AN INVESTIGATION INTO THE IMPACT OF THE NATIONAL WILDLIFE FEDERATION'S CERTIFIED WILDLIFE HABITAT PROGRAM ON MAMMALIAN SPECIES RICHNESS IN URBANIZED RESIDENTIAL PROPERTIES

by

Katherine L. M. Busch
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Committee:

Dr. Larry Rockwood, Thesis Director

Dr. J. Kolowski, Committee Member

Dr. C. Parsons, Committee Member

Dr. Albert P. Torzilli, Graduate Program Director

Dr. Robert B Jonas, Department Chair

Dr. Timothy L. Born, Associate Dean for Student and Academic Affairs, College of Science

Dr. Vikas Chandhoke, Dean, College of Science

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George Mason University
Fairfax, VA

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Katherine L. M. Busch
Masters of Teaching
University of Virginia, 2005
Bachelor of Arts
University of Virginia, 2005

Director: Larry Rockwood, Professor
Department of Environmental Science and Policy

Spring Semester 2013
George Mason University
Fairfax, VA

DEDICATION

This thesis is dedicated to all the elementary and middle school teachers who have their students complete science projects. You never know what a simple project observing garden birds might turn into. It's also dedicated to those who can connect the dots in small pictures to see the big painting in the end. By working together we really can make a difference.

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To all who offered mini-SD cards, phone cords, camera cords, suggestions, and support, my gratitude. To the other graduate students at George Mason, your counsel has been so valuable to me during my studies – this community has amazed me. Thank you.

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LIST OF ABBREVIATIONS

Certified Wildlife Habitat ....CWH, C
A property that is not a Certified Wildlife Habitat ....Non-CWH, NC, NON
National Wildlife Federation ....NWF
Northern short-tailed shrew………………………………………..N. short-tailed shrew
Northern short-tailed shrew……………………...…………………………………...NSTS
Southeastern shrew…………………………………………………………..S.E. shrew
Southeastern shrew…………………………………………………………………….SES
North American least shrew…...……………………………..……….N. Am. Least shrew
North American least shrew…...……………………………………………….....NALS
Meadow jumping mouse………………………………………………………...MJM
Woodland jumping mouse……………………………………………………....WJM
Deermice..………………………………………………………………………Drmc
Eastern chipmunk……………………………………………………………………..Ch
Southern flying squirrel………………..…………………………………………….....SFS
Eastern gray squirrel…………………………………………………………………...EGS
White-tailed deer……………………………………………………………………...WTD
Red fox………………………………………………………………………………..RF
Eastern cottontail……………………………………………………………………..EC
Striped skunk…………………………………………………………………………SS
Virginia opossum…………………………………………………………………….VO
Northern raccoon……………………………………………………………………..NR
Coyote…………………………………………………………………………………C
Domestic cat.....……………………………………………………………...D. cat
Domestic cat……………………………………………………………….…DC
Domestic dog……………………………………………………………………..D. dog
Domestic dog…………………………………………………………………...DD

ABSTRACT

AN INVESTIGATION INTO THE IMPACT OF THE NATIONAL WILDLIFE FEDERATION'S CERTIFIED WILDLIFE HABITAT PROGRAM ON MAMMALIAN SPECIES RICHNESS IN URBANIZED RESIDENTIAL PROPERTIES

Katherine L. M. Busch, M.S.

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Thesis Director: Dr. Larry Rockwood

The National Wildlife Federation's Certified Wildlife Habitat (CWH) program was developed to encourage the planting of native vegetation and to connect people to the outdoors. In reestablishing native flora, this program could hypothetically increase the number of animals in these habitats. To explore this hypothesis, mammalian species richness in urbanized residential properties was surveyed. Large, medium, and small mammal species were observed via camera and Sherman traps in 40 backyard habitats in the Northern Virginia region. Paired testing was carried out with 20 residences in the CWH program and 20 backyard habitats not in the CWH program but within 0.5 km of participating properties. In order to assess the impact of the CWH program the habitat usage frequency by species and the average species richness were compared between CWH and non-CWH habitats. The capture rate per species was compared between the two study groups to examine habitat use intensity. Species richness was contrasted between CWH and non-CWH habitats. Capture rate per species and species richness

were also compared between CWH properties that were actively maintained and those that had allowed the program requirements to lapse. Accumulation curves were created for both medium/large and small mammals. Significantly higher capture success was discovered in CWH property results for Eastern gray squirrels (*Sciurus carolinensis*), Northern short-tailed shrew (*Blarina brevicauda*), and red fox (*Vulpes vulpes*), white-tailed deer (*Odocoileus virginianus*), Virginia opossum (*Didelphis virginiana*), and domestic cat *(Felis catus*). No significant difference was observed between the certified and non-certified habitats' species richness using a t-test on the Shannon's Diversity Index. After pooling data from all 40 properties for accumulation curves, it was determined that the suggested minimum trapping effort necessary for surveying medium and large mammals is 12 nights. The minimum small mammal trapping effort is larger than 95 trap nights. The precise trapping effort is unknown, due to insufficient sampling time. With a heightened concern about animals in urbanized areas and how they interact with their environments, the results of this study are highly relevant. Animals are affected as people change habitats and ecosystems to fit our desires. Without a strong understanding of the vegetative, insect, and animal relationships within those ecosystems, people do not have the ability to make educated predictions of how our alterations and additions of domestic animals will cause changes in the environment and dependent species. It would be possible to cause undesired increases or decreases in species, due to a lack of understanding of a particular ecosystem's relationships. Zoonotic illnesses such as Lyme disease are linked to host mammals including deermice, chipmunks, Northern short-tailed shrews, and masked shrews. Due to this human-mammal interaction, medical and political personnel are now interested in the ecological relationships of native flora, small mammals, and their predators. Potential impacts of this study include the clarification of how creating wildlife-friendly urban habitats affect the use of the areas by mammals, which could affect how communities, homeowners associations, and politicians set up property management regulations.

INTRODUCTION

The National Wildlife Federation's Certified Wildlife Habitat (CWH) program encourages the creation of environments that offer native vegetation, water and food sources, cover, and a safe location for wildlife to raise young (National Wildlife Federation 2012). The original purpose of this certification was to act as an education program for people, increase their knowledge about wildlife habitats, and connect them more to the outdoors. Participation is not limited by type of housing, but ranges from apartments to community gardens, businesses to schools, and places of worship. Upon completion of the certification process and a fee, recipients receive a one-year subscription to *National Wildlife*, a certificate for the wildlife location, and quarterly habitat tips via traditional or electronic mail (Paul 2012).

Species richness, or the number of species in a community, is affected by many different factors. Microclimate, patch size, food, water, and vegetation availability can help determine what species live in a particular place at a specific time. Increased patch size can result in more habitat variations, microclimates, and soil types (Vieira *et al.* 2009). This, in turn, can influence which plant species survive. The plant community then helps determine which animal species survive based on food and cover provided by these plants. Increased patch size also provides more interior space versus edge habitat, which can have significant ramifications for diversity of certain groups of species. The result may be a higher species richness overall (Smith & Smith 2009). Extreme fragment sizes, either very small or large, have been observed to have a significant effect on small mammal species richness (Vieira *et al.* 2009). Energy availability (food access) within a habitat influences mammal species richness of a local area (Kerr & Packer 1997). Fløjgaard et al. (2011) also noted that habitat heterogeneity, resulting in the increased variety of vegetative cover, acts as a predictor of mammal species richness. Bird species richness has been found to increase based on topographic complexity, having significant effects on successful rearing of young (Hawkins, Diniz-Filho & Alexandre 2006; Davies *et al.* 2007). With an increase in food sources and living areas for birds and small mammals of lower trophic levels, carnivorous mammals that prey on such species would also benefit. Therefore habitat complexity can also affect species richness of animals at higher trophic levels including carnivorous mammals.

Habitat fragmentation and movement corridors have notable effects on mammalian species richness. Fragments of wildlife areas provide protection for residential and migratory species that move between populations (Heller & Zavaleta 2009), and patches of urban land serve as corridors for animal movement (Way, Ortega & Strauss 2004). Way et al. (2004) noted that coyotes use urban residential areas of Cape Cod, MA for both travel and resting places, and were observed in yards (Way, Ortega & Strauss 2004). By contrast, isolated habitat fragments reduce species richness. For example, Antunes, et al. (2009) found that fragment isolation had a negative relationship with small mammal species richness. Their study indicated that high and low species richness values were correlated to economic activity and fragmentation size of a habitat.

Significantly increased economic activity, as evidenced by increased housing and decreased rural farm use, can lead to a reduction in species richness (Vieira *et al.* 2009).

Many species currently face challenges of fragmented ecosystems and industrial development that reduce access to needed resources and restrict territory and migration routes. Habitat restrictions also lead to human-wildlife conflict, which may reduce species richness. This problem is occurring globally for animals including Asian elephants (*Elephas maximus*) (Leimgruber *et al.* 2003), hippopatomi (*Hippopotamus amphibius*) (UNESCO World Heritage Centre 2006), coyotes (*Canis latrans*) (Draheim 2012), bobcats (*Felis rufus*) (Riley *et al.* 2003), mountain lions (*Puma concolor)* (Beck 2005), reptiles and amphibians (Olson 2009), gorillas (*Gorilla beringei*) (UNESCO World Heritage Centre 2007), hoof stock (Fløjgaard *et al.* 2011), and many others. Establishing whether small plots of residential land can function as resting areas, migration stops, resource pockets, or pieces of movement corridors for these animals is important. It is possible that these backyard habitats could support self-sufficient breeding populations and form a patchwork corridor system for animal movement. This information may help scientists and citizens address basic survival concerns for many species, including those that require a nomadic or migratory lifestyle for survival, whether this is due to seasonal migrations, large territory needs, or the exchange of genes among distant populations.

Purpose

While the CWH program has increased the planting of native vegetation, the additional indigenous flora and resources may have also served to attract wildlife to the location, increasing the local area's ability to address the energy needs of animals in various life stages. With this in mind, an exploration of whether or not the CWH encouragement program is effective in increasing, or at least promoting persistence of wildlife in certified areas was carried out. If the encouragement of land owners to increase native vegetation and other requirements of life for animals on their property increases the mammalian wildlife found, the program may act to increase large scale wildlife habitat. In survey research by Widows (2011), 80% of her CWH study participants in Orlando, FL responded that they had observed a noticeable increase in their yard's wildlife. Increased small mammal presence was perceived by 53% of participants, while only 10.2% believed an increase in large mammals could be seen in their yards.

The purpose of my study was to investigate whether mammalian species diversity in areas with certifications is significantly higher than areas in comparable habitat but without certification. Species richness and an index measure of relative use intensity were used as indicators. In addition, I assessed the minimum sampling effort needed to effectively estimate species richness on these types of properties.

Objectives

1) Determine if CWH participation locations have greater species richness of terrestrial mammals than non-CWH locations in the same type of habitat.

2) Investigate differences in mammalian intensity of use between CWH and non-CWH properties by comparing the average capture rate (number of capture events per unit effort for each animal species) between the two property types.

3) Estimate the average minimum effort needed to assess the species richness of a participating location.

Hypothesis

Due to the ease of movement through the urbanized environment by small and large mammals, I hypothesize that the NWF's Certified Wildlife Habitat program will not result in a larger number of mammal species in certified urbanized backyard habitats compared to non-certified locations. However, there will be a higher usage frequency by species in certified habitats, representing a higher population size, due to the increased availability of resources. This will be evident from a higher capture success rate of those species observed on CWH properties as compared with non-CWH study locations.

Study Area and Species

The study area chosen was in Northern Virginia, including Arlington and Fairfax Counties, the Towns of Vienna and Herndon, and the Cities of Falls Church, Alexandria, and Fairfax. This region was chosen due to its status as an urban environment and its proximity to natural geographic features such as waterways that have the potential to function as movement corridors. I wanted to determine if individual plots of land in an urbanized ecosystem, such as private properties located randomly throughout the landscape, form useful patches of habitat for mammal species. Private properties occur more frequently in the urbanized setting than other locations that could be certified such as churches, businesses and schools. Theoretically, the possible continuity of habitat could provide a movement corridor for mammals. Private properties were also chosen instead of churches, businesses, and schools to decrease the amount of traffic and disturbance in the study areas. Lastly, these locations were chosen in order to increase the reliable security of live traps and to reduce the probability of camera traps being stolen.

The study area is located near the political border of Washington, D.C. and Virginia, near the Potomac River.

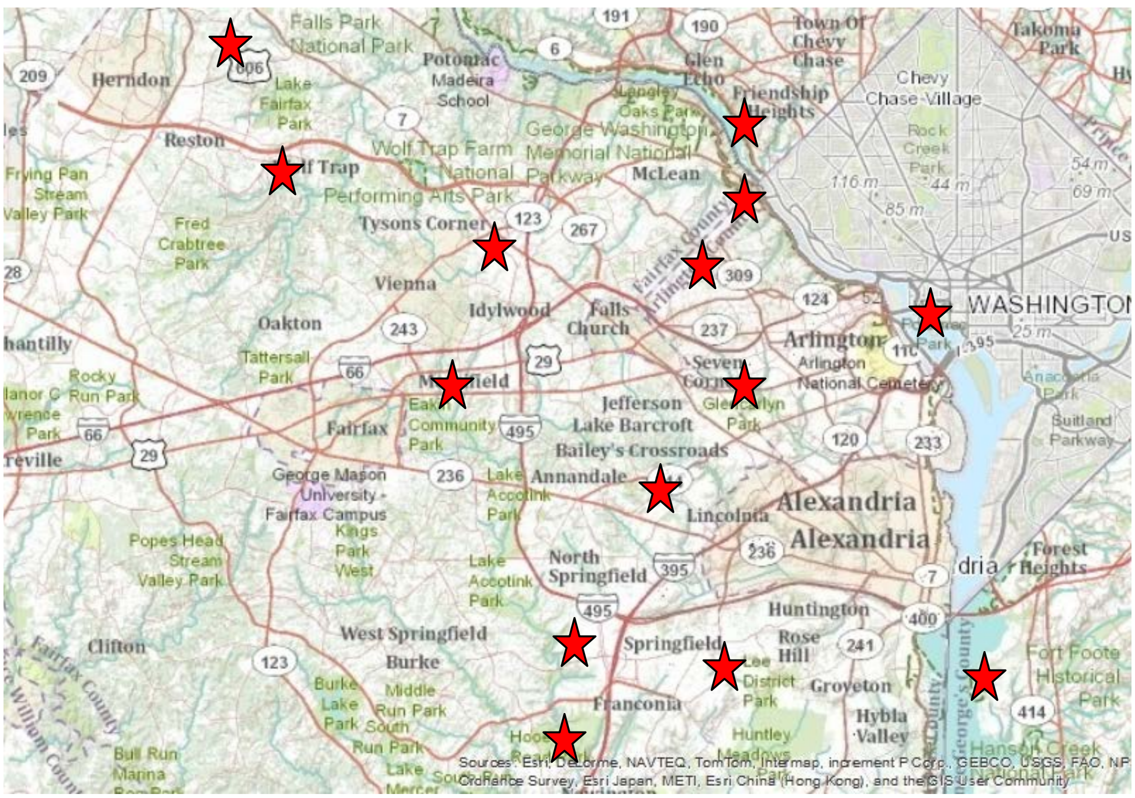


Figure 1: Map of the study area
Stars were placed to mark areas of one or more research pairs on the study area map.

The study area in Figure 1 covers habitat that is considered part of the Temperate Deciduous forest biome or Southeastern mixed forest (Smithsonian National Museum of Natural History). Participating properties were restricted to this area because of proximity to the Potomac River, streams connected to it, and the associated flood plain forests that may serve mammals as a natural transportation corridor.

While there are 105 expected total mammal species with distributions that overlap this study area, the area that was sampled during this investigation is more urbanized than many parts of this region, and was expected to support approximately 44 species (Smithsonian National Museum of Natural History). It was predicted that species requiring large bodies of water were less likely to be seen in the residential locations sampled, as no properties incorporated or were immediately adjacent to sufficiently sized water sources. Northern Virginia non-volant mammals that were expected to be observed originate from seven different orders and fourteen families (Table 1).

Table 1: Mammal species expected to be found in the study areas.
The fourth column indicates the method most likely to be effective in capturing the species.

Order, Family	Scientific name	Common name	Species most likely to be observed, with predicted trappping method
Artiodactyla, Cervidae	*Odocoileus virginianus*	White-tailed deer	Camera
Carnivora, canidae	*Canis latrans*	Coyote	Camera
	Urocyon cinereoargenteus	Common gray fox	Camera
	Vulpes vulpes	Red fox	Camera
Carnivora, Mephitidae	*Mephitis mephitis*	Striped skunk	Camera
Carnivora, Mustelidae	*Lontra canadensis*	North American Otter	
	Mustela ermine	Ermine	
	Mustela frenata	Long-tailed weasel	Camera, possible
	Mustela nivalis	Least weasel	
	Mustela vison	American mink	
Carnivora, Procyonidae	*Procyon lotor*	Northern raccoon	Camera
Didelphimorphia Didelphidae	*Didelphis virginiana*	Virginia opossum	Camera
Insectivora, Soricidae	*Blarina brevicauda*	Northern short-tailed shrew	Sherman
	Cryptotis parva	Least shrew	
	Sorex hoyi	Pygmy shrew	
	Sorex longirostris	Southeastern shrew	
Insectivora, Talpidae	*Condylura cristata*	Star-nosed mole	
	Scalopus aquaticus	Eastern mole	
Lagomorpha, Leporidae	*Sylvilagus floridanus*	Eastern cottontail	Camera
Rodentia, Castoridae	*Castor canadensis*	American beaver	
Rodentia, Dipodidae	*Zapus hudsonius*	Meadow jumping Mouse	Sherman
Rodentia, Muridae	*Clethrionomys gapperi*	Southern red-backed vole	Sherman
	Microtus pennsylvanicus	Meadow vole	Sherman
	Microtus pinetorum	Woodland vole	Sherman
	Ondatra zibethicus	Muskrat	
	Oryzomys palustris	Marsh rice rat	
	Peromyscus leucopus	White-footed mouse	Sherman
	Reithrodontomys humulis	Eastern harvest mouse	Sherman
	Synaptomy cooperi	Southern bog lemming	
Rodentia Sciuridae	*Glaucomys volans*	Southern flying squirrel	
	Marmota monax	Woodchuck	Camera
	Sciurus carolinensis	Eastern grey squirrel	Camera
	Scirurus niger	Eastern sox squirrel	
	Tamias striatus	Eastern chipmunk	Camera
	Tamiasciurus hudsonicus	Red squirrel	Camera

Methods

Participation Criteria

Many different factors were considered to determine study locations. As discussed previously, large differences in the interior and edge habitat of an environment can affect species presence. To reduce the effect of large variations in habitat sizes, property acreage size was restricted, as explained below.

Way et al. (2004) noted in their study of coyote movement that while radio-tagged coyotes were often located in residential areas; they tended to avoid residential properties with fences and dogs. With this in mind, the study was restricted to locations that had fences on three or fewer sides to provide wildlife entry and exit, and domestic pets, if present, with only restricted access to the observation area. In this way, wildlife may be present when pets are not in the property area.

It was also determined that poisoning or trapping activity on research properties would change the population density of targeted animals, which would then skew the study results. I was concerned that it would have restricted able participant properties too significantly to require no trapping in the immediate area (neighboring locations included). For the above reasons, I implemented the following criteria for all study properties themselves:

1. The property is 1/4 to 1 acre in size.
2. The yard has at most three sides closed in by fencing and the house. (This was to ensure the ability of wildlife to move in and out of the property, regardless of fence type, height, and spacing.)

3. For those properties that have pets, those pets have restricted time access to the habitat area. In other words, the dog(s) or cat(s) may be outside at times, but domestic pets are not able to enter the habitat area at will at all times of the day and night. This was to make sure that wildlife could conduct diurnal and/or nocturnal activity without the influence of domestic animals.

4. No prior use of poison or lethal trapping methods.

The restrictions above also functioned to increase the uniformity between properties and reduce confounding influences of the noted characteristics. Further reduction in the influence of potential confounding variables was achieved through paired comparisons of nearby certified and non-certified properties. This method ensured similarity between CWH and non-CWH groups for data comparison. For example, while it is possible that the study may include a CWH property that is five km from a forested stream, its paired non-CWH property would be a comparable distance to this stream. Mammals observed in certified habitats would have access to similar nearby resources and be exposed to the same broad environmental situations as those in the non-certified paired location. This would reduce the confounding factors of varied resource accessibility, weather, and geographic features between the two research groups (Wade-Smith & Verts 1982; Larivière & Pasitschniak-Arts 1996; Larivière & Walton 1998).

Participant Determination

In order to assess the impact of the National Wildlife Federation (NWF)'s Certified Wildlife Habitat (CWH) program on mammalian species richness, 20 properties were reviewed from each of two separate groups: those with the certification and those in the same habitat without involvement in the program. Initially 150 letters (Appendix A, Figure 9) were sent to a participant list of the CWH program, as provided by the NWF. The list was limited to those in Fairfax and Arlington Counties, the Towns of Vienna and Herndon, and Alexandria, Fairfax and Falls Church Cities. Every third name on the list was selected to receive the study invitation, with a request to respond via email if interested. Included with the study information was a letter of endorsement from the NWF which can be found in Appendix B, Figure 10.

For any homes that met the criteria, yard size was confirmed by an online property website (Zillow Real Estate Network 2013). The first 20 certified (CWH) homes that responded and met the criteria upon visitation were selected for study participation. It was determined that participants would not be screened based on whether or not their habitats had lapsed in maintaining the CWH requirements, as the purpose of the study was to determine the overall effectiveness of the program, not that of its most active adherents.

In order to identify a non-CWH habitat for each certified participant, a circumference of 0.5 km was drawn around each CWH participant location. By checking the online property website (Zillow Real Estate Network 2013), a list of homes whose property fell within the 0.5 km radius with an acreage difference of 500 ft^2 (0.01 acre) greater or less than the CWH home was determined. This list was further limited to properties that did not involve the need for animals to cross roads exceeding two lanes of traffic from the certified property. If comparable sized homes were not found meeting these criteria, the acreage difference between CWH and intended non-CWH properties was extended up to 1500 ft^2, or 0.03 acres. These homes were randomly visited by placing them in a list prior to arrival, in order to reduce researcher bias.

If the residents were present, the researcher explained the project and asked if they would be interested in participating. All were also offered the NWF endorsement letter. If no one was available to talk to, an explanatory letter was left at the door with a request to email the researcher if the resident was interested in participating (Appendix C, Figure 11). Upon receiving a verbal or email response residents were asked if their properties met the previously mentioned four requirements. Non-CWH participants were also required to meet the restriction of not being a participant in the NWF'S CWH program. If all criteria were reached, a confirmation meeting was set up to answer any questions. All residents, both CWH and non-CWH, were asked if they would be willing to sign a permission form (Appendix D, Figure 12) recognizing that the researcher and helper would be accessing their external property for the purpose of this study. Involvement was not contingent upon signing, but all participants signed willingly. This was kept in the research binder, on person, during the study to allay concerns of neighbors.

Required paperwork

Permits were obtained for the purposes of this study. The Virginia Department of Game and Inland Fisheries granted a permit for scientific research, including the live trapping of small mammals. The Institutional Care and Use Committee (IACUC) of George Mason University approved the study's animal care protocol.

Trapping Techniques

Sherman Traps

Sherman traps were used to assess small mammal species presence since probability of detection of these smaller animals is low with cameras (Gompper *et al.* 2006). Sherman traps are solid, small, folding aluminum box traps with a trip door. For the present study, the 2 x 2.5 x 6.5 inch and the 3 x 3.5 x 9 inch trap sizes were used. These traps are able to capture a variety of small mammal species, are non-lethal, and can be made to minimize hunger, temperature loss, and discomfort. The main causes of trap mortality, in the rare cases that it occurs, include hypothermia, heat stress, and dehydration. The provision of bedding material can reduce the danger of hypothermia. To avoid dehydration, moist food can be provided and traps should be checked promptly to minimize containment time (Collins 2012).

The 40 study habitats were divided into groups of six and assigned to one of seven trapping periods from September through November, 2013. Each group had three CWH and non-CWH study pairs. Traps were set at each location as described below. If, for whatever reason, a habitat member of a study pair had a reduced trap load (e.g. damaged or missing Sherman traps) the corresponding habitat's traps were reduced to match the number of trap nights. This only occurred if there was not a replacement trap to exchange for the missing or damaged item. It was found that by placing fluorescent orange tape on the bottom of the Sherman traps it was easier to locate them if they had been disturbed. As the tape was on the underside of the trap, it was believed that this would not affect specimen trap interaction, but did significantly increase the ease of spotting moved traps.

Nineteen Sherman traps were placed at each site and were positioned along log runways, undergrowth and building edges, and in immediate proximity to used-burrow entrances. All 19 traps were set closed for two nights to allow animal acclimatization in each habitat, then were baited for five trap nights to determine the presence of small terrestrial mammal species. Peanut butter-oatmeal bait and a small amount of bedding were provided to minimize stress to captured specimens. Voss and Emmons (1996) noted in their study of Neotropical mammal diversity that oats are a good food source, along with peanut butter, bacon and raisons (Voss & Emmons 1996; Edalgo & Anderson 2007). In this study, bacon was avoided to reduce medium and large sized mammal predation. Oats alone can be removed by ants, as observed. To this end, it was determined that a peanut butter-oatmeal mixture would be used. The peanut butter provides an additional protein source that can help sustain those species such as shrews which have a high metabolism (Ruff & Wilson 1999), while the oats are beneficial for seed-eating animals. Additionally, peanut butter can attract insects that stick to it, which can improve trapping success of insectivores (Collins 2012).

The bedding was altered within the first week from native vegetation to cotton balls. This was to provide increased warmth to trapped animals, especially those such as the Northern short-tailed Shrew. The Northern short-tailed shrew is an insectivore that also eats vertebrates, plants and fungi. This species has a high metabolism, requiring them to consume up to half their weight daily, and lose large quantities of water to evaporation (Ruff & Wilson 1999). In order to reduce mortality, more bait was provided along with cotton balls to increase specimens' abilities to burrow into the nesting material. The external temperature dropped over the course of the study. The September average minimum temperature was 63.7°F, with a low of 53°F. November's average minimum temperature was 38.3°F, with a low of 31°F (National Oceanic and Atmospheric Association 2013). Bedding was changed from cotton balls to raw sheep wool and felting (Silvy 2012) in order to increase insulation as the temperature dropped.

Sherman traps were baited Sunday through Thursday evenings, and checked the following mornings. Daily results for each property were recorded on the Small Mammal Trapping Datasheet (Appendix E, Figure 13)**.** Small mammals were inspected at the trap sites to confirm species identification, and photographs were taken. Animals were then released back into their environment unless dead or injured. In the event of injury or impaired functioning, animals were observed for a recovery period of 15 minutes in a warm setting providing cover, and released if they had recuperated. If animals were deceased they were transported to a freezer at George Mason University for preservation, and were ultimately donated to the teaching collection at the Smithsonian Conservation Biology Institute in Front Royal, VA.

There were at least two weeks with no research sampling between Sherman and camera trapping sessions. This period of inactivity was set to allow any animals that were disturbed by the frequent visitation required for small mammal assessment to reacclimatize to a more normal foot traffic pattern.

Camera traps

To record the small, medium, and large mammals present in urbanized backyard habitats, camera traps were deployed. The use of camera trapping allowed for documentation and evidence of the presence of species that moved in view of the camera. Trap shy/wary mammals may be less likely to enter a baited trap, but have little qualms regarding camera traps, especially those with invisible infrared flashes (Gompper *et al.* 2006). Larger animals, which can be more difficult and potentially dangerous when captured, can set off a camera trap, again providing evidence of presence that may otherwise not have been found (Kays *et al.* 2011).

Properties were organized into five groups of eight participant locations each, four CWH and non-CWH pairs, for camera distribution from September to December, 2013. One Reconyx™ camera trap was deployed for 14 trap nights at each of eight properties. The eight camera traps used included four PC900 Hyperfire™ with 32GB SD HC memory cards, and four PM75 RapidFire™ cameras with 4GB Compact Flash memory cards. Camera traps were set on trees or stable sites at a height < 0.5 meters, approximately knee height, in areas to maximize the chances of species observation. If available, cameras were set to observe water features or feeding stations established on the property. Alternatively, cameras were positioned to look over animal paths indicated by trampling in the undergrowth or wear on the ground, or animal cross paths such as fallen trees (Kolowski 2012).

Camera traps were set to record pictures of nocturnal and diurnal activity. Each camera was set in RapidFire™ mode, for a burst of sequential photo events when triggered by motion. They were set to take 3-5 pictures then rest for 1-3 minutes. PC900 Hyperfire™ cameras were attached to their supports with extendable bungee cords and secured with key accessed bicycle locks. The PM75 RapidFire™ cameras were tied and secured with a Python Professional lock cable. Cameras were left on location for 14 trap nights then brought in to retrieve picture data. Picture captures were downloaded into a computer file and an external hard drive. Camera battery life was checked to assure run life for the next group, and cameras were put out to record the next trapping group.

Statistical Analysis

The capture success rate for species was compared between the CWH and non-CWH groups to examine use-intensity differences. The total usage by species and species richness were tabulated and compared between the two study groups in order to assess the differences in patterns of the mammalian community associated with the certification program. Accumulation curves were assessed for small and medium/large mammal sizes. Lastly, species richness was compared between actively maintained CWH properties and those that have allowed the program requirements to lapse.

Camera trap data were collected and edited to remove any pictures or sequences that involved humans or plant movement triggers. Adjustments were carried out for any properties needing date and time corrections for a mistake assigning the A.M., P.M. values in camera set-up. Date and time were adjusted for each picture upon species selection identification and organization. Remaining pictures were then reviewed for date and time, assigned a species identification and number of specimens, and assigned a trap night identification (1-14) for each 12:00 p.m. to 12:00 p.m. time period. Data were then organized and summarized by trap night and species for each of the 40 locations.

Capture success and diversity data for both Sherman and camera traps were entered into tables that were then further organized by CWH and non-CWH pairs, with group summaries. To see the complete diversity data for Sherman and camera trapping, see Appendix F, Table 6 and Appendix G, Table 12.

While diversity data reflects the number of properties each species is found in, capture success data indicates how many specimens of each species were caught. Capture success was used as a measure of species relative abundance. With more Eastern chipmunks in the environment, for example, there would be higher capture success rates.

Habitat frequency usage by species

Statistical comparisons of capture success for individual species were limited to species categories with sufficiently large capture rates. Only those species with a combined CWH and non-CWH averaged capture success rate (the expected value of observed animals per property type) higher than five animals were included in statistical analysis of CWH and non-CWH results (expected value: CWH capture success + non-CWH capture success / 2).

Species categories were examined to determine if each had large enough capture success for median testing, the preferred analysis method to understand data trends. Due to the analysis problem with ties in paired data, i.e. ‘0’ values for capture success of a particular species in both the CWH and non-CWH properties of Pair 1, these ‘0’ pair results were removed from further analysis. Those with five or fewer ‘0’ pair capture success entries could be analyzed by median data. These species capture success data were reviewed using quantile comparison plots in R (R. Core Team) to determine if the remaining categories were normally distributed. CWH and non-CWH non-normally distributed data was then compared with the non-parametric, one-tailed, Wilcoxon signed rank test accounting for matched pairs. This test compared the two samples' medians against each other, and is valuable for sample sizes less than 50 (Institute of Phonetic Sciences (IFA)).

Chi-squared goodness of fit was employed if the raw capture success numbers were not sufficiently large to use the Wilcoxon signed rank test. Species with overall data that had more than five '0' capture success entries, an expected value ≥ 5, and whose paired capture rates were not equal were assessed by the chi-squared test using the selected species' raw summary capture success data of all 40 properties. If capture success populations were too small, the results of this statistic would not be very accurate or valid (Zar 1999), which was why minimum capture success rates were required for analysis.

Species richness - Shannon's Index of Diversity

Shannon's Index of Diversity was chosen to assess the overall distribution of capture success among species for both CWH and non-CWH study locations. All species categories were included in this statistic. A high diversity resulted from a large distribution of capture rates among species in a property type. If capture rates indicated a large number of one or two species and few of other animals at a property type, this could result in a low diversity (Zar 1999). A t-test was then used to compare the diversity results between CWH and non-CWH study locations.

Shannon's Index of Diversity

Pilot study

A pilot study was carried out to assess optimum field trapping techniques to yield capture results and lead to a comprehensive assessment of the mammal populations present in urbanized backyard habitats.

Originally, ten small Sherman traps were set out in a 1/3 acre wooded backyard habitat in the Northern Virginia area that met the prerequisite study location criteria. Traps were set along fallen tree limbs, on the border of bramble bushes, near areas of known small mammal activity (anecdotal evidence provided by the resident), or other edge areas of the habitat. Traps were baited each evening and provided natural bedding from the immediate area, and were checked the following morning for capture success.

Initially, peanut butter-oatmeal bait was used. With no capture success on multiple days of the peanut butter-oatmeal mixture, the bait was changed in an attempt to improve animal attraction. Each bait technique was tested for at least two days to determine its efficacy. Oatmeal alone was removed from the traps by ants, without springing the door mechanism. This was confirmed by both the absence of bait and the trail of ants at multiple traps on consecutive days. Bananas also attracted insect attention, although no mammal captures occurred. Additionally, bananas left the traps sticky and slimy, a condition that resulted in increased ant activity and a higher risk of molding. Tuna fish supplied on small plastic flat tops placed at the back of the Sherman traps did produce closed traps; however there were no small mammals inside. Raccoon activity was suspected, as multiple traps were transported between one and twenty feet from their original locations with doors tripped and all food removed.

After eight nights with no results, large Sherman traps were set near each small Sherman trap to determine if it was possible that the small models were causing trap avoidance issues. Peanut butter and oatmeal were used as bait. This decision was the result of a lack of success with food lures to yield capture results during the pilot study to date, coupled with supporting literature and previous successful experience with peanut butter-oatmeal bait on a separate trapping study. The combined trapping at this location of small and large Sherman traps resulted in 160 trap nights.

On the same trap night that the large Sherman traps were set out at the first location, ten more traps were set in another backyard habitat in the same region of Northern Virginia, less than 1.6 km away. This property also met study criteria. Peanut butter-oatmeal bait was used at this location, along with natural bedding from the environment. Over the course of five days, 50 traps nights were recorded, with no capture success.

Upon completion of the pilot study, with no small mammal captures in 210 trap nights, it was determined that the bait of choice for trapping was peanut butter-oatmeal mixture. However, it was not ascertained if the planned trapping schedule of five nights with 19 traps each night would be sufficient to survey the small mammal populations present.

Camera traps were employed at each of the two pilot study habitats. Two cameras were set up at the first habitat for 14 trap nights, one a PM75 RapidFire™ and the other a

PC900 Hyperfire™ . The RapidFire™ was set to observe the end of a fallen log that could act as a movement corridor, while the Hyperfire™ overlooked a through path in the ivy with trample evidence of perpetual use. A PM75 RapidFire™ was set up at the second site for the five trap nights, set at ground level to observe one of the baited traps. Each camera trap was angled for target viewing. Capture success was immediate, with activity from Northern raccoon, White-tailed deer, Eastern gray squirrel, and Red fox, in addition to humans.

Upon careful consideration, I began the study itself with the intention of reconsidering the small mammal trapping design if no Sherman trap capture success was achieved in the first week.

Results

Small mammal results

Small mammal trapping data were summarized by trap night and species for each of the 40 study locations. Eastern gray squirrels, Eastern chipmunks and deermice were categorized as small mammals for the purpose of statistical analysis, although many observations of these animals were caught on camera traps. To reduce the possibility of confusion in the identification of deermice species, all *Peromyscus sp.* recorded were considered deermice. The white-footed deermouse (*Peromyscus leucopus)* and North American deermouse *(Peromyscus maniculatus)* are very similar and can both be found in the study area. Some differences between white-footed deermice and North American deermice were observed in the field such as; indistinctly versus distinctly bi-colored tails, end of tail hairs > or <5 mm, body color, and the presence or lack of a dorsal stripe (Kays *et al.* 2011). However, the most conclusive method of differentiating between these two species is the dental patterns of molars and premolars (Collins 2012). As no specimens were captured for dissection and review, it was not possible to use this species identification technique. Due to this specific species question, and to reduce the chances of misidentification within the overall *Peromyscus* genus, all deermice were grouped together for analysis.

A total of nine species of small mammals were observed using Sherman traps (Table 2). Eastern gray squirrels, deermice and Northern short-tailed shrews were caught at the most properties; 92.5%, 80% and 45% respectively.

Table 2: Diversity data of small mammal trapping.
This table shows the number of properties exhibiting presence for each listed small mammal species in certified (CWH) and non-certified (NON) properties, respectively. The overall number and percentage of properties for each of these species is also indicated.

Status (CWH, NON)	Northern short-tailed shrew	Southeastern shrew	North American least shrew	Meadow jumping mice	Woodland jumping mice	Deermice	Chipmunk	Southern flying squirrel	Eastern gray squirrel
CWH	11	1	1	1	0	17	3	0	18
NON	7	0	2	1	2	15	4	2	19
TOTAL	18	1	3	2	2	32	7	2	37
% of study properties	45%	2.5%	7.5%	5%	5%	80%	17.5%	5%	92.5%

As seen in Figure 2, it is apparent that the highest small mammal capture success rates for CWH and non-CWH properties include the deermice (104:119) and Eastern gray squirrel (795:570). Northern short-tailed shrew numbers are not as high (19:7) but are also notable because the capture population is large enough to statistically analyze. The data for these three small mammal species were sufficiently large for analysis. Capture success numbers for the North American least and Southeastern shrews, woodland and meadow jumping mice, Eastern chipmunks and Southern flying squirrels were too low to be used for statistical analysis.

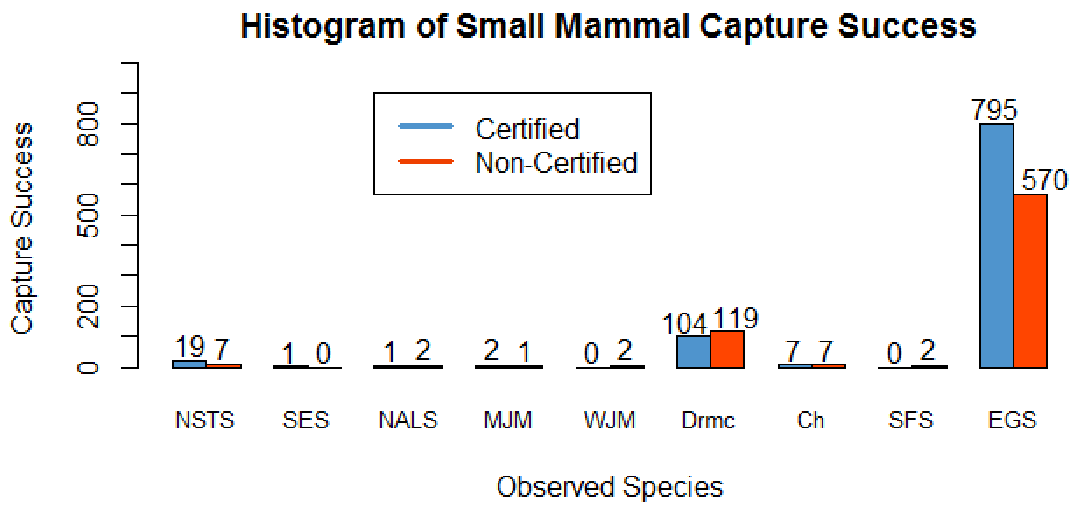
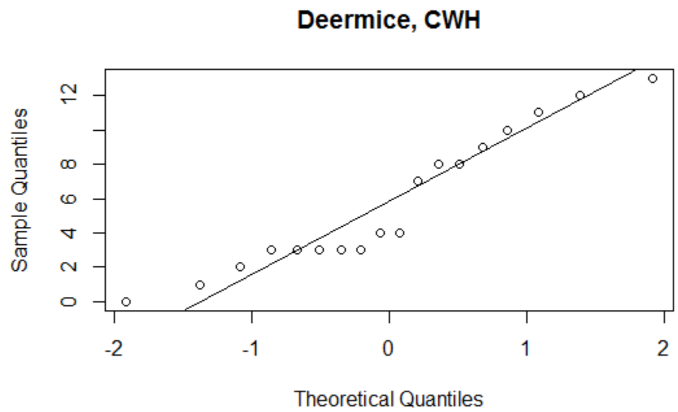


Figure 2: Histogram of small mammal capture success.
This graph shows the number of specimens of each small mammal species that were observed at certified and non-certified properties. (NSTS – Northern Short-tailed shrew, SES – Southeaster shrew, NALS – North American least shrew, MJM – meadow jumping mouse, WJM – woodland jumping mouse, Drmc – Deermice, Ch – Eastern chipmunk, SFS – Southern flying squirrel, EGS – Eastern gray squirrel)

On review of the data and its non-normal distribution, see quantile comparison plots in Figures 3 and 4, deermice and Eastern gray squirrel data were analyzed with the Wilcoxon signed rank test accounting for matched pairs (Zar 1999). These species were also considered with the chi-squared goodness of fit test, as were the North American short-tailed shrew data.



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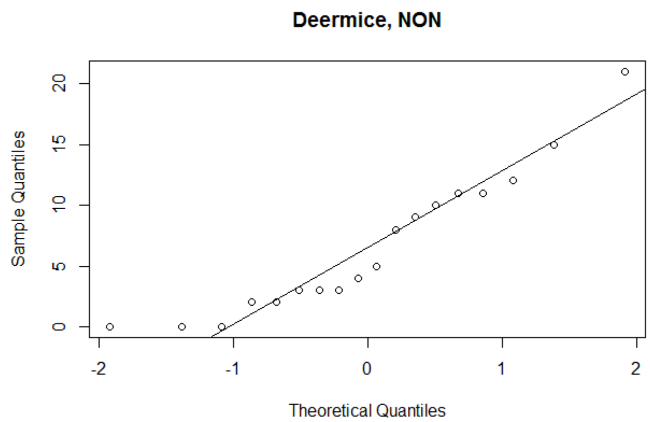

Figure 3: Quantile comparison plots of CWH and non-CWH (NON) deermice capture success indicating non-normal distribution, supporting the use of non-parametric analysis.

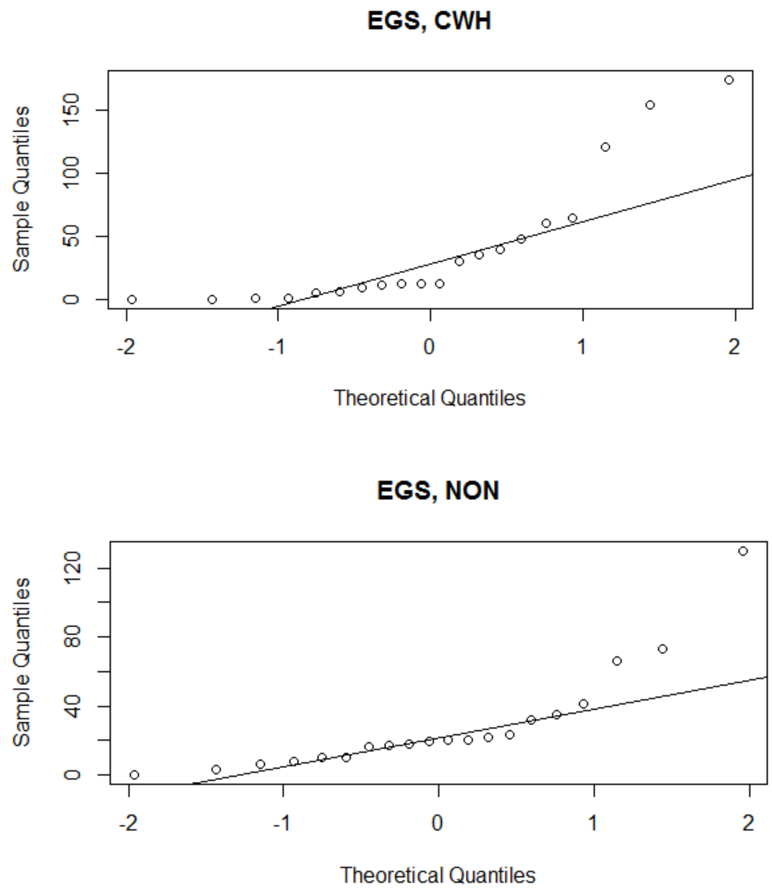

Figure 4: Quantile comparison plots of CWH and non-CWH (NON) Eastern gray squirrel capture success indicating non-normal distribution, supporting the use of non-parametric analysis.

Wilcoxon test results for deermice indicated no significant difference in the higher capture success in non-certified properties (W(n_1= 18, n_2=18) = -1.000, p = 0.769). Wilcoxon results for Eastern gray squirrel also indicated that the higher observation rate in certified properties was not significant (W(n_1=20 , n_2= 20) = 9.000, p = 0.314).

A goodness of fit chi-squared test confirmed the Wilcoxon test findings of no significant difference for deermice capture success between property types, with $X^2 = 1.009$, $p = 0.315$. However the high CWH capture success of Eastern gray squirrel chi-square value was significant, $X^2 = 37.088$, $p < 0.0001$. The higher CWH capture success rate of Northern short-tailed shrews was also found to be significant, $X^2 = 5.538$, $p = 0.019$).

Medium and large mammal results

As seen in Table 3, red fox were observed at the highest percentage of properties (90%). Domestic cats were observed at very similar rates for both study groups (13:12), while Northern raccoons had the most dramatic difference with respect to photo events between CWH and non-CWH properties (17:11)

Table 3: Diversity data for camera trapping results of medium and large mammals:
This table displays the number of properties in which each of these 9 species was observed via camera trap, listed by certified (CWH) and non-certified (NON) properties. The total number of properties where these animals were captures is indicated, followed by the percentage of overall properties. The final column indicates the overall number of wildlife species observed in each property type.

	Domestic cat	Domestic dog	White-tailed deer	Red fox	Eastern cottontail	Striped skunk	Virginia opossum	Northern raccoon	Coyote	Total # Wildlife Species
CWH	13	5	12	19	7	1	7	17	2	16
NON	12	8	8	17	3	0	4	11	0	15
TOTAL	25	13	20	36	10	1	11	28	2	18
% of study properties	62.5%	32.5%	50%	90%	25%	2.5%	27.5%	70%	5%	45%

Seen below, Domestic cat capture success rates showed the largest difference between CWH and non-CWH properties (203:113) followed by red fox (172:90) and white-tailed deer (133:72) (Figure 10). The striped skunk and coyote categories had such low capture rates they could not be analyzed. The data for white-tailed deer, red fox, Eastern cottontail, Virginia opossum, Northern raccoon, and domestic cat and dog were statistically reviewed.

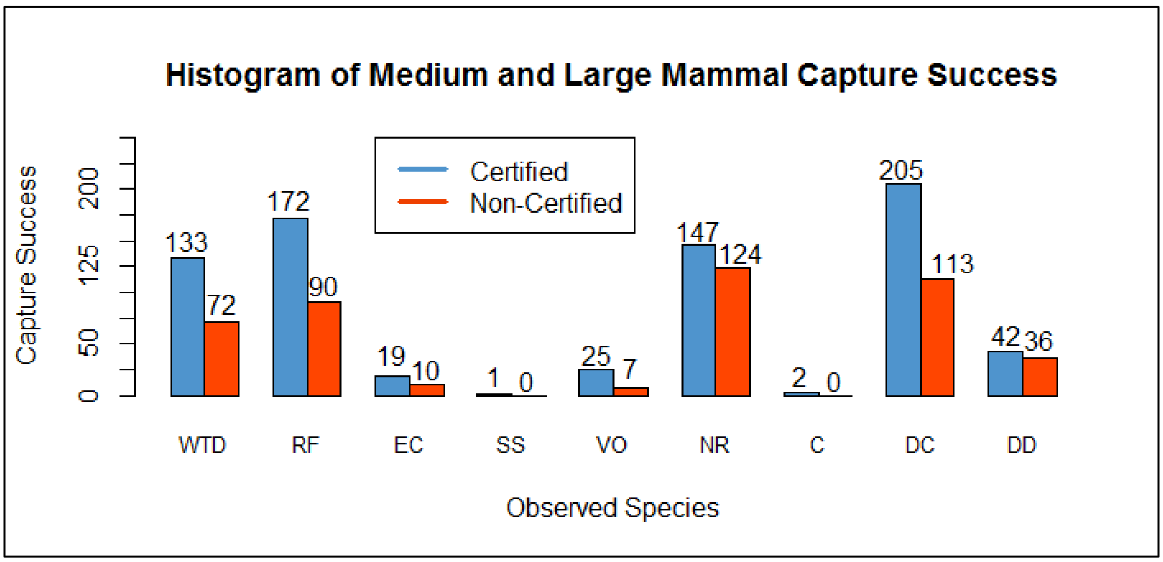

Figure 5: Histogram of medium and large mammal capture success.
The graph shows capture success numbers, or the number of specimens observed for medium and large mammal species at certified and non-certified habitats. (WTD – White-tailed deer, RF – red fox, EC – Eastern cottontail, SS – striped skunk, VO – Virginia opossum, NR – Northern raccoon, C – coyote, DC – domestic cat, DD – domestic dog.)

Red fox capture success results were reviewed with quantile comparison plots, Figure 6, to ascertain the need for nonparametric Wilcoxon signed rank test analysis.

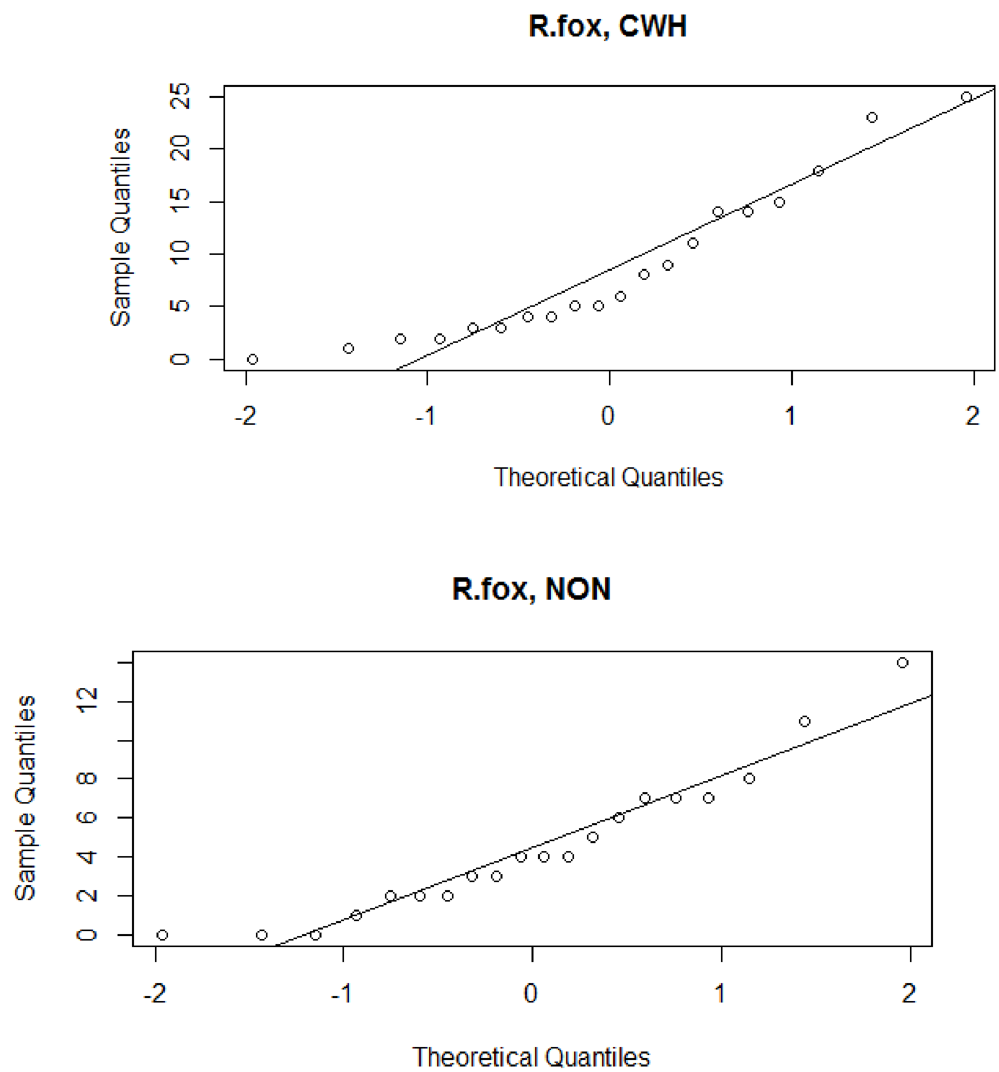

Figure 6: Quantile comparison plots of CWH and non-CWH (NON) red fox capture success indicating non-normal distribution, supporting the use of non-parametric analysis.

The Wilcoxon signed rank test results indicated a significant difference in the higher capture numbers of CWH compared to non-CWH properties for Red fox ($W(n_1=20, n_2=20) = 4.500$, $p = 0.040$).

Medium and large mammals with sufficiently large capture success results to allow goodness of fit testing included red fox, white-tailed deer, Eastern cottontail, Virginia opossum, Northern raccoon, and domestic cat and dog. Significant differences were found in the higher capture success in certified properties of five medium and large mammals. The significance of higher CWH captures of red fox was confirmed, X^2=25.664, $p < 0.0001$). White-tailed deer, X^2=18.15, $p < 0.01$, Virginia opossum, X^2=10.13, $p < 0.05$, and domestic cat, X^2=26.62, $p < 0.05$ had significantly higher CWH capture success results. Goodness of fit results indicated no significant difference between capture success of CWH and non-CWH properties for Eastern cotton tail X^2=2.79, $p > 0.05$, Northern raccoon X^2=1.95, $p > 0.05$, and domestic dog, X^2=0.46, $p > 0.05$.

Shannon's Index of Diversity showed a higher species capture diversity in the CWH group (H_1=0.756) compared to the non-CWH group (H_2=0.738). Comparison test results of the Shannon's Index of Diversity between certified and non-certified properties did not show evidence of a significant difference between the H values (*n=40, critical value=1.96,* $p > 0.05$*)*.

The average species accumulation data table for small mammal trapping indicates a continued increase in the number of species observed over the number of trap nights (Table 4). Ideally, towards the end of the study the rate of observed new species would decline.

Table 4: Average species accumulation data table, small mammal trapping.
The following indicates the accumulated average number of small mammal species found for each night of Sherman trapping (TN=trap nights, 19 traps per night).

	TN 19	TN38	TN 57	TN76	TN95
Average Accumulation	0.85	1.1	1.325	1.45	1.575

In Figure 7 the average species accumulation curve is provided. The curve's line is not at a plateau and does not reach an asymptote even at 95 trap nights. This led me to believe the small mammal trapping time period was not long enough to thoroughly assess the presence of the small mammal community.

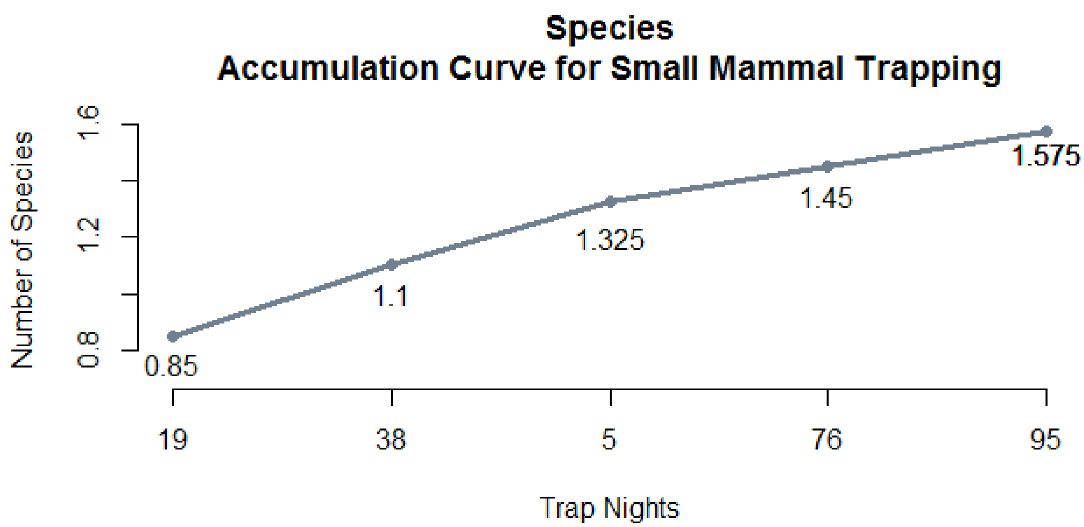

Figure 7: Average species accumulation curve for small mammal trapping.
Nineteen traps per night, indicating the amount of trapping effort required to assess the species present.

In Figure 8 the increase in average accumulation of medium and large mammals slows down near Trap Night 10.

Table 5: Average species accumulation data table of camera trapping.
This table refers to the average number of accumulated species sighted by each trap night for certified (CWH) and non-certified (NON-CWH) properties. (T = Trap night during camera assessment)

Trap Night	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14
Ave. accumulation	1.625	2.175	2.55	2.925	3.25	3.525	3.7	3.95	4.1	4.325	4.425	4.6	4.675	4.725

The species accumulation for camera trapping data table (Table 5) and accumulation curve (Figure 8) indicate a reduction in species capture success for habitats at Trap night 10, with a more distinct plateau at Trap night 12. This represents a reduced probability of observing a new medium or large mammal per time unit. Therefore, a person could expect to find most of the medium and large mammals in a habitat of this size with 12 camera trap nights.

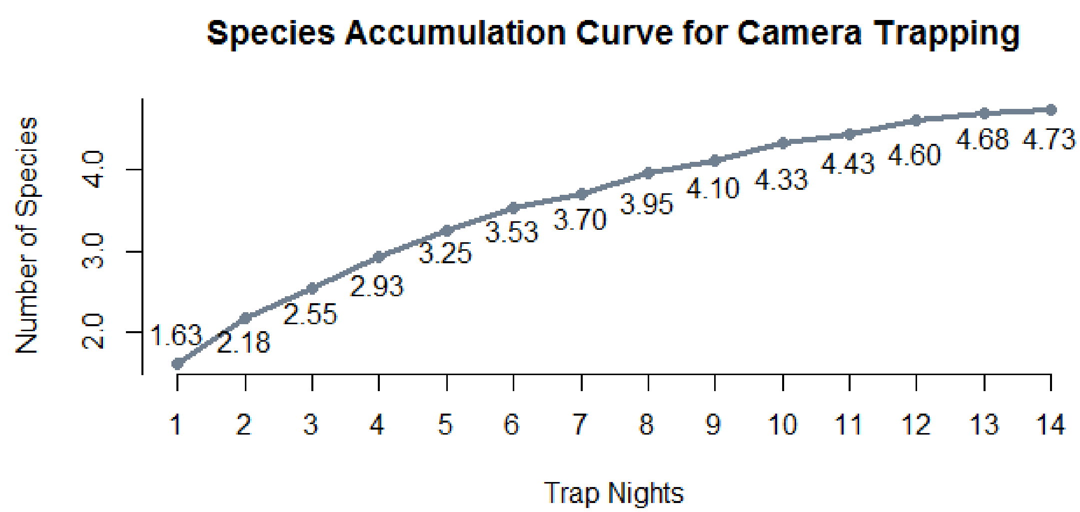

Figure 8: Average species accumulation curve, camera trapping

DISCUSSION

Upon review of the statistical analysis, the results of the Wilcoxon signed rank tests for paired data for both deermice and Eastern gray squirrel showed that there is no significant difference between these populations in CWH and non-CWH sites. When analyzed with the chi-square test however, the higher capture success of Eastern gray squirrel in CWH habitats was significant, X^2=37.088, p <0.0001. It is possible that four extreme CWH: non-CWH paired capture success values (174:23, 9:130, 121:16, and 154:41) may have skewed the median value for this species in the Wilcoxon test. The summary data and the chi-square test would not have been affected in the same manner.

Many certified locations provided supplemental food, as required by the study, which served as squirrel meal stations. It was very apparent upon review of camera data that Eastern gray squirrels utilize these feeder stations throughout daylight hours, though the locations were often established for birds. This increased ease of access and availability may have resulted in the significant difference of Eastern gray squirrel capture success in certified properties.

The last small mammal species capture success to be reviewed was the Northern short-tailed shrew. Chi-square test results yielded significant differences in higher CWH captures success summaries for Northern short-tailed shrews than non-CWH properties. Many CWH participants anecdotally reported high numbers of insects (primarily pollinators) and birds in their habitats. It is possible that the provision of native vegetation also increased other insect populations, which are a prime source of food for Northern short-tailed shrews. This small mammal is also an opportunist though, consuming vertebrates, plants, and fungi (Ruff & Wilson 1999). In order to investigate the cause of higher Northern short-tailed shrew populations it might serve well to look at the diversity, availability, and population size of plants, fungi, and insects in CWH vs. non-CWH habitats.

In reviewing the small mammal trapping methods used in this study, it is clear that a number of small mammals that were predicted to be caught in Sherman traps were not found. As noted by Laurance et al. (1992), there are many characteristics that can affect species capture rates between different trap types. Food preference, trap placement within a vertical microhabitat, the body size of the animal, and specific trap type avoidance can all affect which animals are caught. It is possible for trap methods to be biased towards some species and against others. To adjust for possible trapping bias weaknesses, alternative trapping techniques should be used. Pitfall traps, arboreal traps, and an extension of the trapping period may ensure a more significant capture sample (Laurance 1992). It is possible that the more invasive and environmentally destructive techniques of small mammal sub-terrestrial trapping would be rejected by urbanized home owners, so this should be carefully reviewed.

One such invasive trapping method that is often used to catch small terrestrial mammals is the pitfall trap. These traps are made of buckets or piping set flush with the ground in a prepared hole. They can be hard to set due to subterranean growth and uneven ground surface. It was determined that these traps would not be used in this experiment due to damage caused to yards and the increased efficacy reached by lethal control at the bottom of the pitfall: Museum traps, water to induce drowning, or preservative solution (Collins 2012). Few property owners would have agreed to participate in this study if these two criteria had been required. While it is possible that there would have been a higher number of small mammals captured if additional trapping techniques were used, all properties used the same method of small mammal trapping, therefore these results can still be compared across the study properties.

The significant difference in higher CWH capture success rates of red fox, confirmed through both the Wilcoxon signed rank test and the chi-square value is noteworthy as this animal is a top predator. Red fox diet varies throughout its range, but can include small ground mammals, seeds, fruit, earthworms, fish, reptiles, ground-nesting birds, Galliformes (heavy-bodied, ground feeding birds), carrion, rabbits, and the Sciuridae (squirrel) family, to the infrequent meal events of larger mammals such as raccoons and opossums (Larivière & Pasitschniak-Arts 1996). The emphasis on seed and native vegetation of the CWH program (National Wildlife Federation 2012) may encourage red fox presence through increased small mammal and bird presence in the habitat, as well as the availability of vegetative options that this omnivorous animal eats.

Occupancy modeling analysis to ascertain correlations between overall small mammal presence and red fox observations could explore this theory further. Dissections of red fox scat on CWH and non-CWH properties could also illuminate the meal contents of observed animals, which could further indicate what foods the animals consume at the time of the study.

Fox is a top predator in the urban landscape since gray wolves and cougars were extirpated in the Eastern United States in the early 1900s (Beck 2005). Top predators within the state of Virginia include black bear, coyote, fisher (Virginia Department of Wildlife and Inland Fisheries 2013a), eastern gray fox, bobcats (both *Lynx rufus rufus* and *Lynx rufus floridanus*)(Virginia Department of Wildlife and Inland Fisheries 2013b; c), and unconfirmed cases of cougars (Virginia Department of Wildlife and Inland Fisheries. 2013). While there have been numerous sightings of coyote, including two in this study, Red fox are already common in both urban and rural settings. Coyote-human wildlife conflict, on the other hand, has increased noticeably in urban and suburban areas (Timm *et al.* 2004; White & Gehrt 2009). An increase in other top predators such as coyote (Gompper *et al.* 2006), cougar, and fisher, the last of which were extirpated but are moving into the area from West Virginia (Virginia Department of Wildlife and Inland Fisheries 2013a) could cause ecosystem shifts. These shifts would result in overall food web and trophic level adjustments. To understand what environmental affect these original and reinvading top predators may have on our urban ecosystems, expanded study of the current carnivores could prove useful. Of course, this change could also produce human-wildlife conflict.

Though top predators are often a source of alarm for humans, they serve an important environmental health role. Red fox populations may have an effect on diseases that plague urban humans and pets. Red fox prey heavily upon small mammals, many of whom can act as vectors for disease. Some small mammals act as zoonotic disease vectors that transmit illnesses such as Lyme disease to humans and pets (Levi *et al.* 2012).

While the traditional Lyme vector culprit, the white-footed deermouse, is well known, this animal is not the only source of Lyme disease. Brisson et al. (2008) observed in field research of the Northeastern United States that mice only make up approximately 8.5% of nymphal tick Lyme disease infections sites. Of the Lyme disease infected ticks found on rodents, 80-90% had blood meals from mice, chipmunks, short-tailed shrews, and masked shrews. These data suggest that there are a number of small mammals that acts as disease vectors for Lyme's disease. Factors beyond the previous year's rodent abundance impact the infection rate of nymphal ticks, note Brisson et al. (2008) although what these are is not currently known. It is possible that influences on the current year's population alter the infection and vector rate (Brisson, Dykhuizen & Ostfeld 2008).

Levi et al. (2012) noted in their research that a reduction in red fox populations causes a decrease in predation on small mammals. A decrease in small mammal predation could result in an increase of lower trophic level zoonotic disease vectors, in turn causing higher infection rates. Thus, red fox may play an important role as a small mammal predator and disease control agent. Levi et al. (2012) went further in their discussion to argue that the resettlement of urbanized areas by coyotes is exacerbating the Lyme disease infection problem, because these animals do not prey on small mammals as much as red fox do. It is also noted that red fox are adaptable, and kill large numbers of small mammals for caching (Levi *et al.* 2012).

A decrease in red fox populations is certainly a concern, but the increase in other top predators does not automatically indicate small prey animals will not be harvested. Levi et al.'s claim was based on the idea that other predators don't eat enough small mammals or adapt well to an urban environment. As observed by Gehrt et al. (2009), the number of coyotes removed annually from the City of Chicago increased from >20 to >300 specimens from 1999 to 2009 (Gehrt, Anchor & White 2009). In a study of a Northeast coastal, suburban region by Ortega et al. (2004), coyotes were observed in all parts of neighborhoods. While Gompper's (2002) research indicated that coyotes in the Northeast prey heavily on hoofstock, this cannot be the case in suburban areas and cities, so another food source must be consumed. A field study of the contents of urban coyote diets in Calgary, Alberta found that small mammals made up 84.7% of the 484 scat contents analyzed (Lukasik & Alexander 2012). This finding directly contradicts the claim by Levi et al. that coyote don't significantly prey upon small mammals. From these studies it is clear that a greater understanding of current and changing predation on small mammal zoonotic disease vectors is needed. These larger carnivores affect human life through direct conflict as well as trophic level management, and the value of these interactions cannot be emphasized enough.

Small mammals such as moles, voles, mice, rats, and shrews are also sources of human-wildlife conflict regarding gardens, house invasions, and general human alarm. Many city, county, and state health departments are interested in the possible population control influence that top predators may exert on disease vectors. Local laws can affect neighborhood property regulations, including those that determine vegetation allowances.

For example, Fairfax County, Virginia requires that grass at all residential properties of $\leq$0.5 acres be kept no higher than 12 inches (Department of Code Compliance, Fairfax County, Virginia 2013). Long grasses can be considered unsightly and provide cover for animals and insects that cause disease, such as ticks, mice, and rats. It is possible that the study of urbanized wildlife could result in ordinances that are designed to incorporate more environmentally cooperative practices. A greater understanding of predator-prey relationships could allow wildlife management laws and policies that promote natural predation of animal disease vectors and a functioning food web. In promoting these natural relationships, humans would be engaged in a functioning ecosystem, yet still be proactively reducing health risks to themselves and their pets.

White-tailed deer, Virginia opossum, and the domestic cat were found to have significantly higher CWH capture success rates. It is possible that the significantly higher capture success of white-tailed deer is related to the availability of native vegetation, and cover provided. Virginia opossum, scavengers and fruit, grain, and grub eaters (Kays & Wilson 2009), may also be able to access more food sources on CWH properties. Also, a high number of insects on CWH properties (Widows 2011) may provide more grubs for opossum consumption than found on non-CWH properties.

While domestic cat are not generally interested in vegetation as food sources, the increased activity of bird and small mammals (such as Northern short-tailed shrews, coupled the high capture success observed of deermice), might lead to a higher predation rate in CWH habitats. The carnivorous interests of domestic cats have been documented and heatedly contested by scientists and civilians for a long time. Out-door domestic and feral cat kills have been identified as a significant source of wildlife predation (Goldstein 2012). Research has provided evidence of increased cat populations and public opinion of the need and measures of control for outdoor cats (Coleman & Temple 1993; Ash & Adams 2003). In order to explore this potential link, research should be carried out to ascertain habitat occupancy of the small mammal populations, resident and neighborhood feline predation, and other wildlife populations (such as birds) in CWH habitats.

In regards to the immediate impact of this study, anecdotal evidence relayed by a CWH participant indicated that the observation of feline predation by the property cat has changed the owner's attitude about outdoor access. This CWH participant is now making her cat an indoor-only animal. It is unknown how other participants reacted to predation evidence by domestic animals.

To confirm the non-significant results of capture success between CWH and non-CWH properties for Eastern cottontail, Northern raccoon, and domestic dog collections over a larger property sampling size and longer time period could be conducted to establish higher capture success values. However, Northern raccoon have been observed in a wide variety of habitats, accessing various vegetation and anthropogenic food sources (Kern Jr. 2012). This animal's adaptability may be the reason there is no significant difference between CWH and non-CWH properties, as it is able to negotiate living in various habitats comfortably (Davis 1907; Kern Jr. 2012).

For this study, the Shannon's Diversity Index produced no significant community diversity differences between CWH and NON-CWH habitats. Unfortunately, as noted earlier, this test can be strongly affected by small sample sizes. Southern flying squirrels were found twice, both on NON-CWH properties. Anecdotal evidence from homeowners also indicated the presence of these creatures on two CWH properties. Coyotes were also observed twice, both in CWH properties, and striped skunk was observed only in one CWH property. Thus, the Shannon's Diversity Index may not have provided a clear picture of the overall diversity of the two site categories.

I originally intended to compare the results of those CWH habitats that did not maintain adherence to the certified program criteria with those that did. To my surprise, all CWH habitats met and maintained the NWF's program conditions. In reviewing the non-CWH habitats, seven (35% of non-certified properties) were observed that would have immediately qualified for CWH status with no modifications. Three more non-CWH habitats (15% of non-CWH properties) would have needed to install a water feature to qualify. Ten non-CWH habitats (50% of non-CWH properties) lacked multiple indigenous flora for food sources or human-provided alternatives, regardless of the presence of a water feature. English Ivy was a common form of groundcover, but was not considered a native plant as it is invasive. With this break down, it is apparent that the study did randomly select properties without the CWH status, maintaining an unbiased leaning towards those that lacked all NWF requirements.

For further study it would be very interesting to survey human participants to determine what led them to live on their property and their perceptions of wildlife in the habitat. Some of the study residents mentioned a keen attraction to the wildlife or natural vegetation in their environment during the original study discussion. A number of people, both CWH and non-CWH participants, noted that this led to their decision to rent or purchase the studied property. I decided to call this the idea of ‘neighborhood environmental attitude’. It would be interesting to find participants who had not selected their residence primarily due to its natural setting, and find comparison study locations nearby. It is possible that this might remove the effect of ‘neighborhood environmental attitude’ on study pairings and provide an idea of how changing the habitat to increase native vegetation impacts mammal species presence in areas without an emphasis on a diverse natural setting.

Exploration of the number of non-certified participant properties that have been modified to increase wildlife presence/usage would be useful. This information could increase an overall understanding of the percentage of locations that do not participate in the CWH program but are interested in the promotion of native floral and faunal wildlife. Further developing this investigation to review the intent of all participants native floral plantings could also provide understanding of what the end goal was, whether aesthetic, pollination, bird, or general wildlife encouragement.

It is possible that this study had a bias towards property owners who were already interested in wildlife, and thus were more likely to agree to study participation. While this study reviewed the efficacy of the NWF’s Certified Wildlife Habitat program in promoting mammalian wildlife in certified habitats as compared to non-certified locations, it did not look at whether it was the CWH program’s focus areas that resulted in higher mammalian species presence. A further comparison would focus on the presence and absence of criteria that are believed to attract wildlife and form the basis of the NWF’s program. In order to do that, it would be necessary to further survey properties, but restrict non-certified properties to those that do not meet the four requirements of the certification process: 1) planting of native vegetation, 2) availability of a water source, 3) provision of natural and supplemental food sources, 4) cover for safety and rearing of young. Additionally, running occupancy modeling analysis could provide insight into what covariate interaction occurred at the property types, providing further understanding of environmental relations.

In conclusion, the National Wildlife Federation's Certified Wildlife Habitat program does not result in a significant difference in species richness of its properties, but does affect usage frequency by these animals. Higher usage by animals for CWH properties was clear for Eastern gray squirrel, white-tailed deer, red fox, Eastern cottontail, Virginia opossum, Northern raccoon, deermice, Northern short-tailed shrew, domestic cat and domestic dog. Four of these species were found to have significant differences between the capture success of certified and non-certified locations. It is clear that the certification program can make a difference in yard wildlife use by mammals.

The results of this study confirm the original hypothesis that there would be a significant difference in usage, but not in species richness between certified and non-certified habitats. Lastly, the average minimum effort recommended for someone to investigate the medium and large mammals in their backyard habitat is 12 trap nights. Unfortunately, this study was not conclusive in determining the time required to assess the small mammal population present.

Finally, this study suggests that there may indeed be significant habitat benefits provided to the mammalian community by the CWH program. A study that is both longer in time and encompasses a larger study area with a larger number of samples sites will be necessary to more conclusively demonstrate these benefits.

APPENDIX

Environmental Science and Policy
4400 University Drive, MSN 5F2
Fairfax, Virginia 22030-4444
(703) 993-3187

Hello,

My name is Katie Busch. I'm a graduate student at George Mason University, studying environmental science. I'm writing to you to ask if you would be willing to allow me to use your Certified Wildlife Habitat (CWH) in my graduate research. I am surveying what wildlife mammal species are present in different yards.

The key points you might be interested in are as follows:

- This is a short term study, with two parts:
  a) One part involves putting a camera trap in the yard for two weeks to capture images of mammals that pass through your area. Two weeks after the camera traps are installed, they will be collected, with no access required between times. Cameras will be attached to trees or other standing objects. In the case that no supporting structure is available facing a desired animal area, a small wood stake may be pushed into the dirt. All images of people will be discarded.
  b) The other portion of the study involves live small animal trapping for one week. Small aluminum box traps will be used, with a small amount of food and plant bedding provided to ensure warmth and food overnight. Animals will be released directly back into your yard immediately upon species notation. Animals will not be harmed, or physically changed in any way. The food provided will not be strewn around the area, nor will it be enough to attract animals from other yards into your property.

- Results are anonymous, and locations will be given numbers so they cannot be identified to study reviewers.

- Results of individual yards CWH status will not be reported to the National Wildlife Federation.

- The condition of your Certified Wildlife Habitat is not being evaluated.

- The study does NOT require or request access to the inside of your home. I'm interested in the species of wildlife mammals in your yard.

- Study participants are not liable for research equipment on their property.

I hope to start this project shortly. I plan to be in touch with you soon, however if you're interested in participating in this study, I welcome your contact as soon as possible. Participants will be incorporated into the study on an ongoing basis. My email address is [redacted]

Thank you for your consideration, and I hope to work with you soon,

Katie Mandel Busch

Figure 9: Appendix A, Certified Wildlife Habitat Participation Request Letter

NATIONAL WILDLIFE FEDERATION

11100 Wildlife Center Drive · Reston, VA 20190 · 703.438.6000 · www.nwf.org

August 23, 2012

Dear **National Wildlife Federation Certified Wildlife Habitat®** owner,

The National Wildlife Federation is very excited about George Mason University graduate student Katie Busch's research proposal to assess the richness of mammalian diversity in Certified Wildlife Habitat sites compared with comparable non-certified sites.

Ms. Busch presented us with a very impressive research proposal and we are anxious to learn what we can about the impact of our program on local species. Intuitively, of course, we feel that having a Certified Wildlife Habitat helps local wildlife, but there has been very little research so far to prove the point.

Please know that she has the full endorsement of the National Wildlife Federation to conduct the research she is doing through George Mason University. We hope you will consider participating in her study if your yard meets the criteria she has set.

Please feel free to contact Ms. Busch directly or me, should you have any concerns about this study.

Sincerely,

Roxanne Nersesian Paul
Sr. Coordinator, Community & Volunteer
Outreach

paul@nwf.org
703-438-6586

Inspiring Americans to protect wildlife for our children's future.

Mixed Sources Cert no. SW-COC-002708 ©1996 FSC

Figure 10: Appendix B, National Wildlife Federation Endorsement Letter

Environmental Science and Policy
4400 University Drive, MSN 5F2
Fairfax, Virginia 22030-4444
(703) 993-3187

Hello,

My name is Katie Busch. I'm a graduate student at George Mason University, studying environmental science. I'm writing to you to ask if you would be willing to allow me to use your yard in my graduate research. I am surveying what wildlife mammal species are present in different yards.

The key points you might be interested in are as follows:

- This is a short term study, with two parts:
  a) One part involves putting a camera trap in the yard for two weeks to capture images of mammals that pass through your area. Two weeks after the camera traps are installed, they will be collected, with no access required between times. Cameras will be attached to trees or other standing objects. In the case that no supporting structure is available facing a desired animal area, a small wood stake may be pushed into the dirt. All images of people will be discarded.
  b) The other portion of the study involves live small animal trapping for one week. Small aluminum box traps will be used, with a small amount of food and plant bedding provided to ensure warmth and food overnight. Animals will be released directly back into your yard immediately upon species notation. Animals will not be harmed, or physically changed in any way. The food provided will not be strewn around the area, nor will it be enough to attract animals from other yards into your property.

- Results are anonymous, and locations will be given numbers so they cannot be identified to study reviewers.

- The study does NOT require or request access to the inside of your home. I'm interested in the species of wildlife mammals in your yard.

- Study participants are not liable for research equipment on their property.

I hope to start this project shortly. I plan to be in touch with you soon, however if you're interested in participating in this study, I welcome your contact as soon as possible. Participants will be incorporated into the study on an ongoing basis. My email address is [redacted]

Thank you for your consideration, and I hope to work with you soon,

Katie Busch

Figure 11: Appendix C, Non-Certified Wildlife Habitat Participation Request Letter

On this day, _________________, I ___________________________, grant Katie Busch and her assistant access to my yard from __________________ to __________________ in order to carry out trapping activities for her George Mason University graduate research project.

Signature: ___________________________ Date: _________________

Address: ____

Figure 12: Appendix D, Property Access Approval Form

Small Mammal Trapping Data Sheet

An investigation into the impact of the National Wildlife Federation's Certified Wildlife Habitat program on mammalian species richness in urbanized residential properties

CWH: _____ Non-CWH: _____ Date: ________________ Day # (1-5): ________

Site Address: ____ Start Time: ________ End Time: ________

Weather conditions: ________________________ Total traps functioning previous night on location: ________

Trap #	Species	Comments

Figure 13: Appendix E, Small mammal trapping Data sheet

Table 6: Appendix F, Small mammal diversity data by study pair, presence or absence

Pair #	Status (CWH, NON)	Domestic cat	Domestic dog	Northern short-tailed shrew	Southeastern Shrew	North American least shrew	Meadow jumping mice	Woodland jumping mice	Deermouse	Chipmunk	Southern flying squirrel	Eastern gray squirrel,	Total # Wildlife Species
1	CWH	0	0	1	0	0	0	0	1	0	0	1	3
	NON	1	0	0	0	0	0	0	1	0	0	1	2
2	CWH	0	1	0	0	0	0	0	1	0	0	1	2
	NON	0	0	1	0	0	0	0	1	0	0	1	3
3	CWH	1	0	0	0	0	0	0	0	0	0	1	1
	NON	0	0	0	0	0	0	0	0	0	0	0	0
4	CWH	1	1	0	0	0	0	0	1	0	0	1	2
	NON	1	0	0	0	0	0	0	1	0	0	1	2
5	CWH	1	0	0	0	0	0	0	1	1	0	1	3
	NON	1	1	1	0	1	0	0	1	1	0	1	5
6	CWH	1	1	0	0	0	0	0	1	0	0	1	2
	NON	1	1	0	0	0	0	0	1	0	0	1	2
7	CWH	0	1	1	0	0	0	0	1	0	0	1	3
	NON	1	0	1	0	0	0	0	1	1	0	1	4
8	CWH	0	0	1	0	0	0	0	0	0	0	1	2
	NON	1	0	0	0	0	0	0	0	1	0	1	2
9	CWH	0	0	1	0	0	0	0	1	0	0	0	2
	NON	0	1	0	0	0	0	0	1	0	0	1	2
10	CWH	1	0	1	1	0	0	0	0	1	0	1	4
	NON	1	1	0	0	0	1	1	1	0	1	1	5
11	CWH	1	0	0	0	1	1	0	1	0	0	1	4
	NON	0	1	0	0	0	0	1	1	0	1	1	4
12	CWH	0	0	1	0	0	0	0	1	1	0	1	4
	NON	1	1	1	0	0	0	0	0	1	0	1	3
13	CWH	1	1	1	0	0	0	0	1	0	0	1	3
	NON	1	1	0	0	0	0	0	1	0	0	1	2
14	CWH	1	0	0	0	0	0	0	1	0	0	1	2
	NON	1	0	1	0	0	0	0	1	0	0	1	3
15	CWH	1	0	0	0	0	0	0	1	0	0	1	2
	NON	0	0	0	0	1	0	0	0	0	0	1	2
16	CWH	1	0	1	0	0	0	0	1	0	0	1	3
	NON	0	1	1	0	0	0	0	1	0	0	1	3
17	CWH	1	0	1	0	0	0	0	1	0	0	1	3
	NON	1	0	0	0	0	0	0	1	0	0	1	2
18	CWH	0	0	0	0	0	0	0	1	0	0	1	2
	NON	0	0	1	0	0	0	0	1	0	0	1	3
19	CWH	1	0	1	0	0	0	0	1	0	0	0	2
	NON	0	0	0	0	0	0	0	1	0	0	1	2
20	CWH	1	0	1	0	0	0	0	1	0	0	1	3
	NON	1	0	0	0	0	0	0	0	0	0	1	1
Total		25	13	18	1	3	2	2	32	7	2	37	

Table 12: Appendix G, Medium and large mammal diversity data, presence or absence

Pair #	Status (CWH, NON)	White-tailed deer	Red fox	Eastern Cottontail	Striped skunk	Virginia Opossum	Northern Raccoon	Coyote	Total # Wildlife Species
1	CWH	1	1	0	0	0	1	0	8
	NON	1	1	1	0	0	0	0	6
2	CWH	1	1	0	0	0	0	0	7
	NON	0	1	0	0	0	1	0	6
3	CWH	0	1	0	0	0	1	0	7
	NON	0	1	0	0	0	1	0	2
4	CWH	1	1	1	0	0	1	0	11
	NON	0	1	0	0	0	0	0	4
5	CWH	1	1	1	0	1	1	0	14
	NON	0	1	1	0	1	1	0	10
6	CWH	0	1	0	0	0	1	0	11
	NON	0	0	0	0	0	0	0	3
7	CWH	1	1	1	0	0	1	0	15
	NON	0	0	0	0	1	1	0	7
8	CWH	1	1	0	0	1	1	0	15
	NON	1	1	0	0	0	1	0	6
9	CWH	1	1	0	0	0	1	0	14
	NON	1	1	0	0	0	0	0	5
10	CWH	0	1	1	0	1	1	0	19
	NON	0	1	0	0	0	1	0	9
11	CWH	0	1	1	0	1	0	0	19
	NON	1	1	0	0	0	1	0	9
12	CWH	1	1	1	0	1	1	0	22
	NON	0	1	1	0	1	1	0	8
13	CWH	0	1	0	1	1	1	0	21
	NON	0	1	0	0	1	1	0	6
14	CWH	0	1	0	0	0	1	0	19
	NON	0	1	0	0	0	0	0	5
15	CWH	1	1	1	0	1	1	0	23
	NON	1	1	0	0	0	0	0	5
16	CWH	0	0	0	0	0	1	0	21
	NON	0	1	0	0	0	1	0	6
17	CWH	1	1	0	0	0	1	0	24
	NON	1	1	0	0	0	1	0	6
18	CWH	1	1	0	0	0	1	0	24
	NON	1	1	0	0	0	0	0	6
19	CWH	1	1	0	0	0	1	1	25
	NON	1	0	0	0	0	0	0	4
20	CWH	0	1	0	0	0	0	1	26
	NON	0	1	0	0	0	0	0	3
	Total	20	36	10	1	11	28	2	

Table 7: Capture success of small mammal trapping,
The number of specimens of each species capture at certified (CWH) and non-certified (NON) properties.

	N. short-tailed shrew		S.E. Shrew		N. Am. least shrew		Meadow jumping mice		Woodland jumping mice		Deermice		Chipmunk		Southern flying squirrel		Eastern gray squirrel	
Pair #	C	NC	C	NC	C	NC	C	NC	C	NC	C	NC	C	NC	C	NC	C	NC
1	1	0	0	0	0	0	0	0	0	0	10	11	0	0	0	0	12	19
2	0	1	0	0	0	0	0	0	0	0	4	11	0	0	0	0	1	73
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0
4	0	0	0	0	0	0	0	0	0	0	3	3	0	0	0	0	35	10
5	0	1	0	0	0	1	0	0	0	0	4	2	3	1	0	0	174	23
6	0	0	0	0	0	0	0	0	0	0	11	4	0	0	0	0	30	3
7	3	1	0	0	0	0	0	0	0	0	13	12	0	4	0	0	48	17
8	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	9	130
9	1	0	0	0	0	0	0	0	0	0	8	15	0	0	0	0	0	6
10	3	0	1	0	0	0	0	1	0	1	0	5	3	0	0	1	121	16
11	0	0	0	0	1	0	2	0	0	1	3	10	0	0	0	1	65	22
12	4	1	0	0	0	0	0	0	0	0	2	0	1	1	0	0	6	20
13	1	0	0	0	0	0	0	0	0	0	1	9	0	0	0	0	154	41
14	0	1	0	0	0	0	0	0	0	0	3	8	0	0	0	0	1	66
15	0	0	0	0	0	1	0	0	0	0	3	0	0	0	0	0	11	18
16	1	1	0	0	0	0	0	0	0	0	7	3	0	0	0	0	39	33
17	1	0	0	0	0	0	0	0	0	0	8	3	0	0	0	0	12	20
18	0	1	0	0	0	0	0	0	0	0	12	21	0	0	0	0	60	8
19	1	0	0	0	0	0	0	0	0	0	9	2	0	0	0	0	0	10
20	2	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	12	35
Total Captures	19	7	1	0	1	2	2	1	0	2	104	119	7	7	0	2	795	570

Table 8: Capture success for medium and large mammals.
The number of each species captured in each study pair, broken down into certified habitats (C) and non-certified habitats (NC).

	White-tailed deer		Red fox		Eastern Cottontail		Striped skunk		Virginia Opossum		Northern Raccoon		Coyote		Dom. cat		Dom. dog	
Pair #	C	NC	C	NC	C	NC	C	NC	C	NC	C	NC	C	NC	C	NC	C	NC
1	7	9	2	2	0	1	0	0	0	0	2	0	0	0	0	3	0	0
2	7	0	5	11	0	0	0	0	0	0	0	3	0	0	0	0	2	0
3	0	0	18	2	0	0	0	0	0	0	3	1	0	0	32	0	0	0
4	1	0	9	2	1	0	0	0	0	0	4	0	0	0	1	60	2	0
5	1	0	3	14	5	1	0	0	10	3	37	2	0	0	1	1	0	6
6	0	0	5	0	0	0	0	0	0	0	4	0	0	0	18	1	15	9
7	5	0	15	0	4	0	0	0	0	1	6	36	0	0	0	4	16	0
8	4	11	1	3	0	0	0	0	1	0	9	11	0	0	0	6	0	0
9	12	5	3	1	0	0	0	0	0	0	8	0	0	0	0	0	0	8
10	0	0	14	7	1	0	0	0	7	0	43	29	0	0	9	3	0	1
11	0	2	8	6	1	0	0	0	2	0	0	9	0	0	1	0	0	5
12	4	0	25	4	2	8	0	0	2	1	2	8	0	0	0	16	0	1
13	0	0	6	4	0	0	1	0	2	2	10	20	0	0	35	13	7	1
14	0	0	14	3	0	0	0	0	0	0	3	0	0	0	49	1	0	0
15	14	7	2	7	5	0	0	0	1	0	2	0	0	0	9	0	0	0
16	0	0	0	7	0	0	0	0	0	0	3	4	0	0	17	0	0	5
17	73	30	23	5	0	0	0	0	0	0	8	1	0	0	26	1	0	0
18	2	4	4	4	0	0	0	0	0	0	1	0	0	0	0	0	0	0
19	3	4	11	0	0	0	0	0	0	0	2	0	1	0	5	0	0	0
20	0	0	4	8	0	0	0	0	0	0	0	0	1	0	2	4	0	0
Total Captures	**133**	**72**	**172**	**90**	**19**	**10**	**1**	**0**	**25**	**7**	**147**	**124**	**2**	**0**	**205**	**113**	**42**	**36**

Figure 6: Shannon's Index of Diversity t-test equation

	0.018345
t=	0.980908
v=	2477.161
t0.05(2),2477=1.96	
0.20<P<0.50	

Figure 7: Shannon's Diversity Index t-test results,
indicating no significant difference between CWH and non-CWH capture success rates.

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BIOGRAPHY

Katherine L. M. Busch received her Bachelor of Arts in sociology and Masters of Teaching from the University of Virginia in 2005. She has begun to explore the realm of making deviled eggs.