THE EFFECT OF HABITAT FRAGMENTATION ON MESOCARNIVORE RELATIVE ABUNDANCE IN AN URBAN LANDSCAPE

by

Kelsey M. Schwenk

A thesis submitted to the Faculty of the University of Delaware in partial fulfillment of the requirements for the degree of Honors Bachelor of Science in Wildlife Conservation and Agriculture and Natural Resources

Spring 2014

THE EFFECT OF HABITAT FRAGMENTATION

ON MESOCARNIVORE RELATIVE ABUNDANCE

IN AN URBAN LANDSCAPE

by

Kelsey M. Schwenk

Approved: ____

Jacob L. Bowman, Ph.D.
Professor in charge of thesis on behalf of the Advisory Committee

Approved: ____

W. Greg Shriver, Ph.D.
Committee member from the Department of Entomology and Wildlife Ecology

Approved: ____

Cristina Bacuta, Ph.D.
Committee member from the Board of Senior Thesis Readers

Approved: ____

Michael Arnold, Ph.D.
Director, University Honors Program

ACKNOWLEDGMENTS

I would like to extend my sincerest appreciation to my thesis advisor, Dr. Jacob Bowman. This research project would not have been possible without the time he invested into the project and his constant guidance during the field season, data collection, and data analysis process. His continual encouragement also fostered my passion for wildlife research, and for that I am so thankful. I would also like to thank the other members of my thesis committee, Dr. Gregory Shriver and Dr. Cristina Bacuta, for their support through the progression of my paper and affirming my ability to complete my thesis.

A great deal of time and effort was spent in the field and I would like to extend my gratitude to fellow students Devon Knauss, Samantha Fino, and Shyanne Miller who were all an integral part in setting up the survey sites and collecting data. The survey sites were situated in public and private lands, therefore I would like to thank the homeowners, businesses, and landowners who allowed us to conduct research or travel through their properties to access the survey sites.

Finally, I would like to thank my family and friends. Their perpetual support has been vital to my wildlife conservation studies and reaching many goals throughout my academic career.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The objective of this study was to identify landscape variables associated with habitat fragmentation, which predicted the presence of mesocarnivores in urban landscapes. I used remote cameras to detect mesocarnivores in 21 urban forest fragments in Newark, Delaware. I conducted remote camera surveys June 2012 through July 2012 and June 2013 through July 2013. Using linear regression models, I determined if any of the following 6 landscape characteristics (i.e. proportion of multiflora rose cover within the plot; distance to the nearest road, stream, and house; patch size; and patch area to perimeter ratio) were related to species richness and relative abundance of northern raccoon (*Procyon lotor*), red fox (*Vulpes vulpes*), Virginia opossum (*Didelphis virginiana*), and domestic cat (*Felis catus*). Patch size was negatively related to species richness and relative abundance of raccoon, opossum, and cat, suggesting these 3 species utilize smaller patches while red fox, the only mesocarnivore with a positive relationship to patch size utilizes larger forest fragments. Species richness and raccoon relative abundance shared a negative relationship with distance to road, a likely result of high raccoon detection and their affinity for human-dominated landscapes. Domestic cats were positively related with patch area to edge ratio, contrary to red fox which was negatively related with patch area to edge ratio. While my research is only applicable to the 4 target species found in Newark forest patches, the results provide further insight to mesocarnivore habitat use within urban forest fragments.

Chapter 1

INTRODUCTION

Mesocarnivores are small to mid-sized predatory species whose diets consist of 50-70% vertebrate flesh (Van Valkenburg 2007). Mesocarnivores are classified in order Carnivora, however, they are often generalist feeders that take advantage of live and dead prey, fruits, vegetables, and fungi (Reid 2006). Mesocarnivore species are more abundant and more diverse than larger charismatic carnivores, and they tend to inhabit areas within close proximity to humans (Roemer et al. 2009). There are 8 mesocarnivore species found in Delaware forests: the raccoon (*Procyon lotor*), red fox (*Vulpes vulpes*), gray fox (*Urocyon cinereoargenteus*), striped skunk (*Mephitis mephitis*), ermine (*Mustela erminea*), long-tailed weasel (*Mustela frenata*), short-tailed weasel (*Mustela nivalis*), and domestic cat (*Felis catus*). Although not classified as a carnivore, the Virginia opossum (*Didelphis virginiana*) was included as a target species because it shares a similar ecological role as a small generalist predator, comparable to that of typical mesocarnivores (Van Valkenburg 2007).

Anthropogenic habitat fragmentation has led to broad-scale habitat change that can result in an increase or decrease in the abundance of mesocarnivore species (Ray 2000). A study in coastal southern California revealed that badgers (*Taxidea taxus*), long-tailed weasels (*Mustela frenata*), spotted skunks (*Spilogale putorius*), mountain lions (*Puma concolor*), bobcats (*Lynx rufus*), and coyotes (*Canis latrans*) are most sensitive to habitat fragmentation based on a lower probability of occurrence and relative abundance in small, isolated habitat patches (Crooks 2002). In comparison, this study also showed the probability of occurrence and relative abundance decreased with fragment area and increased with fragment isolation for more tolerant species such as domestic cats, gray foxes and opossums (Crooks 2002). The landscape variables showed relatively no effect for highly tolerant species such as raccoons and striped skunks (Crooks 2002).

Mesocarnivores are considered generalists that likely benefit from added dietary resources associated with residential development. Mesocarnivore occurrence increased at fragment sites with greater exotic vegetation and closer to an urban edge (Crooks 2002). Raccoons, coyotes, striped skunks, and red foxes are increasingly abundant in landscapes with more edge habitat because they offer more foraging opportunities for these generalist predators (Ray 2000).

Prince Edward Island provides another illustration of habitat modification, especially urbanization on predator populations. In the late 1890s, lynx (*Lynx lynx*), marten (*Martes americana*), fisher (*Martes pennanti*), and otter (*Lontra canadensis*) populations were extirpated from the island. With their absence, striped skunks, raccoons, and coyotes quickly established successful colonies. The present carnivore community is composed of generalist feeders like skunks and raccoons that were able to cope with human development, yielding a simplified community of species.

Human altered environments, specifically fragmentation, can promote the superabundance of some native species, which is an emerging conservation problem. A list of 21 species of "North American species that have proven a problem in their native habitats due to overabundance," includes 5 mesocarnivores found in the Northeast that thrive in domesticated landscapes (Ray 2000). Overabundance of generalist species can reduce local diversity, introduce and spread diseases and parasites, and alter the species composition within a localized area (Ray 2000).

Species found throughout much of the United States such as raccoons, foxes, and striped skunks have been the focus of few studies in human-modified landscapes (Ray 2000). A considerable lack of research has been conducted to gain knowledge about mesocarnivores and the effects of landscape modification on their dispersal (Ray 2000). My objective was to determine which landscape characteristics have an effect on mesocarnivore relative abundance and species richness in urbanized forest fragments of Newark, Delaware.

Chapter 2

STUDY AREA

I conducted my research in 21 forest patch sites, part of the larger Forest Fragments in Managed Ecosystems (FRAME) study (Figure 1). The sites were a mixture of isolated forest fragments and larger contiguous blocks of forest found among the developed landscape.

The sites ranged in size from 2.1 – 16.3 hectares and were composed primarily of mixed deciduous hardwood trees. The sites were variable in shape, some contiguous blocks of forest, others more irregular patches. The study sites also varied in vegetative cover within the plot and their distance from roads, streams, and houses (Table 1). The distance from each plot to the nearest road, stream, and house ranged from 44 m to 527 m, 19 m to 289 m, and 99 m to 1285 m, respectively. Patch sizes, consisting of the total plot area and all adjoining forest, ranged from 4.6 ha to 163.5 ha. The patch perimeter to area ratio ranged from 0.0125 to 0.0387. The percent multiflora rose cover at each plot ranged from 0 to 0.587.

From 1981 to 2010, the mean temperatures for the months of data collection, June and July, on the University of Delaware Farm in Newark, Delaware were 22.9°C and 25.1°C, respectively (ODSC 2014). The mean monthly precipitation for June and July were 10.24 cm and 12.19 cm, respectively (ODSC 2014).

Figure 1 Map of the 21 forest fragments in Newark, Delaware used to examine the effects of landscape parameters on mesocarnivore occupancy in 2012 and 2013. The study sites were variable in shape, size, vegetative cover within the plot, and their distance from the nearest road, stream, and house.

Table 1 Landscape parameters for the 21 forest fragments in which I examined their effects on detection of mesocarnviore individuals in 2012 and 2013.

Study Site	Percent Multiflora Rose Cover	Distance to Nearest Road (meters)	Distance to Nearest Stream (meters)	Distance to Nearest House (meters)	Patch Size (hectares)	Patch Area to Perimeter Ratio
Christina Creek1	0.237	83.082	52.890	501.922	50.805	0.021
Christina Creek 2	0.578	103.416	35.704	129.530	12.714	0.019
Chrysler Woods	0.111	44.893	18.538	285.740	5.530	0.032
Coverdale	0.457	95.593	52.440	104.134	155.490	0.016
Dorothy Miller	0.135	58.840	35.887	156.977	68.785	0.014
Ecology Woods	0.135	164.081	98.697	680.545	16.561	0.015
Folk	0.005	121.480	32.677	130.586	150.062	0.015
Glasgow 1	0.004	457.538	265.432	411.980	75.582	0.013
Glasgow 2	0	142.762	137.482	850.690	75.582	0.013
Iron Hill 1	0.010	137.230	197.504	99.705	150.062	0.015
Iron Hill 2	0.001	78.340	51.341	132.354	150.062	0.015
Laird	0.170	152.734	50.531	302.753	10.100	0.016
Motor Pool	0.411	71.128	34.716	108.583	5.948	0.033
Phillips	0.129	106.210	24.389	106.212	4.618	0.039
Reservoir	0.032	208.501	73.895	210.599	53.343	0.020
Rittenhouse	0.151	155.540	115.094	143.361	50.805	0.021
Sunset Lake 1	0.002	376.763	289.385	351.355	157.867	0.013
Sunset Lake 2	0	513.542	268.455	1284.164	157.867	0.013
Webb Farm	0.137	116.125	54.644	116.128	11.151	0.029
White Clay 1	0.008	527.626	33.723	378.167	163.557	0.016
White Clay 2	0.0129	201.975	277.440	709.299	163.557	0.016

Chapter 3

METHODS

This study was part of the University of Delaware's Forest Fragments in Managed Ecosystems (FRAME) project. The FRAME team had previously plotted each forest fragment with ArcGIS software. The fragments were marked with a grid system of 25m between adjoining points, which were indicated with orange flagging in each site. The University of Delaware's Ecology Woodlot had a preexisting grid of 46m intervals. For my study, I chose the most centrally located grid point for the sampling area. At this central point, I installed a passive infrared camera (HC600 HyperFire, Reconyx, Inc. Holmen, WI, USA) to the nearest suitable tree trunk. The camera was mounted parallel with the tree trunk, at a 90° angle to and 20 cm from the ground to capture small mesocarnivore species. I baited each station with 64 g of dry cat food and 3 drops of a generic scent lure (Cronk's Outdoor Supplies, Wiscasset, ME, USA) placed 3m in front of the camera. I cleared any vegetation that blocked the view of the camera lens to the bait pile.

I conducted 4 series of surveys, 2 during June and July 2012 and 2 during June and July 2013. In 2012, I collected data for 10 days during the first survey period and 12 days during the second survey period. In 2013, I collected data for 10 days during the first and second survey periods. During the first summer of surveys in 2012, I checked survey equipment every other day excluding weekends. During the second summer of surveys in 2013, I checked survey equipment every day. During each check of equipment, I replaced the SD camera card with a blank card, replenished bait and reapplied scent lure. I reviewed the images captured at each site then identified and recorded all target and non-target species photographed.

For each of the 21 survey plots, I measured 6 landscape parameters: proportion of multiflora rose cover within the plot; average distance of the plot to the nearest road; average distance of the plot to the nearest stream; average distance of the plot to the nearest house; patch size; and patch perimeter to area ratio (Table 1). Patch size was a measure of the total plot area and all adjoining forests.

I planned to investigate the influence of landscape parameters on occupancy and relative abundance of mesocarnivores. The occupancy rate for 3 of 4 species was ≥76% for each year so I did no investigate occupancy (Table 2). To investigate relative abundance, I summed the maximum number of indivudals for a species detected per night for each survey. Next, I divdied the sum by the number of trap nights in the survey to provide an estimate of relative abundance measures for each species during a survey. Using linear regressions I modeled the influence of 6 landscape parameters on species richness and relative abundance measures of the 4 target species.

Chapter 4

RESULTS

During the 2012 and 2013 survey periods, the remote cameras captured 124,600 photos and detected 4 target mesocarnivore species. Red fox were detected all of the sites, northern raccoon were detected at 95% (n=20) of the sites, and Virginia Opossum were dected at 90% (n=19) of the sites (Table 2). Domestic cats were less common and detected at only 33% (n=7) of the sites (Table 2). The mean number of maximum individuals detected per trap night for each survey varied for each species in each site: red fox ranged from 0-1.44, northern raccoon ranged from 0-2.33, Virginia opossum ranged from 0-1.11, and domestic cat ranged from 0-1.0 (Table 3).

Species richness and relative abundance of raccoon, opossum and cat were negatively related to patch size with patch size explaining 25% of the variation in richness, 25% of the variation in raccoon abundances, 58% of the variation in opossum abundances, and 21% of the variation in cat abundances (Table 4). Red fox relative abundance was positively related to patch size with patch size explaining 11% of the variation in abundances (Table 4). Species richness and raccoon relative abundance were negatively related to plot distance from road with plot distance to road explaining 20% of the variation in species richness and 20% of the variation in raccoon abundances (Table 4). Domestic cat relative abundance was positively related with patch area to edge ratio with patch area to edge ratio explaining 29% of the variation in cat abundances, while fox was negatively related with patch area to edge ratio with patch area to edge ration explaining 12% of the variation in fox abundances (Table 4). Raccoon relative abundance was negatively related to percent multiflora rose cover with rose cover explaining 20% of the variation in abundances (Table 4). Distance to the nearest stream and house showed no significant relationships to species richness or mesocarnivore relative abundances.

Table 2 The occupancy of mesocarnivores in forest fragments in northern Delaware during 2012-2013.

Study Site	Northern Raccoon Presence		Virginia Opossum Presence		Domestic Cat Presence		Red Fox Presence	
	2012	**2013**	**2012**	**2013**	**2012**	**2013**	**2012**	**2013**
Christina Creek 1	1	1	1	1	1	1	0	1
Christina Creek 2	1	1	1	1	0	0	1	1
Chrysler Woods	1	1	1	1	1	1	0	1
Coverdale	1	1	0	1	0	0	1	1
Dorothy Miller	1	1	1	1	0	0	1	1
Ecology Woods	1	1	1	1	0	0	1	1
Folk	1	1	1	1	0	0	1	1
Glasgow 1	1	1	1	1	0	0	1	1
Glasgow 2	1	1	1	1	0	0	0	1
Iron Hill 1	1	1	1	1	0	0	1	1
Iron Hill 2	1	1	1	1	0	0	1	1
Laird	1	1	1	1	1	1	1	1
Motorpool	1	1	1	1	1	1	0	1
Phillips	0	1	0	1	1	1	1	1
Reservoir	1	1	1	1	0	0	1	1
Rittenhouse	1	1	1	1	0	0	1	1
Sunset Lake 1	1	1	0	1	0	0	1	1
Sunset Lake 2	1	1	1	0	1	0	1	1
Webb Farm	1	1	1	1	1	1	0	1
White Clay 1	0	0	1	0	0	0	1	1
White Clay 2	1	1	1	1	0	0	1	1
Total Sites Occupied	**19**	**20**	**18**	**19**	**7**	**6**	**16**	**21**

Table 3 Relative abundance of 4 mesocarnivore species in forest fragments in northern Delaware during 2012-2013.

Study Site	**Northern Raccoon Relative Abundance**		**Virginia Opossum Relative Abundance**		**Domestic Cat Relative Abundance**		**Red Fox Relative Abundance**	
	2012	**2013**	**2012**	**2013**	**2012**	**2013**	**2012**	**2013**
Christina Creek 1	2.13	1.37	1.00	0.44	1.00	0.29	0.00	0.26
Christina Creek 2	1.10	0.44	1.00	0.07	0.00	0.00	1.00	0.93
Chrysler Woods	1.17	0.70	1.00	0.41	0.00	0.07	0.00	0.44
Coverdale	1.00	0.07	0.00	0.04	0.00	0.00	1.00	0.78
Dorothy Miller	1.88	1.26	1.00	0.15	0.00	0.00	1.13	1.07
Ecology Woods	1.50	2.00	1.00	0.33	0.00	0.00	1.00	0.33
Folk	1.00	0.30	1.00	0.30	0.00	0.00	1.00	1.00
Glasgow 1	1.22	0.44	1.00	0.15	0.00	0.00	0.00	0.93
Glasgow 2	1.00	0.44	1.00	0.41	0.00	0.00	0.00	1.04
Iron Hill 1	1.00	0.56	1.00	0.11	0.00	0.00	1.00	1.07
Iron Hill 2	1.00	0.04	1.00	0.07	0.00	0.00	1.00	0.63
Laird	1.00	0.48	1.11	0.23	1.00	0.19	1.00	1.44
Motorpool	1.25	2.33	1.00	0.26	1.00	0.85	0.00	0.04
Phillips	0.00	0.07	0.00	0.22	1.00	0.15	1.20	0.89
Reservoir	1.14	0.48	1.00	0.04	0.00	0.00	1.00	1.07
Rittenhouse	1.00	1.22	1.00	0.07	0.00	0.00	0.00	1.04
Sunset Lake 1	1.50	0.56	0.00	0.19	0.00	0.00	1.00	0.74
Sunset Lake 2	1.00	0.37	0.00	0.00	1.00	0.00	1.00	0.63
Webb Farm	2.20	1.03	1.00	0.48	1.00	0.03	0.00	0.30
White Clay 1	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.96
White Clay 2	1.00	0.89	1.00	0.04	0.00	0.00	1.00	0.56

Table 4 Linear regression output from SAS program comparing species richness and relative abundance measures of northern raccoon, Virginia opossum, domestic cat and red fox to the six landscape parameters: percent multiflora rose; distance to the nearest road, stream, and house; patch size; and patch area to perimeter ratio.

Dependent Variable	Landscape Parameters	Parameter Estimate	Standard Error	R-Square	P-value
Species Richness	% Multiflora Rose	0.68293	0.62218	0.0762	0.2791
Species Richness	Distance to Road	-0.00178	0.00064380	0.2034	0.0087
Species Richness	Distance to Stream	-0.00088718	0.00110	0.0633	0.4236
Species Richness	Distance to House	-0.00021275	0.000335	0.0573	0.5296
Species Richness	Patch Size (ha)	-0.00468	0.00143	0.2520	0.0023
Species Richness	Patch Area to Perimeter Ratio	24.72678	13.55539	0.1225	0.1225
Raccoon Individuals	% Multiflora Rose	1.18133	0.53688	0.1985	0.0338
Raccoon Individuals	Distance to Road	-0.00131	0.00059875	0.1973	0.0350
Raccoon Individuals	Distance to Stream	-0.00027074	0.00099592	0.1007	0.7872
Raccoon Individuals	Distance to House	-0.00001824	0.00030377	0.0991	0.9524
Raccoon Individuals	Patch Size (ha)	-0.00374	0.00133	0.2510	0.0077
Raccoon Individuals	Patch Area to Perimeter Ratio	4.63490	12.70330	0.1021	0.7172
Opossum Individuals	% Multiflora Rose	-0.04749	0.29594	0.5213	0.8733
Opossum Individuals	Distance to Road	-0.00062480	0.00031436	0.5650	0.0539
Opossum Individuals	Distance to Stream	-0.00086082	0.00049978	0.5548	0.0929
Opossum Individuals	Distance to House	-0.00012821	0.00015665	0.5290	0.4181
Opossum Individuals	Patch Size (ha)	-0.00162	0.00071263	0.5767	0.0290
Opossum Individuals	Patch Area to Perimeter Ratio	1.66250	6.61252	0.5217	0.8028
Cat Individuals	% Multiflora Rose	0.52870	0.33178	0.1406	0.1191
Cat Individuals	Distance to Road	-0.00026528	0.00037919	0.0960	0.4883
Cat Individuals	Distance to Stream	-0.00068959	0.00058938	0.1157	0.2491
Cat Individuals	Distance to House	0.00004085	0.00018262	0.0858	0.8242
Cat Individuals	Patch Size (ha)	-0.00206	0.00081235	0.2144	0.0153
Cat Individuals	Patch Area to Perimeter Ratio	22.44208	6.75837	0.2864	0.0020
Fox Individuals	% Multiflora Rose	-0.36818	0.40959	0.0306	0.3742
Fox Individuals	Distance to Road	0.00041721	0.00045627	0.0313	0.3661
Fox Individuals	Distance to Stream	0.00014548	0.00072431	0.0115	0.9419
Fox Individuals	Distance to House	-0.00010578	0.00022019	0.0163	0.6336
Fox Individuals	Patch Size (ha)	0.00209	0.00101	0.1093	0.0442
Fox Individuals	Patch Area to Perimeter Ratio	-19.14062	8.72804	0.1191	0.0343

Chapter 5

DISCUSSION

I determined a negative relationship between species richness and patch size. This observation was surprising because I expected larger patches to support a wider variety of mesocarnivore species. Previous research noted that these smaller, isolated patches devoid of large, dominant predators are often sites of mesopredator release – a condition when top-down and bottom-up constraints on population growth of the mesocarnivore are reduced, allowing for greater growth of the populations (Crooks 1999; Prugh et al. 2009). Crooks (1999) made a similar observation that smaller, isolated fragments had the greatest mesocarnivore visitation rates. Urbanization and fragmentation can add additional food resources such as pet food, trash, crops, and crop pests (Prugh et al. 2009). Most target species in this study are well adaptable to urban environments and benefit from these anthropogenic food sources, therefore they utilize these patches frequently. Cove et al. (2012) noted the same relationship in their study but concluded their results could be an overestimate, because the daily activities of mesocarnivores are limited in small patches causing an increase in the probability of detection. I determined there was also a negative relationship between species richness and plot distance to the nearest road. This finding could be the result of a variety of factors involving the combined behaviors of the target mesocarnivores. Of the 4 target species, red fox utilize roads to facilitate travel from one patch to another while northern raccoon and Virginia opossum have been found foraging along roads

(Ray 2000). Domestic cats coming from residential areas would likely visit fragments closest to roads, because these patches are easily accessible.

I found a negative relationship between patch size and average northern raccoon individuals. Several studies have found that raccoon populations increase with greater housing development and fragmentation (Oehner and Litvaitis, 1996; Crooks and Soule, 1999; Haskell et al. 2013). This relationship could be a result of raccoons' preference for foraging in smaller patches of forest in the overall landscape (Disney et al. 2008). In addition, smaller patches are typically within closer proximity to human dominated landscapes, which provide increased artificial food sources and result in increased densities of raccoon individuals (Prange et al. 2003). A positive relationship was present between percent multiflora rose and average raccoon individuals. Highly fragmented landscapes, typified by smaller patches, usually contain higher exotic cover, such as multiflora rose. My results are comparable to Crooks' (2002) findings that raccoon visitation rates increased at sites with greater density of exotic plant cover. I found a negative relationship between distance to road and average raccoon individuals. Prange et al. (2003) observed that raccoon densities are greater in urban and suburban areas, which are typically closer to roads than larger, rural forest patches, which could explain the negative relationship. Additionally, in suburban sites, roads were utilized and crossed more frequently by raccoons to find food sources (Prange et al. 2003).

I identified a negative relationship between patch size and average Virginia opossum individuals. Similarly, Crooks (2002) observed a greater occurrence and relative abundance in opossums as the fragment area decreased. Opossums benefit from food subsidies related to human development such as gardens and refuse, in addition, they also use buildings for denning sites (Crooks 2002; Wright et al. 2012). Kanda et al. (2006) noted that opossum abundance was negatively associated with forest cover, therefore they should prefer smaller patch sizes within agricultural and urbanized landscapes.

I determined a negative relationship between patch size and average domestic cat individuals and a positive relationship between patch area to perimeter ratio and average domestic cat individuals. These findings suggest that domestic cats prefer smaller patches with higher proportions of edge. A previous study noted that domestic cats do not characteristically venture far, less than 100 meters, from urban edge into forest interior (Crooks 2002; Kays and DeWan 2004; Ordeñana et al. 2010). Domesticated cats and feral cats may have dissimilar behaviors within forest patches, with domestic cats staying in small patches, closer to the edge and feral cats moving further into the forest interior. The densities and distributions of domestic cats may reflect those of human populations, therefore we expected to find more cats within small patches, closer to human dominated landscapes – however, some cats were observed in larger tracts of forest situated further from development. I assumed the majority of cats observed were homeowner's pets, based on bodily characteristics or the presence of a collar, however it is unclear whether all observed cats were free-ranging pets or feral. I utlilized one remote camera per survey plot, situated in a central location, therefore cameras in larger plots were found deeper within the interior. The location of cameras situated in the interior and not on the patch edge may have provided an underestimate of cats that utilized larger plots, but did not travel far enough to the interior to be detected by the camera.

Contrary to domestic cats, I determined a positive relationship between patch size and average red fox individuals and a negative relationship between patch area to perimeter ratio and average red fox individuals. These findings indicate that foxes may prefer more contiguous tracts of forest over smaller, isolated patches. Likewise, Rosenblatt (1999) detected fox only in larger forest tracts and Ordeñana et al. (2010) noted that gray foxes typically preferred natural vegetation, park interiors, and wide corridors over human urbanized landscapes. This observation is comparable to findings that foxes used vegetation cover more than expected based on habitat availability compared to open areas and residential settings (Adkins and Stotts 1998).

My research provides further insight of mesocarnivore relationships to landscape parameters of urban forest fragments. Relationships varied amongst species, which may be a result of the species adaptability and use of resources in fragmented landscapes. Smaller patch sizes showed an increase in species richness, although suprising because I expected larger patches to support a greater array of mesocarnivore species, the observation was similar to that of Crooks and Soule (1999) who noted greatest mesocarnivore visitation rates in smaller, isolated fragments. Patch sizes were negatviely related to raccoon, opossum, and cat relative abundance because these mesocarnivores benefit from added resources in small patches found among human-dominated landscapes. Additionally, species richness was negatively related to plot distance from the nearest road, a likely result of mesocarnivores utilizing roads to travel and forage between patches. Red fox was the only mesocarnivore with a positive relationship to patch size similar to Rosenblatt et al. (1999) who detected fox only in larger forest tracts, suggesting fox prefer larger forested corridors over human urbanized landscapes.

LITERATURE CITED

Adkins, C.A. and P. Stott. 1998. Home ranges, movements and habitat associations of red foxes *Vulpes vulpes* in suburban Toronto, Ontario, Canada. Journal of Zoology 244:335-346.

Cove, M.V., L.M. Niva, and V.L. Jackson. 2012. Use of probability of detection when conducting analyses of surveys of mesopredators: a case study from the Ozark Highlands of Missouri. The Southwestern Naturalist 57:257-261.

Crooks, K. R. 2002. Relative sensitivities of mammalian carnivores to habitat fragmentation. Conservation Biology 16:488-502.

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

Disney, M.R., E.R. Hellgren, C.A. Davis, D.M. Leslie, Jr., and D.M. Engle. 2008. Relative abundance of mesopredators and size of oak patches in the cross-timbers ecoregion. The Southwestern Naturalist 53:214-233.

Haskell, D.E., C.R. Webster, D.J. Flaspohler and M.W. Meyer. 2013. Relationship between carnivore distribution and landscape features in northern highlands ecological landscape of Wisconsin. American Midland Naturalist 169:1-16.

Kanda, L.L., T.K. Fuller and P.R. Sievert. 2006. Landscape associations of road-killed Virginia opossums (*Didelphis virginiana*) in Central Massachusetts. American Midland Naturalist 156:128-134.

Kays, R.W. and A.A. DeWan. 2004. Ecological impact of inside/outside house cats around a suburban nature preserve. Animal Conservation 7:273-283.

Oehler, J.D. and J.A. Litvaitis. 1996. The role of spatial scale in understanding responses of medium-sized carnivores to forest fragmentation. Canada Journal of Zoology 74:2070-2079.

Ordeñana, M.A., K.R. Crooks, E.E. Boydston, R.N. Fisher, L.M. Lyren, S. Siudyla, C.D. Haas, S. Harris, S.A. Hathaway, G.M. Turschak, A.K. Miles and D.H. Van Vuren. 2010. Effects of urbanization on carnivore species distribution and richness. Journal of Mammalogy 91:1322-1331.

Prange, S., S.D. Gehrt, and E.P. Wiggers. 2003. Demographic factors contributing to high raccoon densities in urban landscapes.

Prange, S., S.D. Gehrt, and E.P. Wiggers. 2004. Influences of anthropogenic resources on raccoon (*Procyon lotor*) movements and spatial distribution. Journal of Mammalogy 85:483-490.

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.

Ray, J.C. 2000. Mesocarnivores of Northeastern North America: Status and Conservation Issues. Wildlife Conservation Society, NY, 83pp.

Reid, F. A. 2006. Peterson Field Guides: Mammals of North America. Houghton Mifflin, NY, 579 pp.

Roemer, G.W., M.E. Gompper, B. Van Valkenburgh. 2009. The ecological role of the mammalian mesocarnivore. BioScience 59:165-173.

Rosenblatt, D.L., E.J. Heske, S.L. Nelson, D.M. Barber, M.A. Miller, and B. MacAllister. 1999. Forest fragments in east-central Illinois: islands or habitat patches for mammals? The American Midland Naturalist 141:115-123.

Van Valkenburgh, B. 2007. Déjà vu: the evolution of feeding morphologies in the Carnivora. Integrative and Comparative Biology 47:147-163.

Wright, J.D., M.S. Burt, and V.J. Jackson. 2012. Influences of an urban environment on home range and body mass of Virginia opossums (*Didelphis virginiana*). Northeastern Naturalist 19:77-86.