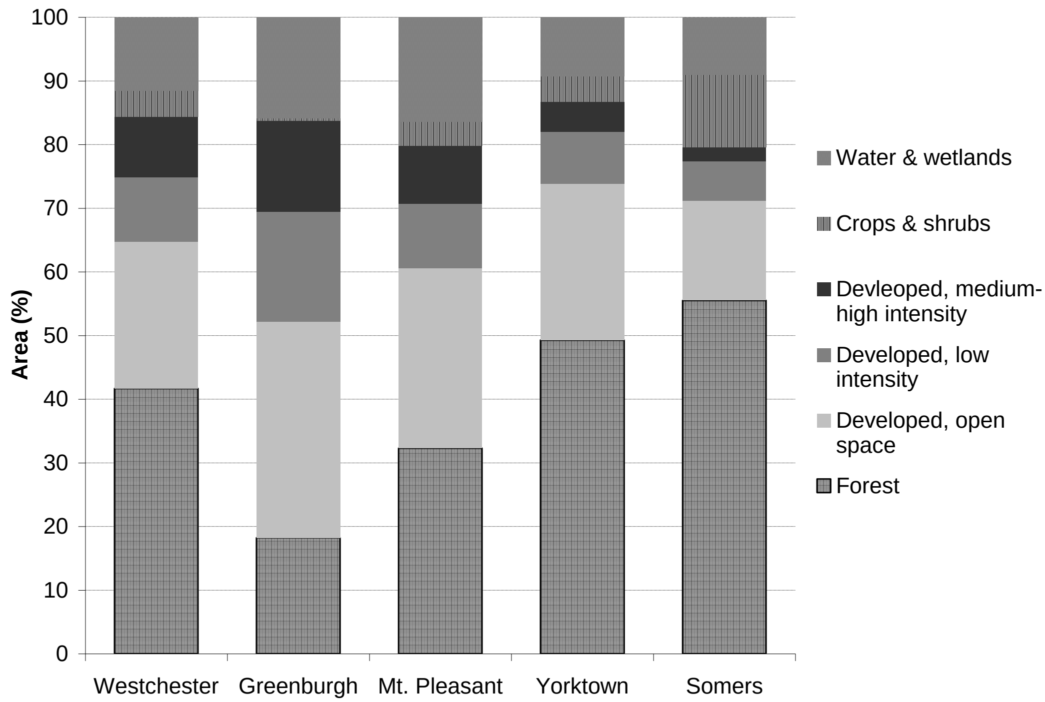


Figure 4.1. Proportion of land-use categories in 4 study towns and Westchester County, New York, USA, during 2006–2008. The 6 land-use categories were generalized from 14 land-use categories from the 2006 National Land Cover Data for Westchester County.

METHODS

Field Collections

I collected coyote scats during 2006–2008 to investigate coyote diets sampled within an urban landscape gradient. I utilized scat collections to study coyote diet due to the difficulty in detecting and visually observing free-ranging coyotes in this area (Bogan et al. 2009), the potential to collect large (>1,000) sample sizes within a 1–2 year period (Andelt 1985, Gompper et al. 2006, Morey et al. 2007, Quinn1997), and freedom from sacrificing animals to acquire gastrointestinal samples (Litviatis 2000), which would have confounded a concurrent live-study of coyote behavioral ecology

(Bogan et al. 2009). Among carnivores in New York, coyotes frequently deposit feces on trails (Gompper et al. 2006) near prominent features, along the center of trails, and at trail intersections (Rezendez 1999). I studied diets for the general population of coyotes, and did not attempt to link specific diet items to individual animals. The analyses do not indicate clear food preferences because availability of diet items was not estimated for selectivity analyses (i.e., use compared with availability).

I used 2 strategies to collect additional scat samples. I opportunistically collected scats (Samson and Crete 1997) from January 2006 to December 2008 at coyote capture sites and while conducting field-work within the context of a larger behavioral ecology study (Bogan et al. 2009). During 2007–2008, I added a systematic method to collect additional scat samples from 26 trail-transects, which also allowed the quantification of sampling effort.

I sampled trail-transects once per month during January 2007 to December 2008 along established trails. I selected established trail-transects in natural areas within state, county, and municipal public lands near residential areas, and also targeted transects along utility corridors, and trails near recreational parks with playgrounds, athletic fields and picnic areas (Figure 4.2). In 2007, I sampled 13 trails located in the Towns of Somers (n = 5), Mt. Pleasant (n = 1) and Greenburgh (n = 7; Figure 4.2). After the first year of sampling, I dropped 7 of the original trails due to very low scat collection yields (0–6 scats annually per trail). I continued sampling 6 of the original trails and added 12 new trails in 2008. These 18 trails were distributed through Somers (n = 3), Yorktown (n = 5), Mt. Pleasant (n = 6) and Greenburgh (n = 4; Figure 4.2). The 2007 trails averaged 2.4 km in length, and ranged from a minimum of 0.80 km to a maximum of 6.25 km, for a total of 31.25 km of trails sampled each month. In 2008, trails averaged 2.26 km, ranging from 0.16 km to 6.25 km, totaling 40.61 km sampled monthly. Systematic trail sampling permitted quantification of sampling effort measured as the linear distance of trails sampled and sampling frequency for a total of 31 trail-based measurements.

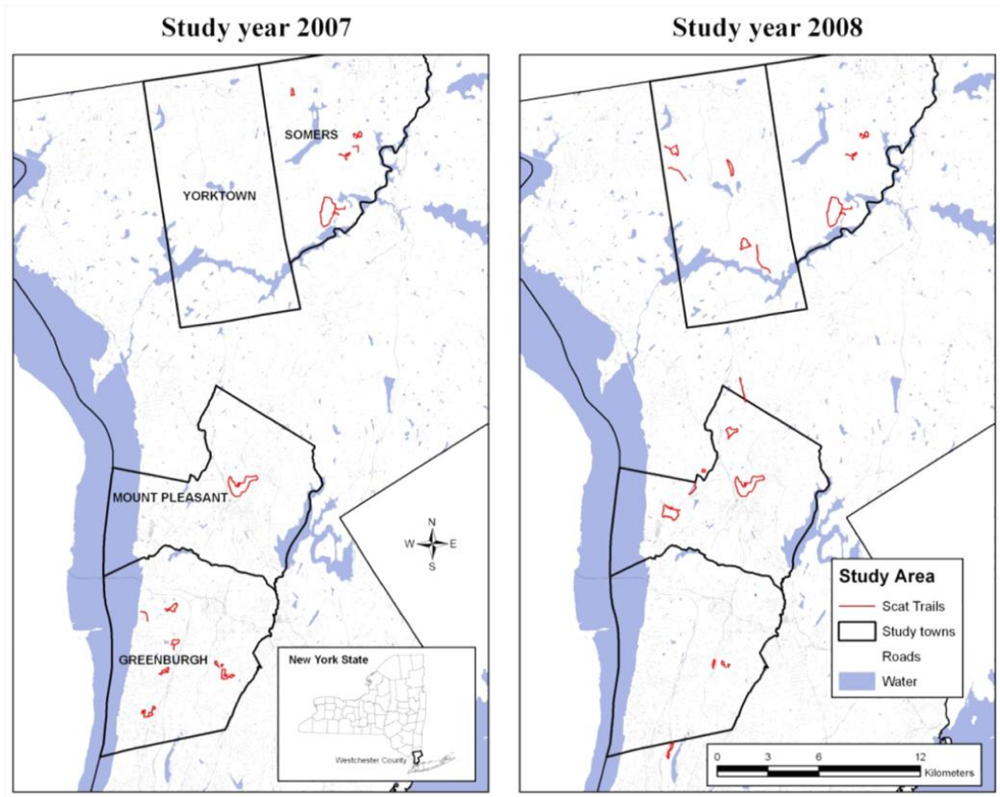


Figure 4.2. The study area with trail-transects used for collecting coyote scats in Westchester County, New York, USA, during 2007 and 2008.

With field assistance, I visually searched for scats across the full width of trails (approximately 1.5–3.0 m wide) and collected all detected scats. For all scats, I recorded coordinates measured by handheld global positioning system (GPS) in NAD 83, UTM Zone 18N coordinate system. I recorded sampling method (e.g., opportunistic or trail), study town, date, field technician initials, and diameter for measurable scats (mm). I identified the scats to species and estimated a subjective observer confidence level in percent, similar to Prugh and Ritland (2005). Additionally, I intentionally sampled putative domestic dog (*Canis lupus familiaris*) scats from trails. I collected these for comparison of diet contents and to validate field identification skills. All information was recorded in indelible marker on each plastic storage bag. All scats were stored at −23 °C for later laboratory analysis.

Laboratory Analyses

Laboratory technicians and I partitioned each frozen scat by weight into 2 samples. Technicians removed ≥80% of each scat sample for the diet analysis. The remaining sample (≤20%) was returned to storage before thawing and was reserved for future fecal DNA analyses. Diet samples were soaked 24 hours in soapy water (Ackerman et al. 1984) to thaw, rehydrate and soften desiccated materials and expedite washing and sieving. Technicians decanted the entire slurry and rinsed the remains through a stack of sieves with screening measuring 4.74mm, 2mm, and 0.425mm from top to bottom, respectively. All remaining contents of sieves were placed separately on paper plates, dried in a drying oven at 50–60 °C, and then separated further into apparent different items.

Representative hair samples were fixed to slides to examine medullary and cuticle scales. Scale castings were made using quick-dry clear nail polish by tacking down individual hairs with nail polish and rapidly removing after 1–2 minutes of drying. Each hair type was identified using a hair identification manual (Moore et al. 1974) and compared with a reference hair collection. Bone fragments were identified using a skeletal reference collection and animal skull key (Elbroch 2006). I identified other diet items by comparing to general reference collections (e.g., commercial bird seed mixes, paper samples, collected fruits and seeds). I recorded all identified items as present or absent to determine frequency of occurrence (Ackerman et al. 1984), and visually assessed the relative percent volume of each item within the scat sample (Gese et al. 1988, Quinn 1997, Samson and Crete 1997). I report both measures of diet contents because frequency of occurrence tends to overestimate the relative occurrence of trace diet items, in comparison to percent volume which accounts for trace items. I did not censor trace items from further analyses as suggested by Weaver and Hoffman (1979) as I retained all evidence of anthropogenic diet items for potential management implications.

I identified diet items as taxonomically or specifically as possible. Some uncertainty remained, as I was unable to identify a few items beyond general categories (e.g., small mammals or Sciuridae), or other groupings (e.g., grass, paper, or glass).

To assess the performance of opportunistic and trail-transect scat collections, I compared diet compositions by frequency of occurrence. For the remainder of the study, I focused the analyses on the trail-transect samples based on large sample sizes and measures of sampling effort. I pooled monthly samples into biological seasons based on Laundré and Keller (1981), and partitioned the year into 3 equal periods defined as Breeding (January–April), Pup-rearing (May–August), and Dispersal (September–December) seasons. I reported the overall diet composition by methods, and by biological seasons. I tested for differences using Pearson Chi-square contingency table analysis (Ott and Longnecker 2001) in JMP 8.0 (SAS Institute, Inc., Cary NC).

Landscape Response

Based on the observations of highly variable scat detection rates among trails during 2007, I shifted the sampling efforts to different trails in 2008 and again observed great variability in the number of scats detected along trails. I examined the number of scats collected with the associated trail length and found no evidence for a linear relationship. This result suggested that factors other than trail length may be influencing the detection or deposition of coyote scats. As such, I define the number scats deposited along trails as an index of relative activity among trails and investigated the influence of surrounding landscape variables. Although a curvilinear relationship has been estimated for the number of individuals detected per number of scats collected along trails (Kays et al. 2008), this index is not a direct measure of abundance.

The objective was to examine the diet composition and scat frequency sampled for 31 trail-transect measurements throughout the landscape and to relate these responses to selected landscape metrics. However, due to the highly variable number of scats detected along trails, I estimated the approximate sample size necessary to reasonably describe the diet. I examined the empirical asymptotic relationship of diet contents per trail-transects by plotting the number of uniquely identified items (y-axis) on sample size (x-axis, *n* scats). Furthermore, I regressed the total number of detected items (y-axis) on sample size per trail to determine the approximate complexity of diet contents. Based on these analyses, I pooled trail-transects by town and further collapsed the analysis into a comparison between the northern and southern study towns. I report the frequency of occurrence and percent volume of diet items detected in northern and southern study towns.

RESULTS

I collected a total of 512 fecal samples using 3 methods (Table 4.1). Fifteen scats were collected at capture sites of trapped coyotes. Trail-transects yielded 12.3 times more scats during the 2-year systematic collection than the 3-year opportunistic collections. Field crews sampled trail-transects for a cumulative 862.32 km of trails to collect the 442 scats, for an overall detection rate of 0.51 scat/km (1.21 scat/mile).

I identified approximately 67 types of items from all 512 scats, which included contents from the 19 field-identified, and genetically confirmed dog scats. Forty-three items were identified to species or other specification, while the other 24 items were classified to general categories. Nutritive items accounted for approximately 66% of the total items detected, although it was unclear whether a portion of the non-nutritive items provided some benefits, or were associated with digested foods. Clearly, some non-nutritive items did not provide nutrition (e.g., a used cigarette filter).

All items were grouped into 11 categories: (1) White-tailed deer (*Odocoileus virginianus*): adult and fawn; (2) Rabbit: Eastern cottontail (*Sylvilagus floridanus*) or other wild Leporidae; (3) Small mammal: including identified genera or species of Soricidae, Talpidae, Dipodidae, Muridae, and Sciuridae except (*Marmota monax*); (4) Meso-mammal: Northern raccoon (*Procyon lotor*), muskrat (*Ondatra zibethica*), striped skunk (*Mephitis mephitis*), woodchuck, and opossum (*Didelphis marsupialis*); (5) Plant: black cherry (*Prunus serotina*), American beech (*Fagus grandifolia*), grape (*Vitis* spp.), Raspberry (*Rubus* spp.), Apple (*Malus* spp.), Acorn (*Quercus* spp.), nut shell remains, trace amounts of 5 unknown seeds, and grasses; (6) Bird: wild turkey (*Meleagris gallopavo*) and other bird species; (7) Insect: Coleoptera, Orthoptera and other unidentified insect remains; (8) Anthropogenic: sponge, human hair (*Homo sapiens*), commercial-mixed bird seeds, grocery store pear sticker/label, latex, dog kibble, aluminum foil, glove, plastic, cloth, glass, corrugated paper, paper, green tennis ball felt, used cigarette filter, string, domestic dog hair (*Canis lupus familiaris*), and domestic cat (*Felis catus*); (9) Unknowns: unknown hair, undercoat hairs, undigested residues, bone, and nutshell; (10) Miscellaneous: fine gravel, soil or sand, and fine wood chips; and (11) Coyote: coyote (*Canis latrans*) hairs. Dog scats contained the lowest proportions of white-tailed deer and other wildlife, and exhibited the highest proportions of anthropogenic items. On average, dog scats contained ≥2 anthropogenic items per scat, resulting in a high (205.3%) frequency of occurrence (Table 4.1). Diet composition by frequency of occurrence was similar ($\chi_5^2 = 6.28$, $P = 0.267$) between opportunistic scat collections and trail-transect collections (Table 4.1).

For all trail-transect scats, white-tailed deer accounted for the greatest proportion of diets by both frequency of occurrence and percent volume (Figure 4.3). Plant materials occurred in 46.4% of scats yet represented 9.7% of the volume of scats. The frequency of occurrence was greater than percent volume for most diet categories with the exception of the rabbit category. Scats containing Leporidae remains typically did not contain other diet items. Anthropogenic items occurred in 5.9% of scats, yet represented a small proportion (1.3 % volume) of scat contents. Diet composition, measured by frequency of occurrence, of trail-collected scats varied ($\chi_{14}^2 = 118.70$, $P < 0.001$) by biological season (Table 4.2).

Few anthropogenic items in trail-transect scats were identified directly as nutritive food items. Three scats contained commercially-available birdseed mix, and only 2 scats collected in different years contained cat remains. No dog remains or kibble were identified in trail (or opportunistic) collections of scats. Other indirect anthropogenic diet items found were plastic (n = 4), cloth (n = 1), latex (n = 1), glass (n = 3), corrugated paper (n = 1), paper (n = 4), and string (n = 4).

Table 4.1. Frequency of occurrence of diet items detected in scats collected in Westchester County, New York, USA, during January 2006–December 2008. Scats were collected opportunistically and at coyote capture sites within the study area, and along 26 systematically sampled trail-transects. Values (%) greater than 100% account for >1 item per category (i.e., multiple anthropogenic items) found in scats. Columns sum greater than 100% because multiple items can occur per individual scats.

	Collection Method	Opportunistically				Trail-transects			Coyote Captures	Putative Dog
		Annual			Total	Annual		Total	Total	Total
	Collection Period	2006	2007	2008	2006–08	2007	2008	2007–08	2006–08	2007–08
	Samples (*n*)	12	11	13	36	190	252	442	15	19
Frequency of occurrence (%)	White-tailed deer	100.0	81.8	84.6	88.9	66.8	83.3	76.2	93.3	10.5
	Rabbit	0.0	0.0	7.7	2.8	15.3	3.6	8.6	0.0	0.0
	Small mammal	8.3	27.3	38.5	25.0	25.3	15.1	19.5	0.0	5.3
	Meso-mammal	0.0	0.0	0.0	0.0	8.4	6.0	7.0	0.0	0.0
	Plant materials	83.3	72.7	53.8	69.4	58.4	37.3	46.4	66.7	89.5
	Birds	16.7	0.0	15.4	11.1	7.9	7.5	7.7	6.7	5.3
	Insects	0.0	18.2	7.7	8.3	5.8	11.9	9.3	6.7	10.5
	Anthropogenic	8.3	9.1	30.8	16.7	7.4	4.0	5.9	6.7	205.3
	Unknown materials	8.3	18.2	0.0	8.3	7.4	3.2	5.0	26.7	52.6
	Miscellaneous	0.0	0.0	0.0	0.0	1.1	0.0	0.5	6.7	10.5
	Coyote	0.0	0.0	0.0	0.0	4.7	2.4	3.4	6.7	0.0

Table 4.2. Frequency of occurrence of diet items detected in scats collected along 26 systematically sampled trail-transects in Westchester County, New York, USA, during January 2007–December 2008. Biological seasons are Breeding (January–April), Pup-rearing (May–August), and Dispersal (September–December). Diet composition varied by biological season ($\chi_{14}^2 = 118.70$, $P < 0.001$).

	Biological season		
Diet category	Breeding	Pup-rearing	Dispersal
White-tailed deer	77.5	87.0	58.6
Rabbit	13.6	2.5	9.9
Small mammal	26.6	6.8	27.0
Meso-mammal	7.1	6.8	7.2
Plant materials	32.5	26.5	96.4
Birds	5.3	4.9	15.3
Insects	4.1	13.6	10.8
Anthropogenic	8.3	1.2	6.3
Unknown materials	5.3	1.9	9.0
Miscellaneous	1.2	0.0	0.0
Coyote	3.0	1.2	7.2
Samples (*n*)	169	162	111

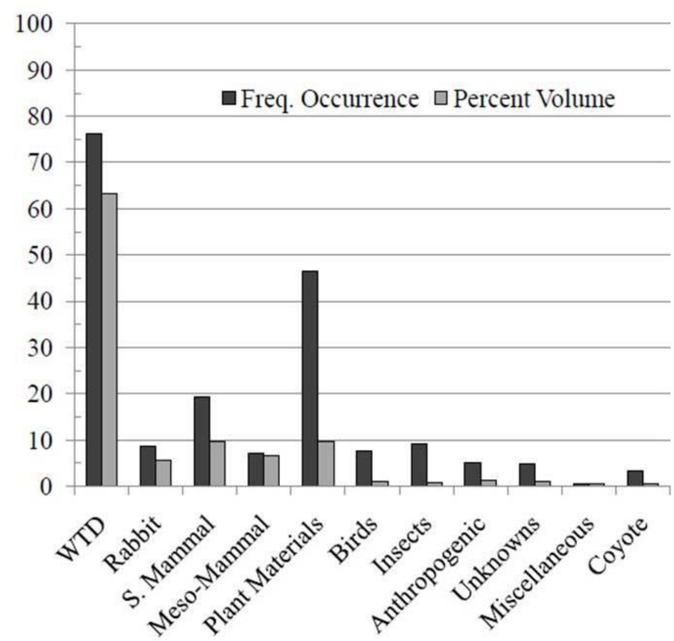


Figure 4.3. Coyote diet composition by frequency of occurrence and percent volume for 11 categories found in scats ($n = 442$) collected along standardized trail-transects within Westchester County, New York, USA, during January 2007–December 2008.

Landscape Response

The total number of items identified per trail was linearly related to the number of scats collected along trails ($r^2 = 0.97$, $F_{1,29} = 1033.2$, $P < 0.01$). The slope of the regression equation ($\beta_1 = 1.8$, SE = 0.06, $t = 32.14$, $P < 0.001$) indicated approximately 1.8 diet items were found per scat along all trails. However, the number of unique items identified per trail appeared to reach an asymptote above minimum sample sizes of 20 scats (Figure 4.4). Therefore, 26 out of 31 trail-transects had insufficient sample sizes to examine diet breadth and composition related to landscape-gradient metrics. The diet composition of northern study-towns varied ($\chi_7^2 = 27.20$, $P < 0.003$) from the diet composition found in the southern study-towns (Figure 4.5).

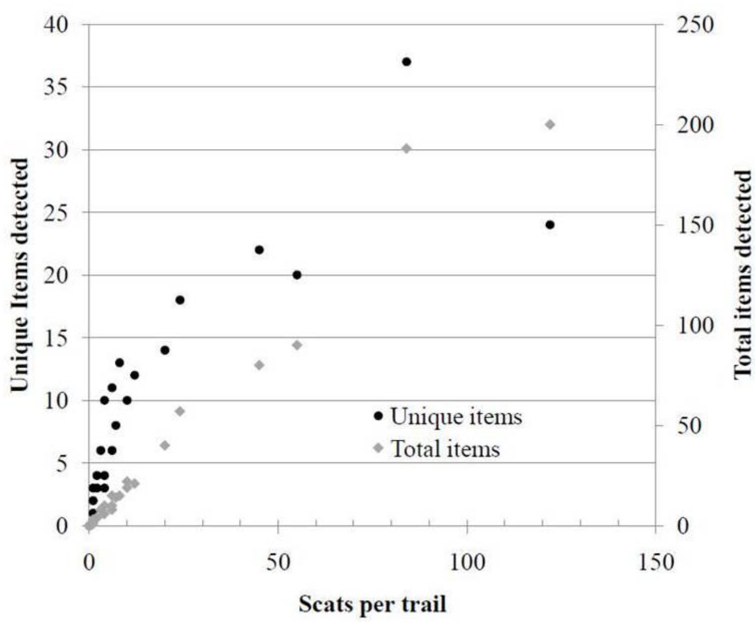


Figure 4.4. The approximately asymptotic association of unique items detected within scats and linear association of total items detected within scats (with repeat items) collected along each of 31 trail-transect samples in Westchester County, New York, USA, during January 2007–December 2008.

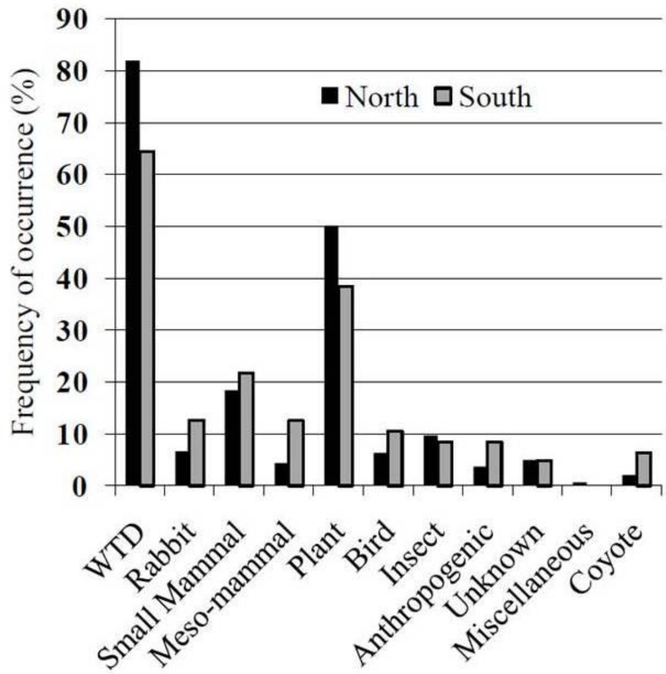


Figure 4.5. The frequency of occurrence of diet items found within diet categories of scats collected in the towns of Somers and Yorktown (North, n = 299) and Greenburgh and Mt. Pleasant (South, n = 143), Westchester County, New York, USA, during January 2007–December 2008.

DISCUSSION

I found little evidence of anthropogenic items in coyote diets, and of the items detected, few were directly nutritive foods such as mixed birdseed or domestic cats. The most dominant food item in coyote diets was white-tailed deer, measured by frequency of occurrence and percent volume per scat. Plant materials were common in scats, yet attributed very little volume overall. Opportunistic sampling detected relatively equivalent diet items compared with trail-transect sampling strategies. Therefore, trail-transect samples are not biased by collecting scats within natural areas along trails used by coyotes.

I found that coyote diets varied among biological seasons, and may reflect a shift in foraging when food sources are seasonally available. For example, the frequency of white-tailed deer decreased during dispersal season (September–December), yet plant materials increased. This is likely due to the increased use of fruits that were available, such as black cherry and apple. Rabbits and small mammals decreased in frequency of occurrence when other food items increased, such as white-tailed deer and insects. This may be a result of increased availability during summer, when insect abundance is likely at its highest, and fawns are present. Interestingly, anthropogenic items, although mostly non-nutritive, occurred more frequently during breeding season. This may be related to behavioral changes, as 1 coyote in Westchester County increased use of residential areas during the breeding season (Chapter 3). However, this also could be a result of coyotes occasionally eating trash or litter during late winter months.

I found slightly more anthropogenic items by frequency of occurrence in southern study towns (9.1%) than in northern study towns (3.7%). This finding provides evidence that coyotes did not make frequent use of anthropogenic foods overall, yet more human-related items were associated with coyote diets from the more heavily human-populated area. Only 1 town (Somers) required trash be placed at roadsides in trashcans with secure lids, and the other 3 towns permitted trash bags for collections. As noted by Morey et al. (2007), trash collections occurred once per week, providing opportunities for coyotes to scavenge refuse. However, coyotes did not seem to utilize this potential food source. I did not find evidence of localized concentrations of human-subsidies among trail-transects, although samples sizes for most trails were low. Coyotes occasionally consumed anthropogenic items, mostly non-nutritive, but relied primarily on a natural diet.

The potential risk that coyotes might pose to pets is a relatively common concern of stakeholders (85% of respondents) in Westchester County (Wieczorek Hudenko 2008*a*). My diet analyses found no evidence of coyotes eating dogs. These results were similar to other studies (Atkinson and Shackleton 1991, Quinn 1997, Fedriani et al 2001, Bogan and Kays 2005, Morey et al. 2007), as few report domestic dog remains in coyote scats. However, coyotes were known to attack and occasionally kill dogs (Chapter 2). Coyote–dog interactions are commonly reported to NYSDEC (Chapter 2). Consequently, coyote–dog interactions are not predatory, but are likely territorial conflicts between conspecifics. Coyotes are territorial and have been observed defending areas through outward aggression towards intruding coyotes (Gese 2001). Similarly, coyotes may perceive dogs as a potential competitor and act territorial or aggressively towards animals (Chapter 2). In fact, several accounts of people injured by coyotes were incidents where coyotes initially attacked a dog and the owner intervened (Baker and Timm 1998, Timm et al. 2004, White and Gehrt 2009). Whereas dogs may be injured or killed by coyotes related to territorial behaviors, domestic cats are eaten by coyotes.

I found evidence that 2 cats (0.45% of n = 442 scats) were consumed during the study. In Chicago, Illinois, the overall proportion of cats detected in coyote scats was also low (1.3%), however this varied by site from a minimum of 0.4% in a less human-developed study site, to a maximum of 6.7% in the most urban study site (Morey et al. 2007). Other studies in residential and urbanized lands have found cat remains in approximately 13% of scats collected in a residential area (n = 735 scats) of Washington State (Quinn 1997) and in southern California (Shargo 1988). However, the sample size (n = 22) from southern California was limited, and may not accurately describe coyote diets. While these studies report more elevated frequencies of cats in coyote diets, other studies typically report trace amounts in scats (<1–5%) similar to this study (Atkinson and Shackleton 1991, Fedriani et al 2001, Bogan and Kays 2005).

In Chicago, small mammals were the dominant food item in urban areas (Morey et al. 2007). In this study, white-tailed deer was the dominant food item and cottontail occurred less than anticipated. A study of coyote diets in Albany, New York, found cottontails in higher proportion than deer (Bogan and Kays 2005). Although available prey species were not quantified in either study, the differences between diets may be due to habitat characteristics. The study in Albany occurred in a heavily managed forest preserve with a mix of successional habitats (Barnes 2003), while natural areas in Westchester County typically were mature forests with poorly regenerating forest understories. Albany likely had more available cottontails, as indicated by the coyote diets in the area.

I found white-tailed deer consumption varied by season and by comparison of northern and southern study towns. This variation may occur due to the seasonal availability of plant materials. During the fall, most scats (96.4%) contained some type of plant materials, dominated by grasses, grape, unknown seeds, apple, and black cherry. Natural areas did have existing fruiting vegetation such as black cherry, apple trees, and grape vines and may have been the source, although it is difficult to determine exactly where coyotes ingested these fruits. Perhaps fruiting trees in residential areas could be a food attractant (Baker and Timm et al. 1998).

Considerations of Scat Surveys

Using scat collections to understand animal diets comes with a few caveats. It is difficult to determine what animals were consumed as live prey rather than being scavenged by coyotes. This is a complicating issue for understanding coyote relationships with prey such as white-tailed deer or domestic cats. Interestingly, I found a limited number of scats that contained fly (Diptera) larvae with animal remains, which suggests scavenging. Scat analyses are further limited in ability to identifying the number of individual prey consumed. For example white-tailed deer was the most dominant food item, yet few deer may have been consumed to produce many scats (Ackerman et al. 1984). Conversely, 2–3 *Microtus* were detected within a single coyote scat. The number of individuals consumed may be overestimated for large-bodied animals, and underestimated for small mammals, such as *Microtus* (Floyd 1978, Ackerman et al. 1984).

Additionally, collecting sufficient samples to adequately describe diets is an important issue. I sampled scats at 26 different trails for 31 trail-transect measures during 2 years. Eighty-four percent of the trail-transects had insufficient sample sizes to describe coyote diets for the trail, so I subsequently pooled samples for northern and southern transects. This prevented investigating coyote diets at the trail-transect level within the landscape gradient.

MANAGEMENT IMPLICATIONS

I found sparse evidence of coyotes utilizing anthropogenic food sources. My results are in agreement with recent human dimensions and ecology studies in Westchester County (Wieczorek Hudenko 2008a, Weckel et al. 2010, Bogan et al. 2008, Chapter 2, Chapter 3). Specifically, I found very little evidence of human–coyote interactions associated with foraging (e.g., food attractants or pet conflicts), and human interactions (Wieczorek Hudenko 2008*a*, *b*; Chapter 2). Coyotes typically were associated with natural areas (Weckel et al. 2010, Chapter 3). Despite the low level of coyote interactions, coyotes living near residential areas posed a concern voiced by residents, and many people requested more information about coyotes (Wieczorek Hudenko 2008*a*). However, coyotes in Westchester County primarily subsisted on natural foods and lived in natural areas (Chapter 3) and are not subsidized by anthropogenic foods, and this may likely limit human–coyote conflicts.

REFERENCES

Ackerman, B. B., F. G Lindzey, and T. P. Hemker. 1984. Cougar food habits in Southern Utah. Journal of Wildlife Management 48:147–155.

Andelt, W. F. 1985. Behavioral ecology of coyotes in South Texas. Wildlife Monographs No. 94, the Wildlife Society, Bethesda, Maryland, USA

Atkinson, K. T., and D. M. Shackleton. 1991. Coyote, *Canis latrans*, ecology in a rural–urban environment. Canadian Field-Naturalist 105:49–54.

Baker, R. O., and R. M Timm. 1998. Management of conflicts between urban coyotes and humans in Southern California. Proceedings of the Vertebrate Pest Conference 18:299–312.

Barnes, J. K. 2003. Natural history of the Albany Pine Bush, Albany and Schenectady Counties, New York: field guide and trail map. New York State Museum Bulletin 502, Albany, New York, USA.

Bino, G., A. Dolev, D. Yosha, A. Guter, R. King, D. Saltz, and S. Kark. 2010. Abrupt spatial and numerical response of overabundant foxes to a reduction in anthropogenic resources. Journal of Applied Ecology 47:1262–1271.

Bogan, D. A., and R. W. Kays. 2005. Ecological trap dynamics of a coyote population in a fragmented suburban forest preserve. 90th Annual meeting of the Ecological Society of America, 4–12 August 2005, Montreal, Canada.

Bogan, D. A., P. D. Curtis, and G. F. Albers. 2009. Numerically common, functionally rare: difficulties in detecting urban coyotes for population monitoring. Proceedings of the Wildlife Damage Management Conference 13:164–171.

Bounds, D. L. and W. W. Shaw. 1994. Managing coyotes in U.S. national parks: human–coyote interactions. Natural Areas Journal 14:280–284.

Carbyn, L. N., 1989. Coyote attacks on children in western North America. Wildlife

Society Bulletin 17:444–446

Cornell, D., and J. E. Cornely. 1979. Aversive conditioning of campground coyotes in Joshua Tree National Monument. Wildlife Society Bulletin 7:129–131.

Curtis, P. D., D. A. Bogan, and G. Batcheller. 2007. Suburban coyote management and research needs: a northeast perspective. Proceedings of the Wildlife Damage Management Conference 12:413–417.

Don Carlos, A. W., A. D. Bright, T. L. Teel, and J. J. Vaske. 2009. Human–black bear conflict in urban areas: an integrated approach to management response. Human Dimensions of Wildlife 14:174–184.

Elbroch, M. 2006. Animal skulls: a guide to North American species. Stackpole, Mechanicsburg, Pennsylvania, USA.

Fararr, R. O. 2007. Assessing the impacts of urban coyote on people and pets in Austin, Travis County, Texas. Proceedings of the Wildlife Damage Management Conference 12:334–341.

Fedriani, J. M., T. K. Fuller, R. M. Sauvaiot. 2001. Does availability of anthropogenic food enhance densities of omnivorous mammals? An example with coyotes in southern California. Ecography 24:325–331.

Fedriani, J. M., and M. H. Kohn. 2001. Genotyping faeces links individuals to their diet. Ecology Letters 4:477–483.

Floyd, T. J., L. D. Mech, and P. A. Jordan. 1978. Relating wolf scat content to prey consumed. Journal of Wildlife Management 42:528–532.

Gehrt, S. D., C. Anchor, and L. A. White. 2009. Home range and landscape use of coyotes in metropolitan landscape: conflict of coexistence? Journal of Mammalogy 90:1045–1057.

Gese, E. M. 2001. Territorial defense by coyotes (*Canis latrans*) in Yellowstone National Park, Wyoming: who, how, where, when, and why. Canadian Journal of Zoology 79:980–987.

Gese, E. M., O. J. Rongstand, and W. R. Mytton. 1988. Relationship between coyote group size and diet in southeastern Colorado. Journal of Wildlife Management 52:647–653.

Gompper, M. E., R. W. Kays, J. C. Ray, S. D. LaPoint, D. A. Bogan, and J. R. Cryon. 2006. A comparison of noninvasive techniques to survey carnivore communities in Northeastern North America. Wildlife Society Bulletin 34:1142–1151.

Grigione, M. M., P. Burman, S. Clavio, S. J. Harper, D. Manning, and R. J. Sarno. 2011. Diet of Florida coyotes in a protected wildlife and suburban habitat. Urban Ecosystems 14:655–663.

Hidalgo-Mihart, M. G., L. Cantu-Salazar, C. A. Lopez-Gonzalez, E. C. Fernandez, and A. Gonzalez-Romero. 2004. Effect of a landfill on the home range and group size of coyotes (*Canis latrans*) in a tropical deciduous forest. Journal of Zoological Society of London 263:55–63.

Howell, R. G. 1982. The urban coyote problem in Los Angeles County. Proceedings of the Vertebrate Pest Conference 10:21–23.

Kays, R. W., M. E. Gompper, and J. C. Ray. 2008. Landscape ecology of eastern coyotes based on large-scale estimates of abundance. Ecological Applications 18:1014–1027.

Knight, J. 2009. Making wildlife viewable: habituation and attraction. Society and Animals 17:167–184.

Lang, S. S. 2005. Why are coyotes getting more aggressive? Cornell five-year study intends to find out. Cornell University News Service. <http://www.news.cornell.edu/stories/May05/coyotes.study.ssl.html> Accessed 15 July 2010.

Laundré, J. W., and B. L. Keller. 1981. Home range use by coyotes in Idaho. Animal Behavior 29:449–461.

Litvaitis, J. A. 2000. Investigating food habits of terrestrial vertebrates. Pages 165–183 *in* L. Boitani and T. K. Fuller, editors. Research Techniques in Animal Ecology, Controversies and Consequences. Columbia University Press, New York, USA.

Lukasik, V. M., and S. M. Alexander. 2011. Human–coyote interactions in Calgary, Alberta. Human Dimensions of Wildlife 16:114–127.

Moore, T. D., L. E. Spence, and C. E. Dugnolle. 1974. Identification of the dorsal guard hairs of some mammals of Wyoming. Wyoming Game and Fish Department Bulletin No. 14, Laramie, Wyoming, USA.

Morey, P. S., E. M. Gese, and S. D. Gehrt. 2007. Spatial and temporal variation in the diet of coyotes in the Chicago Metropolitan area. American Midland Naturalist 158:147–161.

Ott, R. L., and M. Longnecker. 2001. An introduction to statistical methods and data analysis. Fifth edition. Duxbury, Pacific Grove, California, USA.

Prange, S. and S. D. Gehrt. 2004. Changes in mesopredator-community structure in response to urbanization. Canadian Journal of Zoology 82:1804–1817.

Prugh, L. R. and C. E. Ritland. 2005. Molecular testing of observer identification of carnivore feces in the field. Wildlife Society Bulletin 33:189–194.

Quinn, T. 1997. Coyote (*Canis latrans*) food habits in three urban habitat types of western Washington. Northwest Science 71:1–5.

Rezendez, P. 1999. Tracking and the art of seeing: how to read animal tracks and sign. Second edition. HarperCollins, New York, New York, USA.

Samson, C. and M. Crete. 1997. Summer food habits and population density of coyotes, *Canis latrans*, in boreal forests of southeastern Quebec. Canadian

Field-Naturalist 111:227–233.

Shargo, E. S. 1988. Home range, movements and activity patterns of coyotes (*Canis latrans*) in Los Angeles suburbs. Dissertation, University of California, Los Angeles, USA.

Siemer W. F., H. Wieczorek Hudenko, and D. J. Decker. 2007. Coyote management in residential area: human dimensions research needs. Proceedings of the Wildlife Damage Management Conference 12:421–430.

Timm, R. M., R. O. Baker, J. R. Bennett, and C. C. Coolahan. 2004. Coyotes attacks: an increasing suburban problem. Transactions of the North American Wildlife and Natural Resources Conference 69:67–88.

U.S. Census Bureau. 2008. <http://www.census.gov/geo/www/ua/ua_2k.html>. Accessed 5 October 2009.

Weaver, J. L., and S. W. Hoffman. 1979. Differential detectability of rodents in coyote scats. Journal of Wildlife Management. 43:783–786.

Weckel, M. E., D. Mack, C. Nagy, R. Christie, and A. Wincorn. 2010. Using citizen science to map human–coyote interaction in suburban New York, USA. Journal of Wildlife Management 74:1163–1171.

White, L. A., and S. D. Gehrt. 2009. Coyote attacks on humans in the United States and Canada. Human Dimensions of Wildlife. 14:419–432.

Whittaker, D., and R. L. Knight. 1998. Understanding wildlife responses to humans. Wildlife Society Bulletin 26:312–317.

Wieczorek Hudenko, H., D. J. Decker, and W. F. Siemer. 2008*a*. Stakeholder insights into the human–coyote interface in Westchester County, New York. Human Dimensions Research Unit, Cornell University 08-1, Ithaca, New York, USA.

Wieczorek Hudenko, H., D. J. Decker, and W. F. Siemer. 2008*b*. Living with coyotes in suburban areas: insights from two New York State counties. Cornell University Human Dimensions Research Unit HDRU Series No. 08-8, Ithaca, New York, USA.

CHAPTER 5

MANAGEMENT IMPLICATIONS AND CONCLUDING REMARKS

A challenge of modern wildlife conservation and management is maintaining ecosystem integrity while providing desirable and safe conditions for people and wildlife to coexist. Conserving ecosystem integrity involves maintaining viable, self-sustaining wildlife populations and inseparable ecological processes, while considering humans as an integral part of the environment (Grumbine 1997). In urban landscapes, new challenges are emerging as recovering and expanding wildlife populations are subsequently interacting with people, and increasing the potential for conflicts (Timm et al. 2004, Boruch–Mordo 2008, Kretser et al. 2008, Markovchich–Nicholls et al. 2008, Don Carlos et al. 2009). In the United States, over 80% of the population lives in urban landscapes. Many of the requests for assistance from urban residents are non-traditional wildlife issues (Lindsy and Adams 2006). Therefore, it is necessary to find solutions to effectively manage human–wildlife interactions for a desirable end that meet expectations of informed stakeholders (Grumbine 1994, Decker 1997, Riley et al. 2002, Riley et al. 2003).

The recent occurrence of human–coyote (*Canis latrans*) interactions across urbanized landscapes of New York State exemplifies this emerging urban wildlife issue. Apparent increases in human–coyote interactions reported to the New York State Department of Environmental Conservation (NYSDEC) motivated the agency to implement standard operating procedures to guide management responses (i.e., recommendations) to the occurrence of reported conflicts (NYSDEC 2005). Additionally, NYSDEC engaged the Department of Natural Resources at Cornell University to conduct a situational analysis as part of a planning process to inform management (Lang 2005, Siemer 2007, Wieczorek Hudenko 2008*d*). This prompted an integrated ecological and human dimension study to further understand human–coyote interactions, potential for objective and perceived risks, and potential alternative solutions for managing conflicts. Though the initial conception and expectations for the integrated research project was not fully implemented (Table 1.1) the findings of both the human dimensions and ecological research have converged on similar outcomes. This dissertation addressed the basic and applied research needs by improving our understanding of reported human–coyote interactions and the ecological component of the management environment.

Monitoring Coyote Incident Reports

Human–coyote interactions may lead to risks to people and pets, or may cause elevated concern for potential conflicts. Some of the first investigations of human–coyote interactions used unconventional sources to obtain information about conflict events (Howell 1982, Carbyn 1989, Baker and Timm 1998, Timm et al. 2004). Because the issue was relatively new, no wildlife agency conducted systematic monitoring of human–coyote conflicts. Researchers investigated newspaper articles and sparse records collected by municipalities and public agencies for insight into conflicts (Howell 1982, Carbyn 1989, Baker and Timm 1998, Timm et al. 2004). However, human–coyote interactions motivate concerned stakeholders to report their wildlife interactions to government agencies and wildlife professionals (Farrar 2007, Lukasik and Alexander 2011, Chapter 2). Recently, wildlife professionals have turned attention to these reports as a source for learning more about human–wildlife interactions (Farrar 2007, Baruch-Mordo et al. 2008, Kretser et al. 2008, Lukasik and Alexander 2011, Merkle et al. 2011).

Concerned stakeholders may report incidents (e.g., sightings, interactions, or conflicts) with coyotes to state wildlife agencies. However, coyote incident reports

(CIR) filed with NYSDEC occurred in different frequencies when compared with an alternative Internet-based method (Coyote Web-reports, CWR; Chapter 2). Fewer reports and sightings of coyotes were reported to the agency than to the Internet reporting system. Perhaps this may lead to a limited or biased perspective by agencies that monitor incident reports to gain insight into patterns of human–coyote interactions. In fact, I found that incident reports are likely unreliable for monitoring interactions at a large spatial-scale, and may be unreliable for either a near-term study or a longitudinal study over a longer period (Chapter 2).

Stakeholders may not readily recognize state wildlife agencies as a point-of-contact for assistance and information about wildlife (Reiter et al. 1999, Wieczorek Hudenko 2008*a*, *b*) and reporting may be diffused among various entities (e.g., local police departments, nature centers, and county or town parks departments). Interestingly, CWR received a greater proportion of sightings, and the general reporting pattern was more similar to a random survey of stakeholders in Westchester County, New York (Wieczorek Hudenko 2008*a*). To prevent developing a skewed perspective on the frequency and magnitude of human–coyote interactions, wildlife agencies may alleviate this issue by using multiple methods to monitor for all types of human–coyote interactions, such as an Internet-accessible reporting system. Specialized reporting systems (Quinn 1995, Farrar 2007, Lukasik and Alexander 2011) have recorded many more reports of coyotes from smaller focal areas than were reported to NYSDEC from the entire state (Chapter 2). Yet ultimately, stakeholder reports may not adequately represent wildlife population trends (Howe et al. 2010) or the frequency of human–coyote interactions (Chapter 2).

If robust measures of stakeholder tolerance of objective and perceived risks are needed for management decisions, then perhaps the best strategy to scope the issue will be to conduct a strategic survey of stakeholders. Random or systematic survey methods, as opposed to convenience sampling (e.g., non-random incident reports) will provide a more thorough analysis of the issue by providing better definition of the magnitude and prevalence of conflicts in context with other measures of interactions. Additionally, stakeholder surveys can be conducted more rapidly than studying arduous samples of coyotes to learn about the prevalence of conflict behaviors. However, conflicts do occur and wildlife professionals are interested in developing alternative methods, such as non-lethal techniques, to prevent severe conflicts and human injury from occurring.

Urban Ecology and Conflicts

Studies from across North America are finding that coyotes inhabiting urbanized landscapes typically remain embedded in natural areas (Grinder and Krausman 2001, Way et al. 2002, Quinn 1997, Riley et al. 2003, Bogan 2004, Gehrt et al. 2009, Grubbs and Krausman 2009). However, the interface between natural areas and residential areas do increase the potential for interactions and occasional conflicts to occur (Quinn 1997, Weckel et al. 2009). Coyote populations appear to avoid interactions with humans by limiting use of heavily developed urban areas and dense residential areas. The results of my spatial ecology study agree with these findings. Only 1 other study of urban coyotes documented the occurrence of radio collared and tagged coyotes exhibiting nuisance behaviors (Gehrt et al. 2009). In Chicago, few (4%, $n = 7$) coyotes were documented to develop problematic behaviors, of which 3 were residents and 4 were transients (Gehrt et al. 2009). Three individuals exhibited mange when conflict behaviors developed (Gehrt et al. 2009). In my study, I documented 1 case of a radio-collared female coyote interacting with domestic dogs. This event persisted for approximately 4 weeks before the coyote seemingly reverted back to her pervious movement patterns. It is unclear whether the cessation of conflict behavior resulted from internal stimuli or external stimuli, yet clearly occurred before researcher intervention (Chapter 4). These results have important implications for others that may be interested developing non-lethal methods for conflict management in urban field-research settings.

This research project was formulated to identify problem-causing coyotes with the expectation of field testing non-lethal options to manage human–coyote conflicts. Methods such as aversive conditioning through conditioned taste aversion or hazing were identified as potentially valuable management strategies. However, due to the limited duration of conflict-behaviors exhibited by 1 coyote, no suitable opportunity to field-test aversive conditioning occurred during the study. The potential for field-testing aversive conditioning methods and measuring an experimental response may be quite difficult. I was unable to field-test aversive conditioning because conflict interactions were very infrequent. Moreover, sightings of the radio collared coyotes by researchers and residents were rare (Bogan et al. 2009). In order to adequately field-test aversive conditioning, several individuals exhibiting conflict behaviors will be required for comparison between experimental treatment and control animals. If conflict behaviors are short-lived, then measuring a before and after treatment affect may be greatly limited, and this will confound experimental results. Field-testing may only determine failure of treatments to elicit a desirable response, while positive confirmations may be confounded by false positives, committing a type I error.

Despite the lack of conflicts, human tolerance for coyotes was low in Westchester County (Wieczorek Hudenko 2008*a*). If aversive conditioning methods are developed, there remains a need to determine strategies for implementation (i.e., who will implement the methods, private home owners or nuisance wildlife control operators?). Additionally, the likelihood of implementing non-lethal, behavioral modification may be questionable if conflicts become more prevalent, and occur with greater intensity and frequency, potentially surpassing stakeholder acceptance capacity. Essentially, aversive conditioning methods are likely to be most appropriate when conflicts are infrequent and pose low levels of risks. Yet, developing and testing options under these conditions will be difficult. If conflicts become more prevalent, then stakeholders may seek lethal management of nuisance or problematic coyotes. However, there remains potential for aversive conditioning strategies in circumstances when conflicts remain infrequent, and less severe, such as interactions involving emboldened coyotes (Figure 3.1).

Few people responded to sightings of coyotes (Wieczorek Hudenko et al. 2008*b,* Chapter 2), with the exception of coyotes that interacted with pets (Chapter 2). People indicated they attempted to chase or haze coyotes that interacted with pets. This may indicate that people perceived risks to pets as more imminent, and in need of immediate intervention. Yet, intervening in coyote attacks on pets may put people at risk of injury, as described in southern California (Baker and Timm 1998, Timm et al. 2004, White and Gehrt 2009). Perhaps more people could be encouraged to haze coyotes sighted in residential and developed areas to further limit conflicts, as promoted in Vancouver, B.C. (Worcester and Boelens 2007). Wildlife professionals taught people through demonstration to respond to the presence of coyotes with loud and aggressive behavior (Worcester and Boelens 2007). This method may be best practiced by adults at safe distances from coyotes.

Maintaining few food attractants for coyotes, and increasing risks to coyotes (e.g., resident hazing) may prevent conflict behaviors from developing. However, I found limited evidence of coyotes using human sources of food, and this may help explain why conflicts are infrequent. In other regions, conflicts occurred where human-sources of food were available and used by coyotes (Cornell and Cornely 1979, Bounds and Shaw 1994). Use of anthropogenic food items subsidize diets of urban coyote populations and increase their abundance (Fedriani et al. 2001, Hidalgo-

Mihart et al. 2004). The combination of increased abundance and proximity of coyotes to humans may raise the potential for interactions and conflicts. If coyotes use anthropogenic foods and develop conflict behaviors, then it may be possible to alleviate the issue by removing the food resources, as found with foxes in Israel (Bino et al. 2010).

Future research should explore potential ways to increase human awareness and tolerance, and reduce perceived risks of coyotes, while encouraging safe practices to dissuade negative interactions. A combination of information communication and outreach targeting urban coyote issues, and encouragement of people to haze coyotes, may increase tolerance and decrease concerns of potential interactions with coyotes (Worcester and Boelens 2007). Future research should examine strategies to align stakeholder concern of perceived risks with objective risks from coyotes. Perhaps methods to inform and empower stakeholders, while desensitizing their response to wildlife may alleviate concern (Worcester and Boelens 2007, Zinn et al. 2008).

I found that examining human coyote–interactions and studying the ecology of coyotes in Westchester County, New York, provided a better understanding of the nature of conflicts. The integration and convergence of the outcomes from the human dimensions study supported my research findings. Overall, I found no evidence for targeted management intervention at the landscape level in Westchester County. If conflicts occur, then future lethal management of coyotes in residential and suburban lands should target individual coyotes in the specific areas experiencing conflicts. Coyotes currently appear to avoid human–developed areas and direct interactions with landowners.

REFERENCES

Baker, R. O., and R. M. Timm. 1998. Management of conflicts between urban coyotes and humans in southern California. Proceedings of the Vertebrate Pest Conference 18:299–312.

Baruch-Mordo, S., S. W. Breck, and D. M. Theabold. 2008. Spatiotemporal distribution of black bear–human conflicts in Colorado, USA. Journal of Wildlife Management 72:1853–1862.

Bino, G., A. Dolev, D. Yosha, A. Guter, R. King, D. Saltz, and S. Kark. 2010. Abrupt spatial and numerical response of overabundant foxes to a reduction in anthropogenic resources. Journal of Applied Ecology 47:1262–1271.

Bogan, D. A. 2004. Eastern coyote home range, habitat selection and survival in the Albany Pine bush landscape. Thesis, State University of New York, University at Albany, Albany, New York, USA.

Bogan, D. A., P. D. Curtis, and G. F. Albers. 2009. Numerically common, functionally rare: difficulties in detecting urban coyotes for population monitoring. Proceedings of the Wildlife Damage Management Conference 13:164–171.

Bounds, D. L., and W. W. Shaw. 1994. Managing coyotes in U.S. national parks: human–coyote interactions. Natural Areas Journal 14:280–284.

Carbyn, L. N. 1989. Coyote attacks on children in western North America. Wildlife Society Bulletin 17:444–446.

Cornell, D., and J. E. Cornely. 1979. Aversive conditioning of campground coyotes in Joshua Tree National Monument. Wildlife Society Bulletin 7:129–131.

Don Carlos, A. W., A. D. Bright, T. L. Teel, and J. J. Vaske. 2009. Human–black bear conflict in urban areas: an integrated approach to management response. Human Dimensions of Wildlife 14:174–184.

Fararr, R. O. 2007. Assessing the impacts of urban coyote on people and pets in Austin, Travis County, Texas. Proceedings of the Wildlife Damage Management Conference 12:334–341.

Fedriani, J. M., T. K. Fuller, R. M. Sauvaiot. 2001. Does availability of anthropogenic food enhance densities of omnivorous mammals? An example with coyotes in southern California. Ecography 24:325–331.

Gehrt, S. D., C. Anchor, and L. A. White. 2009. Home range and landscape use of coyotes in a metropolitan landscape: conflict or coexistence? Journal of Mammalogy 90:1045–1057.

Grinder, M. I., and P. R. Krausman. 2001. Home range, habitat use, and nocturnal activity of coyotes in an urban environment. Journal of Wildlife Management 65:887–898.

Grubbs, S. E., and P. R. Krausman. 2009. Use of urban landscape by coyotes. Southwestern Naturalist 54:1–12.

Grumbine, R. E. 1994. What is ecosystem management? Conservation Biology 8:27–38.

Grumbine, R. E. 1997. Reflections on "What is ecosystem management?" Conservation Biology 11:41–47.

Hidalgo-Mihart, M. G., L. Cantu-Salazar, C. A. Lopez-Gonzalez, E. C. Fernandez, and A. Gonzalez-Romero. 2004. Effect of a landfill on the home range and group size of coyotes (*Canis latrans*) in a tropical deciduous forest. Journal of Zoological Society of London 263:55–63.

Howell, R. G. 1982. The urban coyote problem in Los Angeles County. Proceedings of the Vertebrate Pest Conference 10:21–23.

Lindsey, K. J., and C. E. Adams. 2006. Public demand for information and assistance at the human–wildlife interface. Human Dimensions of Wildlife 11:267–283.

New York State Department of Environmental Conservation (NYSDEC). 2005. New York State's Coyote Incident Standard Operating Procedures. Bureau of Wildlife, Division of Fish, Wildlife & Marine Resources, New York State Department of Environmental Conservation, Albany, New York, USA.

Quinn, T. 1997. Coyote (*Canis latrans*) habitat selection in urban areas of western Washington via analysis of routine movements. Northwest Science 71:289–297.

Riley, S. P. D., R. M. Sauvajot, T. K. Fuller, E. C. York, D. A. Kamradt, C. Bromley, and R. K. Wayne. 2003. Effects of urbanization and habitat fragmentation on bobcats and coyotes in southern California. Conservation Biology 17:566–576.

Timm, R. M., R. O. Baker, J. R. Bennett, and C. C. Coolahan. 2004. Coyotes attacks: an increasing suburban problem. Proceedings of the Vertebrate Pest Conference 21:47–57.

Way, J. G., I. M. Ortega, and P. J. Auger. 2002. Eastern coyote home range, territoriality, and sociality on urbanized Cape Cod. Northeast Wildlife 57:1–18.

Weckel, M. E., D. Mack, C. Nagy, R. Christie, and A. Wincorn. 2010. Using citizen science to map human–coyote interaction in suburban New York, USA. Journal of Wildlife Management 74:1163–1171.

White, L. A., and S. D. Gehrt. 2009. Coyote attacks on humans in the United States and Canada. Human Dimensions of Wildlife 14:419–432.

Wieczorek Hudenko, H., D. J. Decker, and W. F. Siemer. 2008*a*. Living with coyotes in suburban areas: insights from two New York State counties. Cornell University Human Dimensions Research Unit HDRU Series No. 08-8, Ithaca, New York, USA.

Wieczorek Hudenko, H., D. J. Decker, and W. F. Siemer. 2008*b*. Humans and coyotes in suburbia: can experience lead to sustainable coexistence? Cornell University Human Dimensions Research Unit HDRU Series No. 08-9, Ithaca, New York, USA.

Worcester, R. E., and R. Boelens. 2007. The co-existing with coyotes program in Vancouver, B.C. Proceedings of the Wildlife Damage Management Conference 12:393–397.

Zinn, H. C., M. J. Manfredo, and D. J. Decker. 2008. Human conditioning to wildlife: steps towards theory and research. Human dimensions of Wildlife 13:388–399.

APPENDIX A

NATIONAL LAND COVER DATA

The 14 original land cover classifications of the National Land Cover Database (2006) that occurred in Westchester County, New York USA, were simplified into 6 general categories for analyses. Data provided by the Multi-Resolution Land Characteristics consortium (MRLC) was made available by Fry et al. (2011) and is available for electronic download (National Land Cover Database 2006).

<table>
<tr><th>Original classification</th><th>Area (%)</th><th>Reclassification</th><th>Area (%)</th></tr>
<tr><td>21. Developed, open space</td><td>23.08</td><td>Developed, open space</td><td>23.1</td></tr>
<tr><td>22. Developed, low intensity</td><td>10.10</td><td>Developed, low intensity</td><td>10.1</td></tr>
<tr><td>23. Developed, medium intensity</td><td>7.07</td><td rowspan="2">Developed, medium-high intensity</td><td rowspan="2">9.6</td></tr>
<tr><td>24. Developed, high intensity</td><td>2.50</td></tr>
<tr><td>41. Deciduous forest</td><td>36.29</td><td rowspan="3">Forest</td><td rowspan="3">41.7</td></tr>
<tr><td>42. Evergreen forest</td><td>4.83</td></tr>
<tr><td>43. Mixed forest</td><td>0.57</td></tr>
<tr><td>52. Shrub/scrub</td><td>0.51</td><td rowspan="4">Crops & shrub</td><td rowspan="4">4.0</td></tr>
<tr><td>71. Grassland/herbaceous</td><td>0.17</td></tr>
<tr><td>81. Pasture/hay</td><td>3.28</td></tr>
<tr><td>82. Cultivated crops</td><td>0.09</td></tr>
<tr><td>90. Woody wetlands</td><td>2.18</td><td rowspan="3">Water & wetlands</td><td rowspan="3">11.5</td></tr>
<tr><td>95. Emergent herbaceous wetlands</td><td>0.48</td></tr>
<tr><td>11. Open water</td><td>8.82</td></tr>
<tr><td>Total</td><td>100</td><td></td><td>100</td></tr>
</table>

REFERENCES

Fry, J. A., G. Xian, S. Jin, J. A. Dewitz, , C. G. Homer, L. Yang, C. A. Barnes, N. D. Herold, and J. D. Wickham. 2011. Completion of the 2006 National Land Cover Database for the Conterminous United States. Photogrammetric Engineering and Remote Sensing 77:858–864.

National Land Cover Database. 2006. Multi-Resolution Land Characteristics Consortium. <http://www.mrlc.gov/nlcd06_data.php>. Accessed 10 June 2011.

APPENDIX B

DEMOGRAPHIC INFORMATION

MORTALITY AND FATES: Fate and status of coyotes captured for live study in Westchester County, New York, USA, March 2006–December 2008.

Fate	Category	Occurrence (*n*)
Mortality	Vehicle-killed	7
(*n* = 16)	Capture related	2
	Shot	3
	Rodenticide poisoning	1
	Malnourished pup	1
	Euthanized (Illegal)	1
	Drowning	1
Dispersed & dead	Shot	2
(*n* = 4)	Vehicle-killed	2
Missing	Unknown	4
(*n* = 17)	Possible dispersal	8
	Suspected tracking device failure [1]	5
Tracking	Alive at end of study	5[2]
(*n* = 5)		

[1] Suspected GPS/VHF tracking collar failure suspected due to malfunctions prior to completely losing touch with devices.
[2] Three coyotes have since died, 1 vehicle related, 2 trapped by a nuisance wildlife control operator. As of December 2009, only 2 coyotes being tracked at the end of the study remained unaccounted for with unknown fates.

INDICATORS OF COYOTE REPRODUCTION: Evidence of lactation was determined for female coyotes at the time of capture (*n* = 22), and evidence of lactation and placental scarring was determined for female coyotes (*n* = 6) recovered after mortality events. Female coyotes were captured for live study in Westchester County, New York, USA, during March 2006–December 2008. The number of placental scars detected were 3, 6, and 9 for females with scarring.

Age group at the time of capture	Evidence of lactation at the time of capture	Evidence of lactation at the time of necropsy	Evidence of placental scarring at time of necropsy
Pups (*n* = 4)	0	0	0
Juveniles (*n* = 6)	0	0	0
Adults (*n* = 12)	6	8	3