5-5-2012

Raccoon Acclimation Towards Traps and its Effect on Surveillance and Monitoring of Zoonotic Diseases

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B.S., Quinnipiac University, 2004

A Thesis

Submitted in Partial Fulfillment of the

Requirements for the Degree of

Master of Public Health

at the

University of Connecticut

2012

Approval Page

Master of Public Health Thesis:

Raccoon Acclimation Toward Traps and its Effect on Surveillance and Monitoring of Zoonotic Diseases

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University of Connecticut 2012

Acknowledgements

I would like to acknowledge the advice and guidance of Dr. David Gregorio, major program advisor, as well as Dr. James Grady, associate advisor, and thank them for their encouragement and support throughout this endeavor.

I would like to greatly thank the United States Department of Agriculture for the use of the data analyzed in this thesis. I also want to acknowledge Shylo Johnson, associate advisor, for her assistance on this thesis. Ms. Johnson's critiques, advice, and mentoring have greatly enhanced my understanding of infectious disease research.

I would also like to acknowledge all of the University of Connecticut Health Center administrative staff, particularly Barbara Case, for their help on all aspects pertaining to courses, registration, financial aid, graduation, and such.

Lastly, I want to thank my wonderful family and friends. Words cannot express how important your love, support, and advice has been in guiding me through my life. A very special thank you to my Mom, Cindy Ogorzalek, who has made me into the woman I am today and whose strength, wisdom, and character I am always trying to emulate.

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<u>1 INTRODUCTION</u>

<u>1.1: Raccoons</u>

Raccoons (*Procyon lotor*) are found in the 48 contiguous United States, except in high elevation mountainous regions and in some areas of the arid Southwest. They are classified as omnivores and exhibit nocturnal behavior. Adult males, called boars, travel an area of three to 20 square miles and will establish homeranges based on available food resources and relativity to other raccoons. A female raccoon will travel one to six square miles, and will establish similar, yet smaller homeranges [1]. Social interactions among raccoons vary with the time of year, as well as with age, and temperature. Raccoons have been described as “urban adapters”. They are habitat and dietary generalists capable of utilizing both anthropogenic and natural resources. Species capable of utilizing anthropogenic resources often occur at elevated densities in urbanized areas. Raccoons are no exceptions and are considered one of the most efficient species at adapting to human inhabited environments [2].

<u>1.2: Zoonotic Diseases of Raccoons</u>

The peridomestic nature of raccoons enables them to serve as a host for disease transmission into the human population. Rabies virus is the most notable disease that raccoons can transmit to humans; however there are others that can result in serious sequelea and or death. *Baylisascaris procyonis,* is a roundworm infection of raccoons. There is a wide infection distribution in

raccoons, with infection rates as high as 70% in adult raccoons and exceeding 90% in juveniles. *B. procyonis* eggs are passed in the feces and develop in the soil, where they become infectious and are ingested by raccoons and potentially by humans. The eggs will hatch into larvae and invade the small intestine where they develop into adult worms in the small bowel. Infected raccoons can shed as many as 45,000,000 eggs per day and an infectious dose is <5000 ingested eggs. Eggs are stable in the environment and can remain infectious for months to years. Other animal species can be infected with *B. procyonis*; consequently, 90 species of wild and domesticated animals have been identified as infected [3].

Humans become infected when they ingest the eggs passed in raccoon feces. Most human cases occur in younger age groups because of their increased contact with soil and the increased frequency of touching their mouths. Human *B. procyonis* infection typically results in fatal disease or severe sequelae. Clinical manifestations include eosinophilic encephalitis, ocular disease, and eosinophilic cardiac pseudotumor. There have been eleven recognized human cases, four of which have been fatal. The first case was reported in 1984 in a 10-month old infant with fatal eosinophilic meningeoncephalitis. There is currently no treatment for the visceral form of *B. procyonis*; however laser photocoagulation has been successful at treating ocular infection. Diagnostic testing is also very primitive and currently no serological assay exists. Confirmation of infection requires a biopsy specimen that contains an adequate cross section of a larva. Since small numbers of larvae can cause severe disease and larvae occur sporadically in tissue, a biopsy may fail to include larvae. Larval morphologic characteristics

may not be recognized as well. *B. procyonis* infection is most likely under recognized because of the lack of diagnostic tools and the lack of knowledge of this particular roundworm by physicians. Asymptomatic human infection may be the typical response to infection, and that could explain the few human cases, when it is so widespread in the environment. It has been hypothesized that an unrecognized immune defect may be necessary to cause severe disease in humans [3]

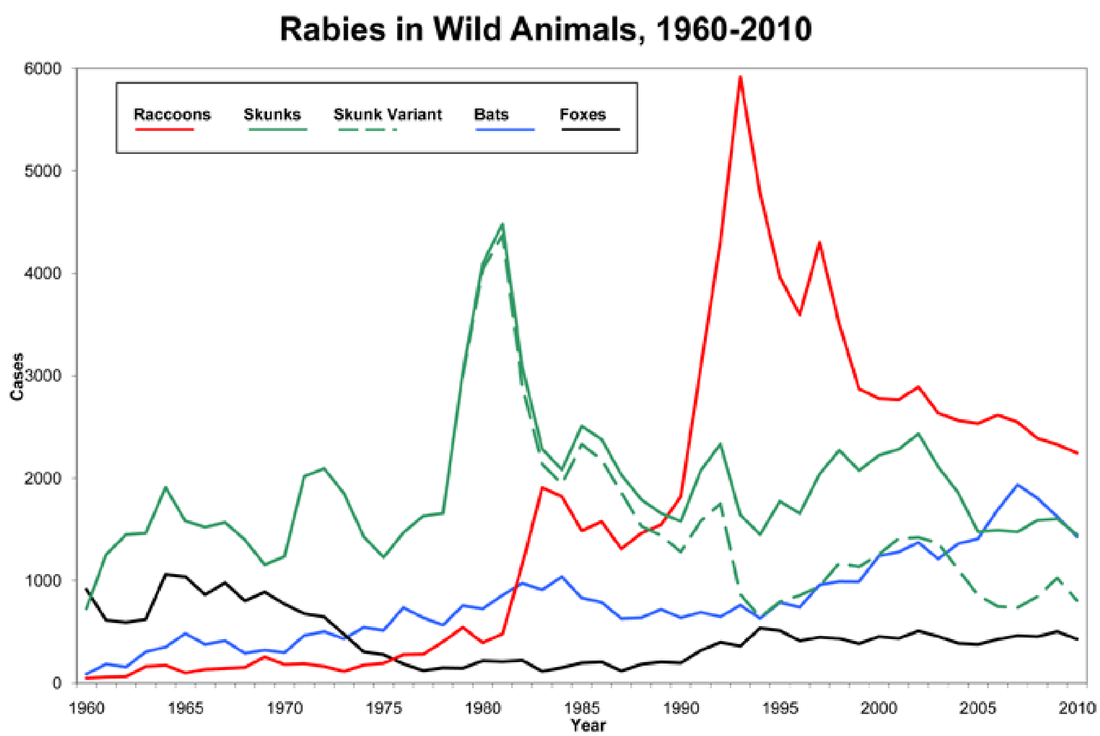
In 1975, Bigler et al. performed a study examining the possible role raccoons could serve as sentinels for human disease. Their results revealed that raccoons were found to be infected with many pathogens infectious to humans, and could not only serve as sentinels to measure pathogen burden in the environment, but could also serve as a source of infection into the human population. In this study, Raccoons tested serologically positive for St. Louis encephalitis, Venezuelan equine encephalomyelitis, Leptospirosis, tularemia, and some enteric bacteria and viruses. In total, raccoons in the Southwest were exposed to at least 13 pathogens known to cause human disease. Nineteen serotypes of Salmonella were also isolated [4]. Appendix A details the specific zoonotic etiological agent of infection found in raccoons and resultant disease in humans.

1.3 Rabies

Raccoons are clearly a source for disease transmission not only into other animals, but to the human population as well. Of most notable importance is the

raccoon's role in the spread of the rabies virus, which is almost 100% fatal in all mammals, including humans. Humans can be exposed through direct contact with a rabid raccoon, or an animal that has been bitten by a raccoon, and therefore has become infected itself. Rabies is caused by a number of rhabdoviruses, which are bulleted shaped RNA viruses belonging to the genus *Lyssavirus*. These viruses are unique because they have the ability to replicate in hosts' cerebral spinal fluid. Different strains of rabies viruses are adapted to particular species, however spillover into different species can occur, and any mammal is susceptible to rabies. Contrarily, it is only carnivours and bats that have the ability to spread the infection [5]. Rabies was added as a nationally notifiable disease in 1948 [5]. In the United States, the dog variant of rabies has been successfully eliminated; however other virus variants are most commonly reported among wild mammals with identifiable virus variants circulating in bats, raccoons, skunks, and foxes. Wildlife species have accounted for more than 80% of infection since 1975 and of all reported rabid animals in 2010, raccoons were the most reported (36.5%), which is a continuing trend, with most reports of raccoon rabies made because of human contact or impact [6]. Figure 1.1 depicts the number of confirmed rabies cases in various wildlife host species from 1960 to 2010. The red line represents the number of rabies infected raccoons, which has been increasing since 1980 and has been the prominently infected host since 1990.

Figure 1.1:



Source: Centers for Disease Control and Prevention: Rabies [7]

Animals are not believed to be subclinical carriers of rabies virus, and will die shortly after contracting the virus. The incubation period is ten days to six months. There are two classifications of rabies virus in animals, the furious and dumb type, with the furious type seen most frequently in raccoons [8]. First stage symptoms of the furious type include hiding in dark corners, acting agitated, circling nervously, and reflex excitability is heightened. After one to three days, excitation and agitation intensify; the animal becomes dangerously aggressive, attacking objects, animals, humans, and itself. Salivation is abundant because the muscles required for swallowing have become paralyzed. The animal gains a propensity to leave its territory and travel long distances, attacking other animals

or humans that it may come in contact with. Generalized convulsions develop in the terminal phase followed by muscular incoordination and paralysis of the trunk and extremities, and finally generalized paralysis which leads to death. The dumb form of the disease is characterized predominantly by paralytic symptoms, with only a brief excitation phase or none at all. Paralysis begins in the head and neck and then travels to the extremities, and finally becomes generalized throughout the body, which is followed by death. The course of the disease can take one to eleven days [5].

Rabid animals are known to approach towns and attack humans and domestic animals. Wild carnivores shed more virus in saliva than do infected dogs and in areas where canine rabies has been eradicated, the disease may be reintroduced by wild carnivores if the canine population is not adequately immunized [8]. Cattle are usually targeted by rabid animals. A recent outbreak in New Mexico (NM) has caused the NM Health Department to recommend vaccination of livestock in the Carlsbad region. Since January 2011, 32 animals have tested positive for rabies and livestock infections are feared because the current drought conditions has forced wildlife into closer proximity to humans and areas of water. At least a dozen people are undergoing treatment for rabies exposure [9]. A cow in northeast Georgia was confirmed to be infected with rabies in March, 2011 resulting in the quarantine of the entire herd [10]. Cats may serve as a spillover host to the human population. In 2010, cats represented the majority (62.2%) of reported rabid domestic animals. Most (82.2%) of the 303 rabid cats were reported from states where raccoon rabies was enzootic [6].

All people can contract rabies, however groups most at risk are those that travel to foreign countries where rabies is endemic in the dog population, veterinarians, people working with wildlife, children may be considered at risk because of their behavior of contacting wild and domestic animals, and immunocompromised individuals [5]. Rabies enters the body by a bite, an open wound, or by contact with mucous membranes and replicates near the site of exposure. It slowly travels through the nervous system until reaching the central nervous system, causing encephalitis. From here it will spread to the salivary glands and other organs. Blood, urine, and feces are not considered infectious. Humans are most commonly exposed and infected through the bite of an infected animal. The incubation period is between two to eight weeks and early symptoms include a feeling of anxiety, headache, slightly elevated body temperature, malaise, and indefinite sensory alterations. This is followed by an excitation phase characterized by hyperesthesia[1] and extreme sensitivity to light, sound, dilation of the pupils, and increased salivation. As the disease progresses, spasms occur in the deglutitory muscles[2] and liquids are violently rejected by muscular contractions, resulting in the inability to swallow. Generalized convulsions can also occur. The excitation phase may dominate until death, or can be followed by generalized paralysis. People remain conscious and aware of their suffering and the disease can last for two to six days [8]

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[1] Hyperesthesia is an abnormal or pathological increase in sensitivity to sensory stimuli, as of the skin to touch or the ear to sound 11. in *Merriam-Webster Dictionary*. 2011.

[2] These are the muscles that enable swallowing

1.4 Detection and Treatment

In animals, brain tissue from at least two different locations (usually the brain stem and cerebellum) is examined for the presence of the rabies virus. This can be accomplished through several different methods: Direct fluorescent antibody test, histological examination, and or immunohistochemistry. To perform these tests on brain tissues, the animal must be euthanized and samples sent to state public health laboratories or veterinary diagnostic laboratories. Results are usually confirmed in 24 to 72 hours [7]. There is not treatment for rabies in animals, and suspect animals are euthanized [8].

Detection in humans is different from animals since the samples are not retrieved post-mortem. There are several tests used to confirm a diagnosis of rabies. These tests require samples of saliva, serum, spinal fluid, and skin biopsies of hair follicles at the nape of the neck. Saliva can be tested by virus isolation or reverse transcription followed by polymerase chain reaction (RT-PCR). Serum and spinal fluid are tested for antibodies to rabies virus. Skin biopsy specimens are examined for rabies antigen in the cutaneous nerves at the base of hair follicles [7].

Treatment of rabies in humans has proven to be difficult if not impossible. Jackson et. al state that, “The dismal outcome of patients with rabies provides little optimism for heroic efforts.” and that the probability of failure in such treatments is extremely high [12]. Rabies post exposure prophylaxis (PEP), which is highly effective if given promptly, includes wound cleansing,

immunization with a modern cell culture vaccine, and administration of human rabies immunoglobulin (HRIG). Palliative therapy is of paramount importance in this fatal disease. Specific treatments for consideration at the present time include rabies vaccine, HRIG, ribavirin, IFN-a, and ketamine [12].

In 2005, a 15 year-old girl was successfully treated for rabies by inducing her into a coma in order for her native immune response to mature. The rabies vaccine was not administered and the patient was treated with ketamine, midazolam, ribavirin, and amantadine. An increased level of rabies antibody was noted eight days after coma induction and sedation was tapered. The patient was removed from isolation after 31 days and discharged to her home after 76 days. At nearly five months after her initial hospitalization, she was alert and communicative, but with choreoathetosis[3], dysarthria[4], and an unsteady gait. The long term effects of such a treatment are unknown. To date, there have only been five well-documented survivors of rabies. All of the patients had received either occupationally related pre-exposure rabies vaccination or post exposure prophylaxis [14].

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[3] Choreoathetosis is defined as rapid involuntary and slow writhing movements due to congenital or acquired defects of the basal ganglia 13. Krude, H., et al., *Choreoathetosis, hypothyroidism, and pulmonary alterations due to human NKX2-1 haploinsufficiency.* The Journal of Clinical Investigation, 2002. **109**(4): p. 475-480.

[4] Dysarthria is difficulty in articulating words due to disease of the central nervous system 11. in *Merriam-Webster Dictionary*. 2011.

1.5: Rabies History

The source of the original introduction of rabies into the raccoon population is unknown. The first documented outbreak of raccoon rabies occurred in central Florida in 1947. It gradually spread south and northward into Georgia in 1962 and South Carolina in 1971. Starting in 1975, raccoons began to be shipped legally and illegally from Florida to other states for hunting purposes; rabid raccoons were confirmed to be present in two of those shipments. In 1977, West Virginia reported its first case of raccoon rabies. The wave front spread southward into North Carolina and in 1995, it met the expanding southern front. Raccoon rabies traveled at an average rate of approximately 40km/year, and was found in Maryland in 1981, Pennsylvania in 1982, Delaware in 1987, and New Jersey in 1989. Raccoon rabies continued to spread northward during the 1990's and New York State reported its first case in 1990, Connecticut in 1991, Massachusetts and New Hampshire in 1992, Rhode Island, Vermont, and Maine in 1994. Finally, in 1999, raccoon rabies reached the Canadian province of Ontario and New Brunswick in 2000. Currently, the epizootic stretches along the entire eastern seaboard of the United States, a distance of nearly 2800km. Westward expansion has been relatively slow, not reaching Ohio until 1997. This is most likely due to various geographic boundaries, most prominent of which are the Appalachian Mountains [15]

1.6: Oral Bait Program

Under the direction of the United States Department of Agriculture (USDA), the Animal Plant and Health Inspection Services (APHIS) in 1995 developed a National Rabies Management program that uses an oral rabies vaccine to prevent the spread of rabies into uninfected areas. An oral vaccine allows for minimal human contact with wildlife while still targeting the majority of the desired population. Oral rabies vaccination (ORV) is an edible bait that consists of a sachet, or plastic packet, containing the Raboral V-RG rabies vaccine [16]. In response to the risk of raccoon rabies spread, ORV zones were established ahead of the raccoon rabies front in northeastern Ohio and northern Vermont in 1997. The goals of the ORV program are to prevent raccoon rabies from spreading to new uninfected areas and to eliminate raccoon rabies virus variant by progressively targeting regional, national and international elimination [17]. Approximately 6.5 million packets are distributed in selected states to create a zone where raccoon rabies can be contained. In 1998, the ORV program was expanded to states of strategic importance in preventing the spread of specific terrestrial variants of the rabies virus. By 2005, the program had been expanded to include 16 states to create ORV zones designed to serve as barriers to raccoon rabies spread [16]. The current ORV program includes 102,650 km_2 or about 64,000 square miles [18].

ORV has been successful at: Containment and eliminations of canine rabies in coyotes from south Texas; containment and new elimination of raccoon rabies from Ohio; prevention of raccoon rabies spread through Lake Champlain

Valley in New York and across northern Vermont and New Hampshire; and reduced incidence of rabies cases where other sizable ORV projects targeting raccoons have occurred. Other benefits have included: Reduced human exposure and PEP costs, reduced epizootic-related pet vaccination, quarantine, and euthanasia; reduced burden on state services for animal diagnostic tests; and reduced livestock losses. A key component to a successful ORV program is accurate bait to species density ratios [17].

1.7: Rabies in the United States

In 2010, 2,246 rabid raccoons were reported to the Centers for Disease Control and Prevention (CDC). The percentage of raccoons submitted for rabies testing that were rabid increased from 11.9% in 2009 to 15.6% in 2010. States in the Northeast and mid Atlantic accounted for 72.1% of the 2,246 rabid raccoons. Southeastern states (Alabama, Florida, Georgia, North Carolina, South Carolina, and Tennessee) reported 27% of all rabid raccoons. States in which rabies is enzootic reported 65.2% of the national total of rabid animals and 77.6% of all rabid animals other then bats. Overall these states submitted 41 animals per 100,000 persons for rabies testing [6].

There were a total of 40 human samples sent to the CDC in 2010, resulting in two confirmed cases of rabies in humans. Since 2001, a total of 29 human rabies cases have been reported in the United States. The bat virus variant is responsible for the majority of human cases (69% of cases) followed by

the dog variant (21% of cases)[5] . The raccoon variant was found in 3% of human cases, as was the fox variant. There was one case of unknown origin [6]. Appendix B depicts the number of fatalities due to rabies infection from 1995 to 2011 by state and by year.

There is a national surveillance network for rabies, which is comprised of more than 125 state and local health and agriculture laboratories and university based veterinary pathology laboratories. They provide primary testing of animals suspected to have rabies and support is also given to this network by local health departments, animal control services, law enforcement departments, private veterinarians, and the general public who collect process and submit animals for rabies testing [6]

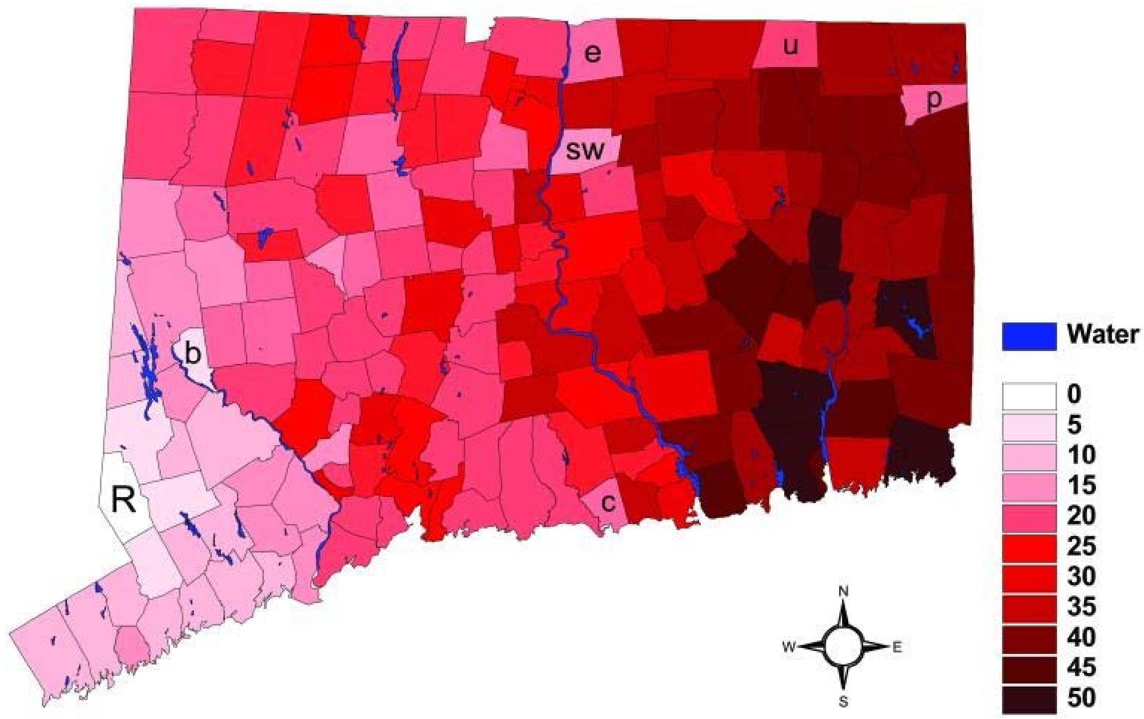
1.8: Rabies in Connecticut

Since 1991, raccoon rabies has been endemic in Connecticut. Initial introduction occurred in Ridgefield and continued to spread across the state. Five years after the first incidence of rabies in wildlife, the entire state of Connecticut was in an epidemic. Figure 1.2, which is taken from Smith et. al 2002, illustrates the expansion of raccoon rabies in the state. The map shows the month when rabies was first observed in each township, *Oi*, relative to the month of the first reported case in Ridgefield Township (March, 1991). The letters are the first

[5] The dog variant of rabies was successfully eradicated from the United States in 2007. The people infected with a dog variant type were people who traveled outside of the country to the Philippines, Puerto Rico, Haiti, El Salvador, and India 6. Blanton, J., et al., *Rabies surveillance in the United States during 2010.* Public Veterinary Medicine: Public Health, 2010. **239**(6): p. 773-783.

names of townships discussed in the text: Ridgefield (R), Enfield (e), Union (u), Putnam (p), Clinton (c), Bridgewater (b), and South Windsor (sw) [19].

Figure 1.2: Spread of Raccoon Rabies in Connecticut



Raccoon rabies continues to be supported in the state by various species, however raccoons are the most frequently reported, comprising 68% of total confirmed positive animals [20]. Fairfield county reported the most cases of rabies in raccoons (n=23) followed by New Haven (n=16). The remaining counties each reported fewer than seven positive raccoons. The tabular form of this data can be found in Appendix C. There were a total of 174 confirmed

positive rabid animals in Connecticut in 2010. There has also been one fatality in the state, which occurred in 1995[20].

1.9: Rabies Economics

The almost 100% fatality rate in rabies has been the impetus for critical monitoring, prevention strategies, and wildlife surveillance. Management of rabies in the United States is not an inexpensive feat. Since the majority of control occurs at the wildlife level, interventions need to be successful at providing attractive bait (in terms of the ORV program), provide enough bait based on population estimates, and predict future areas of outbreaks so that ORV programs can extend into those regions. Other costs associated with rabies management are those incurred when processing suspect animals, paying personnel to catch and test animals, and numerous other expenses related to rabies monitoring. Table 1.1 illustrates the costs (in US dollars) associated with the ORV program in the United States. The annual program costs, which do not include human exposure expenses, are around $12,432,968 [18].

Table 1.1: Costs Associated with the ORV Program

Line item	Cost	Bait Density ($75/km_2$)	Area Baited(102,650 km2)
Bait	$1.30	$97.50/km_2$	$10,008,375
Ariel Distribution	$8.62/km_2$		$884,843
Program Evaluation	$15.00/km_2$		$1,539,750
		Total	**$12,432,968**

The CDC estimates that the inclusive annual costs associated with rabies approaches $300 million annually. These costs include the vaccination of companion animals, animal control programs, maintenance of rabies laboratories, and medical costs, such as those incurred for rabies post-exposure prophylaxis (PEP) [7].The expenditures for routine rabies surveillance and prevention activities in wildlife populations amount to $197.50 for a negative results and $225 for a positive results [21]. Wildlife Services, a division of APHIS, recently did a cost analysis of the ORV program, and they estimated that PEP costs can be reduced by as much as $50 million annually with the continued implementation of the program. This is in addition to savings associated with reduced pet vaccinations, quarantine and euthanasia, surveillance and animal diagnostic tests and livestock loses [16].

Expenses accompanying human post exposure treatment are quite extensive. The CDC estimates that upwards of 40,000 post exposure prophylaxis treatments are given every year, with an associated cost of $150 million [7]. In New Hampshire, a proven single rabid cat precipitated an estimated expenditure

of $1.5 million, of which $1.1 million was attributable to PEP prescribed for at least 665 people.[22]. Annual costs in Connecticut increased more than 20 fold from 1990 ($58,630 for 41 PEP) to 1994 ($1,268,410 for 887 PEP's)[22].

1.10: Public Health Importance

There have been many topics covered in this thesis detailing rabies infection in a variety of ways in order to properly and effective discuss its relevance to public health. Intuitively, any infectious disease that has a 100% fatality rate, and hence the highest case fatality ratio of any infectious disease [14], in the human population should be of major concern to the general population. One might argue that since the cases of human fatalities (only 47 since 2001) are very low as compared to other infectious disease like HIV/AIDS, significant attention and funding should not go towards such expenditures. However, it is because of the deadliness of this virus that such great attention has been given to rabies surveillance and control. Instead of looking at the few fatalities caused by rabies as a poor use of time and money, it should be seen as a success in the measures taken to control it. Without the rigorous and aggressive protocols addressing rabies one would certainly see an increase in wild and domestic animal infection, as well as human disease. Infection of agriculture animals can occur, and cause great economic loss in the farming industry if entire herds need to be culled to prevent the spread into other animals. Rabinowitz et al. 2010 state that, "The public health importance of rabies does

not lie in the number of cases, which is relatively small, but rather the fact that nearly 100% of the patients die. No less important is its psychological and emotional impact, including suffering and anxiety experienced by those bitten faced with the fear of developing disease." [5].

Rabies management can also serve as a model of the One Health philosophy. An idea that attempts to unite human and animal medicine with the environment in order to effectively address infectious diseases. Accompanied with the understanding that microbes know no human, animal, or environmental boundary and to investigate a disease in isolation will only serve as a detriment to that group being studied. "Rabies can therefore serve as a model for improved communication and cooperation among public health, animal health, and human health professionals" [5].

The most effective approach to managing rabies virus is to target the source, which is the wildlife population. The goal is to restrict rabies to only wildlife species, which in turn protects the human population from exposure. The ultimate goal of wildlife intervention is the eradication of all rabies viruses, which has been accomplished for canine rabies variant, and for raccoon rabies variant in Ontario and New Brunswick, Canada [17] .

> "managing and preventing such exposures requires an understanding by human health and animal health professionals of the status of rabies infection in local wildlife and domestic animal populations, the judicious use of vaccination strategies, and animal control measures" [5].

2. LITERATURE REVIEW

The development of newer technologies has improved animal surveillance methods. Where once cameras could not withstand being left in the elements of the environment, nor able to function based on motion sensing, they have those abilities now. Camera trapping is an efficient non-intrusive method in almost any field condition and can provide a more accurate species determination, as well as the possibility of evaluating age, sex, population structure and density in large tracts of land. Initially, the expense to acquire cameras may be costly, but there is potential for long term cost savings as compared to other surveillance methods (track censuses and line transects) [23]. Camera trapping uses fixed cameras, triggered by infra-red sensors to capture images of passing animals. Cameras are equally efficient at collecting data by day and night and provide the opportunity to collect additional information on species distribution and habitat use [24]. Camera trapping has been widely used in conservation and ecology studies, with uses ranging from simple species inventories, the discovery of new species, abundance estimation, conservation assessments, population dynamics, and forest ecology. This explosion in camera trap use is reflected in the 50% annual growth over the past decade in the number of published papers that either directly address camera trapping methods or use them as a research tool [25].

In fact, many studies have employed such technology to monitor species that are elusive and apprehensive towards humans. Silver et al. used motion sensing cameras to obtain photographic capture/recapture images for estimating

abundance of jaguars in South America. Jaguars are a threatened species and are difficult to monitor because of their cryptic nature, large home range sizes, and low population densities [26]. Calculating population density estimates through the use of cameras has also been another noteworthy accomplishment. Rowcliffe et al. developed a model that can estimate such parameters on species that cannot be uniquely identifiable, much like the jaguar can [24]. To date, there has been no such use of cameras recording behaviors of raccoons, or other medium sized mammals for public health surveillance in the United States.

Camera trapping data has advanced the science of studying animal behavior, which is often altered in the presence of humans or while in captivity. The advantage of using camera trapping data for public health surveillance is the ability to monitor animals that are potentially infectious to people. A better understanding of an animal's response and their relative abundance will serve as an extremely useful tool when implementing zoonotic disease interventions. Species can be better targeted and appropriate amounts of intervention (vaccine, bait, etc) can be delivered so the population can be effectively treated. Sealander et al. describes the importance of studying animal behaviors in the following passage:

> "The initial behavior responses of mammals to traps have long been chiefly a matter of inference. Studies in which attempts have been made to evaluate this factor in trapping success for the most part have not been very successful. Lack of information about initial trap responses raises many questions such as the following: were any mammals present in the vicinity of the trap? Was the bait used attractive to mammals? Was the trap investigated by any mammals at close range? Could the trap have been entered and failed to trip due to mechanical failure of the trigger mechanism." [27]

Often times disease surveillance for infectious diseases are better done at the animal level because they can give a direct measurement of infection. In terms of rabies, public health surveillance may lack spatial-temporal sensitivity for refined ORV decision making, as submissions are based predominately on human and domestic animal exposures [6].

An animal's behavior will dictate whether or not it enters a trap. That behavior can be influenced by hunger, territory, seasonality, or weather. In small mammals, Getz et al. found that shrews were less active on sunny days, while voles were just as active on sunny days as compared to cloudy days. The activity of white footed mice was influenced by temperature variations [28]. Sex of the raccoon has been shown to influence trap responsiveness. Males may be more prone to capture during the mating season and again during parturition when movements of females are reduced. Population estimates may be biased towards males because research reporting demographics have suggested estimates may be affected by an increased vulnerability of males as a consequence of their greater movement and activity [29]. Adult males maintain intrasexual social bonds, and frequently den and travel together; therefore the behavior of one male may have an effect on the behavior of other male raccoons. It is possible that capture probabilities of male raccoons vary with different types of social organization. In contrast to males, females move independently of other raccoons [29].While observing small mammals responses to live traps, Getz noted that:

"All species of small mammals do not respond in a similar manner to live traps. In some species, the unmarked individuals are less readily captured than are the ones captured previously, in others the reverse is observed, while still others are isoresponsive[6]. To accurately determine population densities from trapping data one must first determine the response of individuals of each species to the traps. The data involving those species not isoresponsive must then be corrected to obtain valid estimates of population densities." [28]

Animals are trapped in order to study their burden of disease and effectiveness of various interventions; therefore, trapping needs to be maximized in order to see the full effect and or benefit. Trapping does not capture the entire population, similarly as in human studies wherein subjects do not complete written surveys, or are lost due to follow-up. Best estimates of population can therefore only be determined based on the animals that are captured and recaptured. A theory called trap-prone/trap-shy was developed to classify animals into two distinct categories: trap-prone animals are animals that have entered a trap once and will continue to enter the trap, this could be due to learned reward behaviors; a trap-shy animal is an animal that will either never enter a trap, or if it does, it will not enter it again, most likely due to the negative association between entering and being captured. In 1965, M. T. Tanton performed a review of previously published literature on animal responses towards traps. His findings show that there is much debate over how animals respond to traps. In one study, researchers found that mice neither learned to avoid or enter traps, a theory of learned behavior that was previously stated. This same study found however that there was evidence of trap-shy/trap prone behaviors in terms of sexes. Isolated all female populations showed no evidence

[6] Isoresponsive means that marked and unmarked individuals are equally attracted to traps

of trap proneness or trap shyness, but developed these characteristics when males were introduced [30]. Chitty et al. showed that in voles (*Microtus agrestis, Clethrionomys glareolus*) marked animals entered the traps more readily that did unmarked ones [31].

Another well studied response by animals to traps has been New Object Avoidance; this is an avoidance response when an animal encounters a new object in its environment [31]. Previous research is contentious when determining if there is indeed a New Object Avoidance behavior exhibited by animals. It is most often assumed that a mammal encountering a trap exercises a choice and responds either positively or negatively [27]. In order to account for new object avoidance and to maximize captures, prebaiting has been done in order to attract animals to the traps attempting to encourage a positive encounter because they receive the bait without being captured. Chitty and Kempson have shown delays in entering of traps by *Microtus pennsylvanicus*, and that trapping was more effective if traps were opened for one day prior to trapping. They hypothesize that an initial avoidance of unfamiliar objects may be more general, at least among rodents, than has been realized.[31]. The rationale behind prebaiting is that there is a great opportunity for an entire population to become familiar with the traps; relatively large catches may then be expected within a short time after the actual setting [31]. Tanaka and Kanamori found that in voles, the probability of capture was markedly enhanced when traps were prebaited [32].

3. Research Question

Previous research demonstrates various degrees of acclimation to traps by various species of animals, primarily small mammals. There has currently been no reported research conducted on acclimation behavior of raccoons to traps. In order to successfully achieve this goal, a broader evaluation of the trapping environment needs to be observed. Raccoon trapping involves results only obtained from the presence or absence of raccoons in traps, little is known about what occurs around the trap or how often traps are approached by raccoons. The development of motion sensing cameras has led to the ability to examine animals in their natural state and natural responses without disruption. Acclimation can affect calculated capture probabilities and population density estimates because if acclimation is present, the first few days of trapping will yield very little and later days will yield more, with maybe the greatest yield days later. Therefore, it is not that there are no raccoons on the first few days of trapping, but rather there are and they are not entering the traps. The fact that there are fewer numbers in the beginning can distort negatively capture probabilities and population density estimates. Conversely, if there is no acclimation period and acclimation is being controlled for in models, this will over estimate the population and cause an increase in, say, rabies intervention programs.

The purpose of this thesis is to determine if raccoons exhibit “New Object Avoidance” and trap-shy/ trap-prone behaviors. “New Object Avoidance” will be referred to as acclimation in the remainder of this thesis and can be broadly

defined as a period of time that is required for a raccoon to become familiarized with a trap upon which it will enter and become trapped. Acclimation can be a multidimensional scenario and henceforth in terms of this thesis acclimation has been defined in the following ways:

1. Acclimation is an increase in trapped raccoons after trap night two.
2. Acclimation is an increase in the number of visits to a trap by raccoons after trap night two.

If a raccoon exhibits trap-prone behavior, there will be an increase in the number of previously captured raccoons visiting a trap as compared to raccoons that have not been captured. An animal exhibiting trap-shy behavior will avoid traps, most likely due to fear. This behavior can be determined by examining the raccoon's ear markings; a raccoon with an ear tag has previously been captured, whereas a raccoon with no tag has not. Raccoons are always tagged upon capture. It is hypothesized, based on reviewed literature, that there is a period of acclimation, or "New Object Avoidance" for raccoons and they do require at least two days to become familiar with the traps in order to become trapped. It is also hypothesized that raccoons show evidence of trap-prone behavior, which may be perceived as acclimation, but in fact is not. Acclimation and trap-prone behaviors should not be considered one in the same, but two distinct behaviors that influence a raccoon's decision to enter a trap. Each behavior results in the use of different approaches in order to effectively target the entire population during interventions. The following experiment was conducted to evaluate the theory of acclimation and trap prone behaviors in a raccoon population.

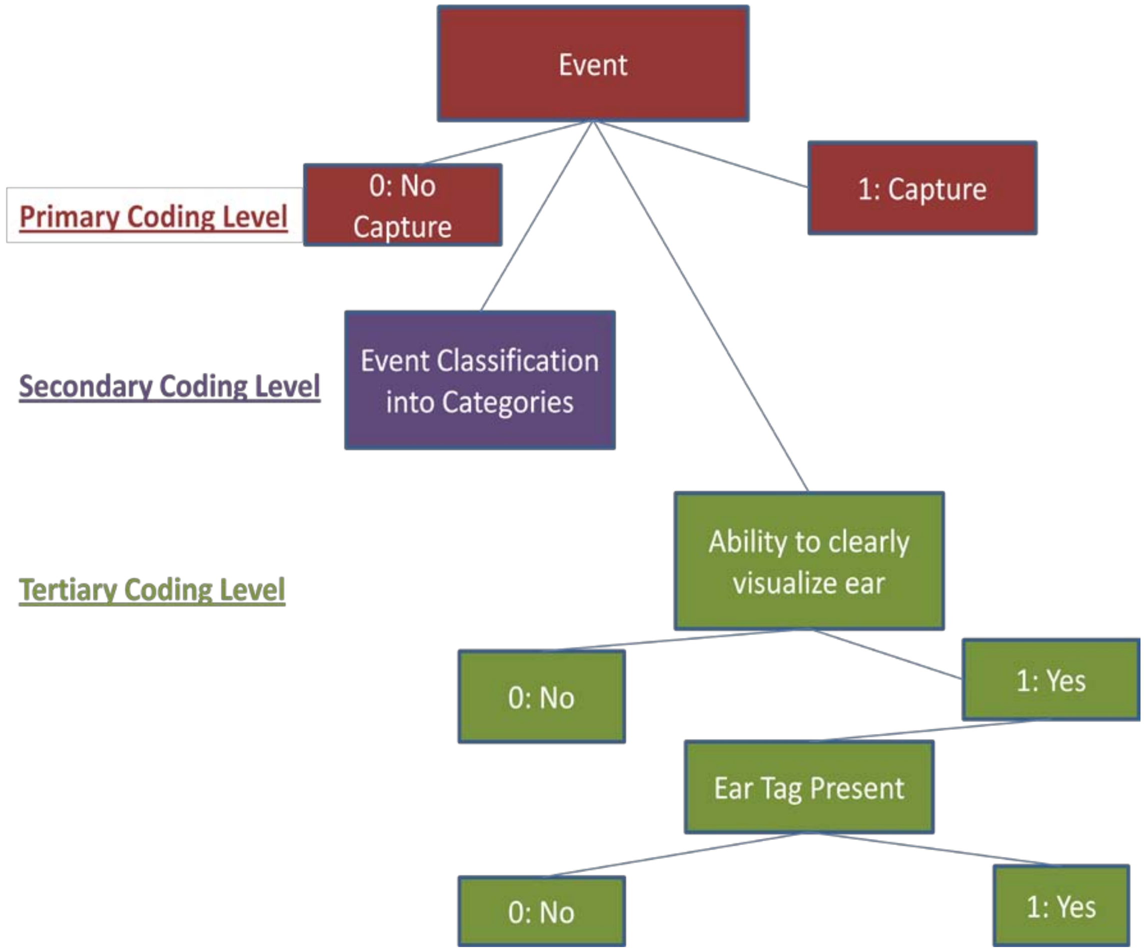
4. Materials and Methods

The dataset that was used for analysis was supplied by the National Wildlife Research Center (NWRC), a division of the United States Department of Agriculture (USDA). The original data consisted of motion triggered photographs, which captured activity/motion around tomahawk traps. Tomahawk traps are routinely used to capture medium sized mammals (raccoons, skunks, and opossums). Trapping was conducted at a forested site for ten consecutive days at a location referred to as “Site A”. The interval between when a trap is baited until the trap is checked for captures the next day is termed “trap night”. For the remainder of this thesis, trap night will be used in place of day. Traps were baited with marshmallows and raccoon lure; a commonly used food to attract raccoons. The photographs were analyzed and a written description was created in order to describe each event using Microsoft Excel software. Entries were then condensed into events; an event was defined as a break in time during visits of raccoons to a trap. In order to best classify events a thirty minute interval of no activity at a particular trap by the same species of animal was used as a quantitative measure of events. As seen by the data, animals spend approximately 3-5 minutes at a trap and so a time lapse of thirty minutes would give the animal time to leave and allow for a new animal to visit the trap.

Raccoon events were coded using a primary, secondary, and tertiary level system. The primary system consisted of listing the raccoon event as “captured” or “no capture”. A value of 0 represented a “no capture” and a value of 1 represented a “capture”. The secondary coding system included a more

descriptive documentation of the activity around the trap. A secondary coding could contain any value from 0 to 13. Complete descriptions of values are listed in Appendix F. The secondary coding system allowed for more in-depth statistical analysis. The tertiary coding system analyzed the presence of ear tags. When animals are trapped they are usually uniquely marked with either a permanent alteration (tattoo, toe clipping) or a semi-permanent (ear tag, leg band). Marking an animal allows for analyzing the progress of that individual; how often they get trapped, how far they travel, or how their biological systems change and adapt to various pathogens. The raccoons in this study were given an ear tag upon capture; each ear tag has a unique number in order to tell individuals apart. Ear tags were noticeable in photos; however the unique number was not. Therefore, one could conclude that the raccoon had been previously trapped, but could not tell how many times. When coding using the tertiary system, it was noted with a 1 if visualization of ears was possible, and a 0 meant that one could not distinguish the raccoons' ears. If the ears were clearly visible, a value of 1 was given if an ear tag was noticed and a value of 0 meant that no ear tag was visible. Figure 4.1 pictorially represents the coding system. The dataset was then imported into the statistical software program SAS 9.2 for all computations and analysis.

Figure 4.1: Primary, Secondary, and Tertiary Coding System Design



Since acclimation is a behavior that is dependent upon time, linear regression will first be employed to determine if there is indeed a linear relationship between acclimation and time. In the case that acclimation does not behave linearly, a t-test analysis will be used to compare event frequency means up to day two with those after day two. Mean values for the number of visits and number of captures will be used in the t-test. Logistic regression will be used to test trap-prone behavior. This is another variable that accounts for an increase in events over time, however since the measure of a trap-prone raccoon is either

the presence or absence of an ear tag, logistic regression will be used to estimate the log odds of a trap being visited by a tagged raccoon compared to an untagged raccoon. All SAS output results can be found in Appendix G.

5. Results

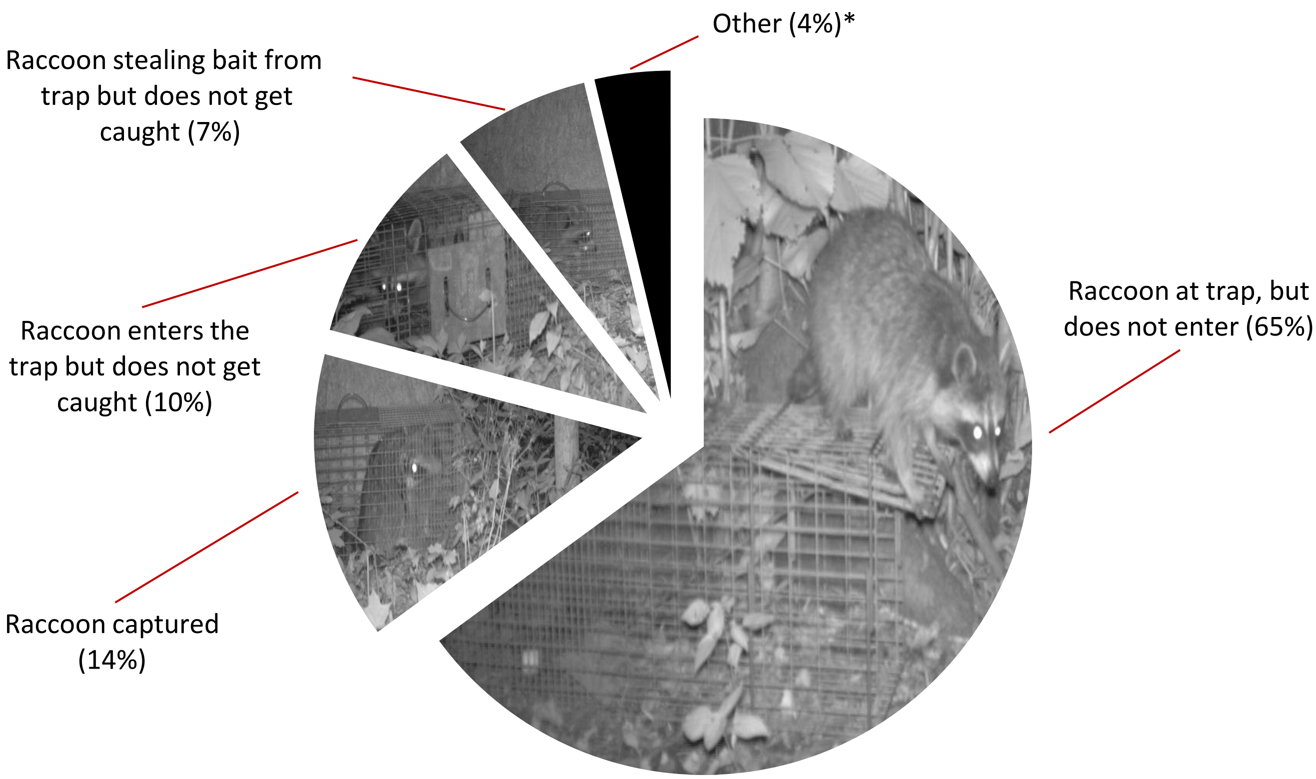
Varieties of species of animals visited the traps and were photographed during the study period. The frequency of species visits are listed in Table 5.1. Not surprisingly, raccoons were photographed the most (44%), followed by small mammals, and a few incidental sightings (cat and rabbit).

Table 5.1: Frequency of all Animals Photographed

Species	Frequency	Percent
Bird	23	8%
Cat	2	<1%
Chipmunk	4	1
Fox	1	<1%
Mouse	8	3%
Opossum	24	8%
Rabbit	1	<1%
Raccoon	134	44%
Rodent	8	3%
Squirrel	52	17%
Unknown	47	15%
Total	**304**	**100%**

Raccoon behavior varied around the trap, however the most commonly photographed behavior was activity around the trap without the raccoon ever entering. This accounted for 65% of all raccoon activity. Figure 5.1 shows the percent distribution of behaviors.

Figure 5.1: Frequency of Raccoon Behaviors at Traps



*Other category is comprised of 3 behaviors: Another raccoon visits a trapped raccoon (2%), More then 1 raccoon at a trap, both are adults (1%), and Raccoon repeated enters into a trap without getting caught (1%)

The raccoon events were tallied and are displayed in Table 5.2. These values are based on the primary coding system, in which Activity is any event that does not include a raccoon becoming trapped.

Table 5.2: Raccoon Activity and Capture Events

	Trap Night										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**
Activity Only	13	14	7	13	12	15	14	9	5	13	115
Capture	3	1	0	2	3	1	3	1	2	3	19
											134

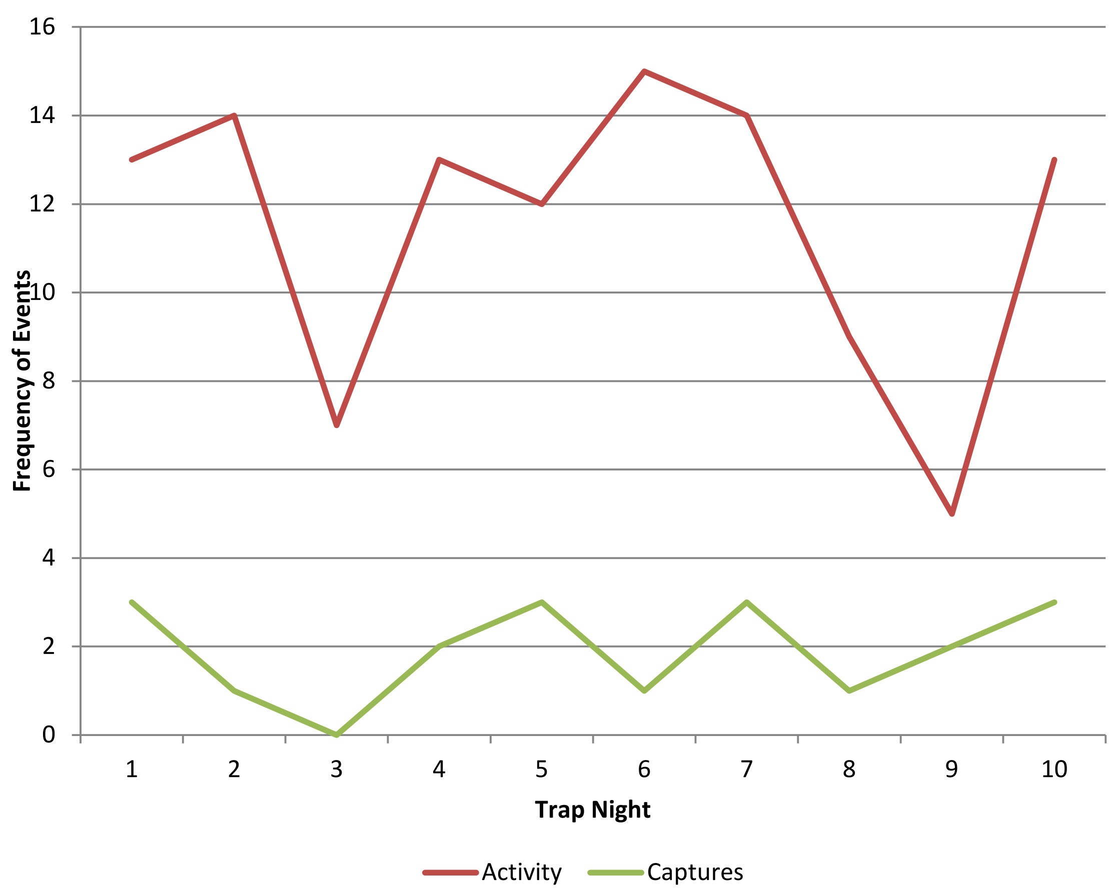
5.1 Statistical Analysis

The analysis revealed that the data does not conform to a linear function, and therefore linear regression is not an adequate test for significance. The first linear model used the trap night as a predictor for the number of captured raccoons, whereas the second model used the trap night as a predictor for the frequency of visits (excluding captures) around a trap. The regression models can be found in Table 5.3. Figure 5.2 depicts raccoon events by trap night. The red line represents the frequency of visits to traps made by raccoons and the green line represents the frequency of raccoon captures. It is clear that a linear trend line cannot be fit to either type of data (frequency of visits or captures).

Table 5.3: Linear Regression Results

	Definition	Regression Model	P value
1	Increase in trapped raccoons after trap night two.	Captured= 1.5 + 0.08*trapnight	0.55
2	Increase in the number of visits to a trap by raccoons after trap night two.	Activity= 13.1 + (-0.28)*trapnight	0.47

Figure 5.2: Raccoon Events by Trap Night



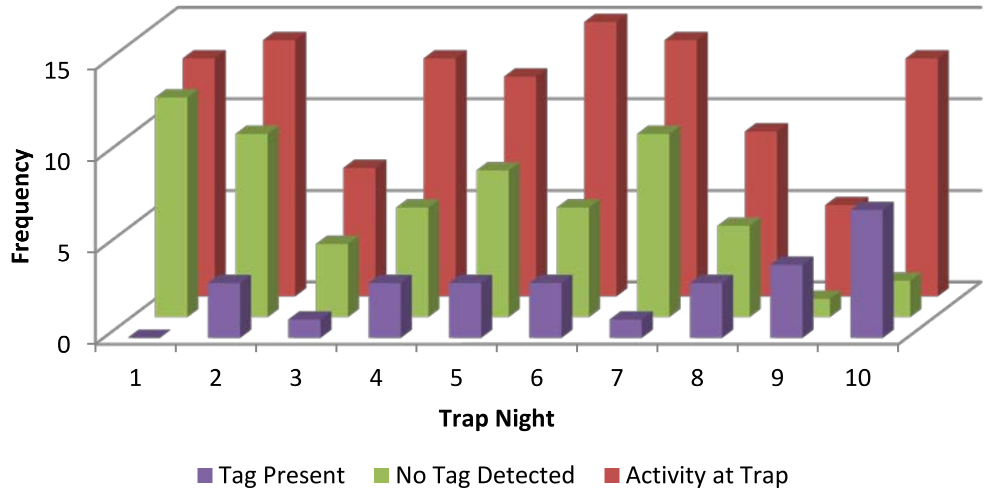
The t-test analysis performed on definition one of acclimation revealed that there is no difference between the mean number of captures before trap night three and trap night three and after. The trap nights were combined into two categories in order to compare mean values; period one included trap nights one and two and period two included trap nights three through ten. This is in agreement with the acclimation definition that acclimation would result in an increase in the number of captures after trap night two. The mean number of captures was 1.5 for both periods. The F test for equality of variance showed that the variances were unequal (d.f=7; F value= 2.86; p=0.85), therefore the Satterthwaite method of unequal variances was used to determine the significance between the two groups. Since both means were identical, the t-test confirmed no significant difference between the two time periods (d.f= 2.7; t value = 0.0; p=1.0).

The t-test analysis for the second definition of acclimation showed no significant difference in the mean frequency values of visits to traps between both time periods. The trap nights were divided into two periods as described in the preceding paragraph. The mean value for visits to a trap for period one was 14 and 11 for period two. The equality of variance assumption was not violated based on the results of an F test (d.f =7; F value = infinity; p < 0.000). The Pooled method produced a t value of -0.98, with d.f= 8 and a p value of 0.36.

Logistic regression was used to estimate the log odds of a trap being visited by a tagged raccoon compared to an untagged raccoon. The odds of a raccoon having an ear tag and visiting a trap increases with increasing trap night

(OR= 1.4; 95% CI 1.2, 1.6 d.f.= 1; $p<0.0001$). The variable trap night was used as a predictor for the presence of an ear tag. Logistic regression was also used to determine the log odds of capturing a previously captured raccoon compared to a non recaptured raccoon. Trap night was used as a predictor for recaptured raccoons while the variable "recaptured" documented if a captured raccoon had been previously captured; this was determined by the presence of an ear tag when captured. Results showed that the probability does not increase over time and one is just as likely to trap a naïve raccoon as a recaptured raccoon ($\chi 2$= 2.98; p= 0.0842; Odds ratio= 1.3; 95% CI= 0.931, 1.948). Therefore, the data suggests that even though recaptured raccoons are visiting traps at an increasingly frequent rate, they are not being trapped more frequently. Figure 5.4 displays the total activity by trap night (red bars), the number of raccoons per trap night that did not have ear tags (green bars) and the number of raccoons per trap night that did have ear tags (purple bars).

Figure 5.4: Presence of Tagged Raccoons during the Course of Trapping



6. DISCUSSION

There does not appear to be a period of acclimation by raccoons towards traps, as supported by statistical analyses of the data. The data does not behave in a linear fashion, and therefore results from the linear regression are inconclusive; however the t-test results conclude that the null hypothesis that there is no period of acclimation cannot be rejected. This in fact could be a behavioral attribute of raccoons; literature has been divided on acclimation of other various small mammals, and these findings further support that mammals do not require time to become familiarized with traps before they will enter them and become trapped. Acclimation may occur in a shorter period of time then the two days used in this thesis, however, if acclimation takes only a few hours or one day there may be no advantage to pre-baiting traps since the time interval is so brief.

To address the trap-shy/trap-prone theories, ear tagged raccoons were analyzed as a measure of attractiveness towards a trap. There is disagreement in the theory of these trap behaviors; whereas Chitty et al. found that marked individuals were more likely to enter a trap, Tantan et al. did not [30, 31]. There is currently no literature on trap behavior exhibited by raccoons, and hence the findings from this research are quite notable. Results from logistic regression revealed that raccoons that are marked are visiting traps at an increasing rate as compared to raccoons that have not been marked. The null hypothesis that there is no trap prone behavior exhibited can therefore be rejected. This could be due to raccoons acquiring learned behaviors of reward; by entering the trap they

receive food and so will frequent traps often versus raccoons that have not been trapped. This could also be due to trapping more of the population as time passes, thereby increasing the number of tagged individuals as compared to the untagged population. An interesting result from the analysis revealed that even though tagged raccoons are more frequently visiting traps, they are not entering traps more often as compared to unmarked animals. However, a trap-shy animal would not visit a trap again after being captured for fear of the trap, but a trap-prone animal would. The hypothesis that raccoons exhibit trap-prone behaviors is still accurate.

The results together suggest that raccoons do not require time to adjust to the presence of traps, and will enter them just as frequently on the first day of trapping as compared to the last day. However, they do appear to exhibit a trap-prone behavior that influences their presence around the trap. The trap-prone behavior is further supported by the raccoons' actions captured by the cameras. They were often photographed on top of the trap, walking around the trap, entering the trap partway without being captured, and even stealing bait from the trap without being caught. In fact, 18% of the events resulted in a raccoon entering a trap, but not getting caught. A raccoon fearful of the trap, which is assumed to be a trap-shy behavior, would not exhibit these traits.

In this research, individual animals could not be identified, and therefore noting an animal that had an ear tag does not always correlate to a unique individual. Therefore the increase in frequency of visits to a trap could be solely due to a trap-prone raccoon that frequents the trap several times over the course

of the night. This finding may support the theory of trap-proneness; however there is not an increase in the probability of trapping a tagged raccoon versus a non-tagged one. This translates into equal trappability of tagged and untagged raccoons, which is contraindicated in the trap-prone/trap-shy theories. It is probable that trap-prone behaviors do exist in raccoons, which explains the frequency of visits to the traps, however there has been a negative association with becoming trapped and they become reticent to enter a trap. However, due to their curious nature, they return to the traps in order to determine if it is possible to obtain the bait without getting caught.

Capture recapture surveys have been used as a general sampling and analysis method to assess population status and trends in many biological populations. The use of marked individuals is analogous to the use of various tracers in studies of physiology, medicine and nutrient cycling [33]. There could be many explanations for the abundance of activity around a trap, but very little trapping resulting from the activity. The bait used for the trait may not have been as attractive as compared to other available baits. Since trapping was done in June, vegetation was plentiful and a readily obtainable source of food. Trapping locations may have been located in close proximity to human establishments, therefore offering another source of food for raccoons. The raccoons that did not enter the trap could have been classified as being trap shy, in as much that they refuse to enter a trap for any number of behavioral reasons.

Raccoons do not prefer traps equally, meaning that some traps are more attractive than others. This could be due to placement, home range, and or other

environmental factors. The data here shows that there is a range of the number of events occurring at each trap; event numbers ranged from 6 to 31. Appendix D lists the range of events by trap. Since traps are preferred differently, it could be possible that acclimation is occurring at the traps with high rates of captures and activity, but the lack of events from other traps is diluting the effect. To address that possibility, the top three performing traps were analyzed using linear regression, following the same definitions of acclimation as before. The top performing traps were those that had the highest number of total events, both non captures and captures. The three highest activity traps were traps 10, 16, and 40; linear regression and t-tests were both done as described previously in the results section. Once again, the data did not conform to a linear function. When analyzing trap night as a predictor for captured raccoons, the model equation was <u>Capture= 0.42 + (-0.005)*trapnight</u>, p=0.90; similarly, when analyzing raccoon visits to traps using trap night as a predictor the resulting model equation was <u>Activity= 2.7 + (-0.07)*trapnight</u>, p= 0.54.

The t-test results support the previous findings that there is no significant difference in the mean frequency values between the two time periods (before day three and day three and after). The Satterthwaite method results for captures alone was: t value= -1.43; d.f.= 8.6; p=0.19. The mean number of captures for period one was 0.67 and 0.32 for period two. The Satterthwaite method was used again for analyzing the frequency of visits made by raccoons to traps. The results were as follows: t value= 0.32; d.f.= 12.6; p=0.76. The mean number of visits for period one was 2.2 and 2.4 for period two. These results suggest that

acclimation is not occurring at highly active traps and there is no dilution effect occurring due to less active traps. This further supports the acceptance of the null hypothesis of no acclimation by raccoons.

There are two measures that are calculated from trapping results, population abundance and population density. Population abundance is the absolute number of individuals that compose the population, whereas population density is the number of individuals of a population in a given unit area [34]. Both estimates rely critically on capture and recapture data. The actually number of raccoons trapped was 19, eight of those raccoons were previously trapped, one raccoon had an unknown previous history, and ten were first time captures, which includes the eight that were recaptured. The Jolly-Seber estimate of population would incorporate the recaptures and first time captures, as well as other parameters like capture probabilities, marked animals not recovered, and maximum likelihood estimates [35]. Population estimates cannot be determined with this data since individuals cannot be identified and trap placement in terms of distance and relatedness to other traps without cameras in unknown. However, since ten captures were first time captures, it can be assumed that there are at least ten raccoons in the area. There were a total of 115 events, excluding captures, recorded around the traps for the total trapping period. Four of those events were inconclusive in terms of visibly identifying an ear tag. There were 74 events involving raccoons that did not have ear tags and 37 events involving raccoons with noticeable ear tags. Since raccoons with ear tags have been recorded previously, they will not be included in the following analysis. If it is

assumed that 50% of events, made by the untagged raccoons, were made by unique individuals, the low end estimation of the population would be approximately 37 raccoons. The explanation for the 50% estimation is that raccoons are making multiple visits during the trapping period. However if all raccoons are unique (100%), the high end estimate of population abundance is 74 raccoons.

These rough estimates indicate that the actual captured population is approximately 3.7 to 7.4 times smaller than the actual population observed. It is acknowledged that these are rough estimates of population abundance, however the importance of this finding is that capture/recapture methods significantly neglects a major segment of the raccoon population. In terms of the ORV program, bait is distributed based on raccoon density estimations, however if those estimations are under reporting the number of raccoons in a given area, the success of the ORV program may be compromised.

This thesis has demonstrated the usefulness of cameras on traps and their ability to capture a significantly larger portion of the raccoon population. Future studies that could expand upon these findings would be to incorporate distance into the traps and camera placements in order to calculate population densities. A trapping area that just has traps with cameras on them would also be useful since it removes the influence that other traps have on one another. To expand upon this theory, it would also be noteworthy to include cameras that could record situations occurring between two traps. However, this might be

difficult since traps are usually placed quite a distance away from one another, usually about ten meters.

7. LIMITATIONS

There are several limitations of this thesis and assumptions of the data. Firstly, cameras were not able to distinguish individual animals, even those that were ear tagged. The camera is not sensitive enough to read the number on the tag. This presents a problem when trying to calculate population abundance. In this thesis there was 115 events noted, however this is most likely not all unique visits, but some repeated. The cameras also only focus around the trap; it is possible that raccoons pass by, but do not trigger the camera and are therefore missed. The traps that had cameras placed on them were part of a larger trapping effort, however the other traps did not have cameras placed on them. The behavior noted by the raccoons could have been influenced by the surrounding traps. However, since this thesis does not include information on the other traps, it was assumed that the traps with cameras on them were isolated. There is also the problem of extrapolating these findings to other raccoon populations in different geographical regions, much like extrapolations made from human results.

8. CONCLUSIONS

To conclude, there appears to be no period of “New Object Avoidance” or acclimation by raccoons towards traps, they do appear to display trap-prone behaviors; however, these two very different characteristics are influential when designing interventions for monitoring of zoonotic diseases. The fact that raccoons do not require time to become adjusted to traps translates into no having to prebait traps for several days. Prebaiting involves the baiting of traps that have been propped open so that the animal can retrieve the bait, but not get captured. This period also allows the traps to obtain the scents of the environment that they are placed in. More broadly, not having a prebaiting period means less man power and money being spent on trapping programs, as well as decreasing the time required to obtain useful results. It may be necessary to employ different types of traps when performing these types of studies in order to capture the trap-shy individuals. The results demonstrate that the majority of the raccoons visiting traps are ones that have been previously captured and can therefore be defined as trap-prone. Trap-shy raccoons have the potential to transmit disease and so need to be targeted for interventions; they may even possess some trait that makes them better carriers of disease which could be related to their response to traps.

As stated previously, raccoons are responsible for the transmission of many infectious diseases. It is often more effective to treat the wildlife populations then deal with disease in humans, as is the case with rabies. These findings can apply to any type of infectious disease program involving raccoons where trapping is

necessary. Extrapolation to other medium sized mammals, like skunks or opossums, may be possible, but unlikely since they exhibit their own defined set of behaviors. Even though the United States has successfully controlled many of its infectious diseases (excluding HIV/AIDS), there is always the possibility that an outbreak can occur and a timely response is needed. In the recent past there have been outbreaks of West Nile virus, Avian and Swine influenza; all of which came from animal hosts and caused great panic in the general public for fear of repercussions from the diseases. Targeting the animal hosts needs to employ an intense knowledge of the animal's response to traps in order to be successful. Waiting too long to trap animals or only targeting a select group from the population may only serve to spread the disease to vulnerable populations and put humans at greater risk for disease exposure. The environment is constantly changing in response to climate, human use, and environmental change. The effect of these changes on pathogens and their potential hosts is unknown; however, developing informed surveillance methods will allow timely responses to future human health threats. The findings from this thesis add to better define a raccoon's response to a trap, which is essential in order to be efficacious in disease outbreak response.

In addition to the primary results of this thesis, secondary findings demonstrate how capture/ recapture methods can underestimate population density and abundance measurements. These estimations are imperative to many infectious disease surveillance programs, particularly rabies management. Treatments and interventions are based on these estimates and can be

ineffective if the proper dose is not given. This not only is a wasteful expense if coverage goals are not met, but can also endanger human lives. Moore and Kennedy state that, “Unless such factors as daily and seasonal differences in response to traps and individual response to the traps are taken into account, and appropriate estimators chosen, the estimates of population size could be off by a factor of two or more.” [36]. As demonstrated by the results, population measurements may be under estimating the actual population by up to seven fold, meaning the true density is seven times that of the calculated one.

The use of cameras has been shown to produce valuable results in terms of animal population studies. Previous work supports the use of cameras and the findings from this thesis suggest that the use of cameras may be more effective than trapping when trying to estimate population abundance and densities because more raccoons were noted in the photographs then were captured in the traps. Recaptured or tagged animals may also be seen in cameras and used to approximate population abundance. Cameras are less labor intensive as compared to setting and checking traps; they also require less people to check and process the information. They may reveal behaviors exhibited by animals, such as: traveling in groups, frequently visiting traps, stealing bait, etc., that would be useful when trying to develop surveillance programs. Cameras also decrease the potential exposure of infectious diseases to people who would have otherwise needed to trap and handle wild animals. Should rapid surveillance in response to a human health threat be required, this will minimize labor and equipment costs.

Studies on raccoon behavior are crucially important in terms of public health in order to better protect the human population. Investigations involving direct animal surveillance help bring together human, animal, and environmental health with the understanding that all three are required to effectively combat infectious diseases.

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<u>Appendix A</u>: Pathogens recovered from raccoons and the resulting human disease symptoms.

Etiologic Agent	Disease	Presentation in humans
Flavivirus	St. Louis Encephalitis (SLE)[1]	Aseptic meningitis or encephalitis. Many cases have only fever with headache Can progress to focal paralysis, intractable seizures, coma and death
Alphavirus	• Western Equine encephalomyelitis virus (WEE) • Venezuelan equine encephalomyelitis (VEE) • Eastern Equine encephalomyelitis virus (EEE) [1]	Same as SLE
Bunyaviridae	California encephalitis virus [1]	Same as SLE
Brucella canis	Brucellosis [2]	Fever, joint pain, abdominal pain, weight loss, fatique, arthritis, endocarditis, epididymitis/ orchitis
Leptospirosis spp.	Leptospirosis [3]	Acute onset of uveitis, conjuntival suffusion, myalgias, fever, renal failure, jaundice
Francisella tularensis	Tularemia [4]	Fever, lymphadenopathy, fatique, pneumona
Salmonella spp.	Salmonella [5]	Diarrhea, often with mucus or blood, abdominal cramping, fever

Trypanosoma cruzi	Chagas disease [6]	Two phases: acute and chronic phase. If untreated, infection is lifelong. Acute: fever or swelling around the site of inoculation Rarely, acute infection may result in severe inflammation of the heart muscle or the brain and lining around the brain. Chronic: an estimated 20 - 30% of infected people will develop debilitating and sometimes life-threatening medical problems over the course of their lives.

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<u>Appendix B</u>: Human Fatalities (1995-2011)

State	Total	Year(s)
AR	1	2004
CA	10	1995, 2000, 2001, 2002,2003, 2004, 2006, 2008, 2011
CT	1	1995
FL	2	1996, 2004
GA	1	2000
IA	1	2002
IN	2	2006, 2009
KY	1	1996
LA	1	2010
MI	1	2009
MN	2	2000, 2007
MO	1	2008
MS	1	2005
MT	2	1996, 1997
NH	1	1996
NJ	2	1997, 2011
NY	2	2000, 2011
OK	1	2004
TN	1	2002
TX	6	1996, 2004, 2006, 2009
VA	2	1998, 2009
WA	2	1995, 1997
WI	3	2000, 2004, 2011

Source: (CDC 2012)

Appendix C: Number of confirmed cases of rabies in raccoons and other animals by county in Connecticut, 2010

County	Raccoon Positive	Total Positive Animals	% of Total
Fairfield	23	34	68
Hartford	6	14	43
Litchfield	5	12	42
Middlesex	2	5	40
New Haven	16	26	62
New London	2	8	25
Tolland	4	4	100
Windham	4	8	50
Unknown	0	1	0
Total	62	112	55

Appendix D: Event Frequencies by Trap

Activity Frequencies			
Trap	No Capture	Capture	Total
2	9	0	9
8	4	1	5
10	29	2	31
16	21	7	28
19	13	0	13
26	5	1	6
31	13	3	16
33	1	4	5
40	14	1	15
44	6	0	6

Appendix E: Camera Images

Appendix F: Secondary Classification Coding Key

0. Raccoon at trap, but does not enter
1. Raccoon enters the trap but does not get caught
2. Raccoon is captured
4. Another raccoon visits a trapped raccoon
6. Raccoon stealing bait from trap but does not get caught
7. Raccoon present with juvenile. They do not enter the trap or get caught.
9. Repeated entering and exiting of trap before being caught
10. Trapped raccoon with juvenile present, who is not trapped
11. More than 1 raccoon at a trap, both are adults

13. Raccoon repeated enters into a trap without getting caught

The REG Procedure
Model: MODEL1
Dependent Variable: trap

Number of Observations Read	10
Number of Observations Used	10

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	0.51212	0.51212	0.39	0.5475
Error	8	10.38788	1.29848		
Corrected Total	9	10.90000			

Root MSE	1.13951	R-Square	0.0470
Dependent Mean	1.90000	Adj R-Sq	-0.0721
Coeff Var	59.97425		

The REG Procedure
Model: MODEL1
Dependent Variable: trap

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|

Intercept	1	1.46667	0.77843	1.88	0.0963
trapnight	1	0.07879	0.12546	0.63	0.5475

The REG Procedure
Model: MODEL1
Dependent Variable: trap

Output Statistics

<table>
<tr><th>Obs</th><th>Dependent Variable</th><th>Predicted Value</th><th>Std Error Mean Predict</th><th>Residual</th><th>Std Error Residual</th><th>Student Residual</th><th>-2-1 0 1 2</th><th>Cook's D</th></tr>
<tr><td>1</td><td>3.0000</td><td>1.5455</td><td>0.6698</td><td>1.4545</td><td>0.922</td><td>1.578</td><td>| |*** |</td><td>0.657</td></tr>
<tr><td>2</td><td>1.0000</td><td>1.6242</td><td>0.5680</td><td>-0.6242</td><td>0.988</td><td>-0.632</td><td>| *| |</td><td>0.066</td></tr>
<tr><td>3</td><td>0</td><td>1.7030</td><td>0.4777</td><td>-1.7030</td><td>1.035</td><td>-1.646</td><td>| ***| |</td><td>0.289</td></tr>
<tr><td>4</td><td>2.0000</td><td>1.7818</td><td>0.4065</td><td>0.2182</td><td>1.065</td><td>0.205</td><td>| | |</td><td>0.003</td></tr>
<tr><td>5</td><td>3.0000</td><td>1.8606</td><td>0.3658</td><td>1.1394</td><td>1.079</td><td>1.056</td><td>| |** |</td><td>0.064</td></tr>
<tr><td>6</td><td>1.0000</td><td>1.9394</td><td>0.3658</td><td>-0.9394</td><td>1.079</td><td>-0.870</td><td>| *| |</td><td>0.044</td></tr>
<tr><td>7</td><td>3.0000</td><td>2.0182</td><td>0.4065</td><td>0.9818</td><td>1.065</td><td>0.922</td><td>| |* |</td><td>0.062</td></tr>
<tr><td>8</td><td>1.0000</td><td>2.0970</td><td>0.4777</td><td>-1.0970</td><td>1.035</td><td>-1.060</td><td>| **| |</td><td>0.120</td></tr>
<tr><td>9</td><td>2.0000</td><td>2.1758</td><td>0.5680</td><td>-0.1758</td><td>0.988</td><td>-0.178</td><td>| | |</td><td>0.005</td></tr>
<tr><td>10</td><td>3.0000</td><td>2.2545</td><td>0.6698</td><td>0.7455</td><td>0.922</td><td>0.809</td><td>| |* |</td><td>0.173</td></tr>
</table>

Sum of Residuals	0
Sum of Squared Residuals	10.38788
Predicted Residual SS (PRESS)	17.05888

The REG Procedure
Model: MODEL1
Dependent Variable: activity

Number of Observations Read	10
Number of Observations Used	10

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	6.69394	6.69394	0.57	0.4716
Error	8	93.80606	11.72576		
Corrected Total	9	100.50000			

Root MSE	3.42429	R-Square	0.0666
Dependent Mean	11.50000	Adj R-Sq	-0.0501
Coeff Var	29.77643		

The REG Procedure
Model: MODEL1
Dependent Variable: activity

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	13.06667	2.33923	5.59	0.0005
trapnight	1	-0.28485	0.37700	-0.76	0.4716

The REG Procedure
Model: MODEL1
Dependent Variable: activity

Output Statistics

Obs	Dependent Variable	Predicted Value	Std Error Mean Predict	Residual	Std Error Residual	Student Residual	-2-1 0 1 2	Cook's D
1	13.0000	12.7818	2.0126	0.2182	2.770	0.0788	| | |	0.002
2	14.0000	12.4970	1.7069	1.5030	2.969	0.506	| |* |	0.042
3	7.0000	12.2121	1.4356	-5.2121	3.109	-1.677	| ***| |	0.300
4	13.0000	11.9273	1.2216	1.0727	3.199	0.335	| | |	0.008
5	12.0000	11.6424	1.0991	0.3576	3.243	0.110	| | |	0.001
6	15.0000	11.3576	1.0991	3.6424	3.243	1.123	| |** |	0.072
7	14.0000	11.0727	1.2216	2.9273	3.199	0.915	| |* |	0.061
8	9.0000	10.7879	1.4356	-1.7879	3.109	-0.575	| *| |	0.035

9	5.0000	10.5030	1.7069	-5.5030	2.969	-1.854	***		0.568
10	13.0000	10.2182	2.0126	2.7818	2.770	1.004		**	0.266

Sum of Residuals	0
Sum of Squared Residuals	93.80606
Predicted Residual SS (PRESS)	149.89628

The TTEST Procedure

Variable: trap (trap)

Acc	N	Mean	Std Dev	Std Err	Minimum	Maximum
After	8	1.5000	1.1952	0.4226	0	3.0000
Before	2	1.5000	0.7071	0.5000	1.0000	2.0000
Diff (1-2)		0	1.1456	0.9057		

Acc	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
After		1.5000	0.5008	2.4992	1.1952	0.7903	2.4326
Before		1.5000	-4.8531	7.8531	0.7071	0.3155	22.5639
Diff (1-2)	Pooled	0	-2.0886	2.0886	1.1456	0.7738	2.1948
Diff (1-2)	Satterthwaite	0	-2.2003	2.2003			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	8	0.00	1.0000
Satterthwaite	Unequal	2.7391	0.00	1.0000

The TTEST Procedure

Variable: trap (trap)

Equality of Variances

Method	Num DF	Den DF	F Value	Pr > F

Folded F	7	1	2.86	0.8546

The TTEST Procedure

Variable: activity (activity)

Acc	N	Mean	Std Dev	Std Err	Minimum	Maximum
After	8	11.3750	3.6228	1.2809	5.0000	15.0000
Before	2	14.0000	0	0	14.0000	14.0000
Diff (1-2)		-2.6250	3.3889	2.6791		

Acc	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
After		11.3750	8.3462	14.4038	3.6228	2.3953	7.3735
Before		14.0000	14.0000	14.0000	0	.	.
Diff (1-2)	Pooled	-2.6250	-8.8031	3.5531	3.3889	2.2890	6.4923
Diff (1-2)	Satterthwaite	-2.6250	-5.6538	0.4038			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	8	-0.98	0.3559
Satterthwaite	Unequal	7	-2.05	0.0796

The TTEST Procedure

Variable: activity (activity)

Equality of Variances

Method	Num DF	Den DF	F Value	Pr > F

Folded F	7	1	Infty	<.0001

The LOGISTIC Procedure

Model Information

Data Set	THESIS.RACCOONA	
Response Variable	tag	tag
Number of Response Levels	2	
Model	binary logit	
Optimization Technique	Fisher's scoring	

Number of Observations Read	134
Number of Observations Used	111

Response Profile

Ordered Value	tag	Total Frequency
1	1	37
2	0	74

Probability modeled is tag=1.

NOTE: 23 observations were deleted due to missing values for the response or explanatory variables.

The LOGISTIC Procedure

Model Convergence Status

Convergence criterion (GCONV=1E-8) satisfied.

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	143.306	126.611
SC	146.016	132.030
-2 Log L	141.306	122.611

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	18.6956	1	<.0001
Score	17.6650	1	<.0001
Wald	15.4632	1	<.0001

The LOGISTIC Procedure

Analysis of Maximum Likelihood Estimates

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-2.5573	0.5520	21.4634	<.0001
TrapNight	1	0.3267	0.0831	15.4632	<.0001

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
TrapNight	1.386	1.178	1.632

Association of Predicted Probabilities and Observed Responses

Percent Concordant	69.9	Somers' D	0.475
Percent Discordant	22.4	Gamma	0.514
Percent Tied	7.6	Tau-a	0.213
Pairs	2738	c	0.738

The LOGISTIC Procedure

Model Information

Data Set	THESIS.RACCOONA	
Response Variable	recapture	recapture
Number of Response Levels	2	
Model	binary logit	
Optimization Technique	Fisher's scoring	

Number of Observations Read	134
Number of Observations Used	18

Response Profile

Ordered Value	recapture	Total Frequency
1	1	8
2	0	10

Probability modeled is recapture=1.

NOTE: 116 observations were deleted due to missing values for the response or explanatory variables.

The LOGISTIC Procedure

Model Convergence Status

Convergence criterion (GCONV=1E-8) satisfied.

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	26.731	25.748
SC	27.621	27.529
-2 Log L	24.731	21.748

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	2.9825	1	0.0842
Score	2.8098	1	0.0937
Wald	2.4916	1	0.1145

The LOGISTIC Procedure

Analysis of Maximum Likelihood Estimates

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-1.9580	1.2428	2.4823	0.1151
TrapNight	1	0.2975	0.1885	2.4916	0.1145

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
TrapNight	1.346	0.931	1.948

Association of Predicted Probabilities and Observed Responses

Percent Concordant	66.3	Somers' D	0.413
Percent Discordant	25.0	Gamma	0.452
Percent Tied	8.8	Tau-a	0.216
Pairs	80	c	0.706

The REG Procedure
Model: MODEL1
Dependent Variable: capture capture

Number of Observations Read	28
Number of Observations Used	28

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	0.00535	0.00535	0.02	0.9002
Error	26	8.67322	0.33359		
Corrected Total	27	8.67857			

Root MSE	0.57757	R-Square	0.0006
Dependent Mean	0.39286	Adj R-Sq	-0.0378
Coeff Var	147.01742		

The REG Procedure
Model: MODEL1
Dependent Variable: capture capture

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|

Intercept	Intercept	1	0.41928	0.23540	1.78	0.0866
trapnight	trapnight	1	-0.00484	0.03817	-0.13	0.9002

The REG Procedure
Model: MODEL1
Dependent Variable: capture capture

Output Statistics

<table>
<tr><th>Obs</th><th>Dependent Variable</th><th>Predicted Value</th><th>Std Error Mean Predict</th><th>Residual</th><th>Std Error Residual</th><th>Student Residual</th><th>-2-1 0 1 2</th><th>Cook's D</th></tr>
<tr><td>1</td><td>0</td><td>0.4144</td><td>0.2024</td><td>-0.4144</td><td>0.541</td><td>-0.766</td><td>| *| |</td><td>0.041</td></tr>
<tr><td>2</td><td>0</td><td>0.4096</td><td>0.1715</td><td>-0.4096</td><td>0.552</td><td>-0.743</td><td>| *| |</td><td>0.027</td></tr>
<tr><td>3</td><td>0</td><td>0.4048</td><td>0.1441</td><td>-0.4048</td><td>0.559</td><td>-0.724</td><td>| *| |</td><td>0.017</td></tr>
<tr><td>4</td><td>1.0000</td><td>0.3999</td><td>0.1226</td><td>0.6001</td><td>0.564</td><td>1.063</td><td>| |** |</td><td>0.027</td></tr>
<tr><td>5</td><td>0</td><td>0.3951</td><td>0.1106</td><td>-0.3951</td><td>0.567</td><td>-0.697</td><td>| *| |</td><td>0.009</td></tr>
<tr><td>6</td><td>0</td><td>0.3903</td><td>0.1110</td><td>-0.3903</td><td>0.567</td><td>-0.689</td><td>| *| |</td><td>0.009</td></tr>
<tr><td>7</td><td>1.0000</td><td>0.3854</td><td>0.1239</td><td>0.6146</td><td>0.564</td><td>1.089</td><td>| |** |</td><td>0.029</td></tr>
<tr><td>8</td><td>0</td><td>0.3806</td><td>0.1459</td><td>-0.3806</td><td>0.559</td><td>-0.681</td><td>| *| |</td><td>0.016</td></tr>
<tr><td>9</td><td>0</td><td>0.3758</td><td>0.1736</td><td>-0.3758</td><td>0.551</td><td>-0.682</td><td>| *| |</td><td>0.023</td></tr>
<tr><td>10</td><td>0</td><td>0.3709</td><td>0.2047</td><td>-0.3709</td><td>0.540</td><td>-0.687</td><td>| *| |</td><td>0.034</td></tr>
<tr><td>11</td><td>1.0000</td><td>0.4144</td><td>0.2024</td><td>0.5856</td><td>0.541</td><td>1.082</td><td>| |** |</td><td>0.082</td></tr>
<tr><td>12</td><td>1.0000</td><td>0.4096</td><td>0.1715</td><td>0.5904</td><td>0.552</td><td>1.070</td><td>| |** |</td><td>0.055</td></tr>
<tr><td>13</td><td>0</td><td>0.3999</td><td>0.1226</td><td>-0.3999</td><td>0.564</td><td>-0.709</td><td>| *| |</td><td>0.012</td></tr>
<tr><td>14</td><td>1.0000</td><td>0.3951</td><td>0.1106</td><td>0.6049</td><td>0.567</td><td>1.067</td><td>| |** |</td><td>0.022</td></tr>
<tr><td>15</td><td>0</td><td>0.3903</td><td>0.1110</td><td>-0.3903</td><td>0.567</td><td>-0.689</td><td>| *| |</td><td>0.009</td></tr>
<tr><td>16</td><td>0</td><td>0.3854</td><td>0.1239</td><td>-0.3854</td><td>0.564</td><td>-0.683</td><td>| *| |</td><td>0.011</td></tr>
<tr><td>17</td><td>1.0000</td><td>0.3806</td><td>0.1459</td><td>0.6194</td><td>0.559</td><td>1.108</td><td>| |** |</td><td>0.042</td></tr>
</table>

The REG Procedure

Model: MODEL1
Dependent Variable: capture capture

Output Statistics

Obs	Dependent Variable	Predicted Value	Std Error Mean Predict	Residual	Std Error Residual	Student Residual	-2-1 0 1 2	Cook's D
18	1.0000	0.3758	0.1736	0.6242	0.551	1.133	| |** |	0.064
19	2.0000	0.3709	0.2047	1.6291	0.540	3.016	| |******|	0.653
20	1.0000	0.4144	0.2024	0.5856	0.541	1.082	| |** |	0.082
21	1.0000	0.4096	0.1715	0.5904	0.552	1.070	| |** |	0.055
22	0	0.4048	0.1441	-0.4048	0.559	-0.724	| *| |	0.017
23	0	0.3999	0.1226	-0.3999	0.564	-0.709	| *| |	0.012
24	0	0.3951	0.1106	-0.3951	0.567	-0.697	| *| |	0.009
25	0	0.3903	0.1110	-0.3903	0.567	-0.689	| *| |	0.009
26	0	0.3854	0.1239	-0.3854	0.564	-0.683	| *| |	0.011
27	0	0.3806	0.1459	-0.3806	0.559	-0.681	| *| |	0.016
28	0	0.3709	0.2047	-0.3709	0.540	-0.687	| *| |	0.034

Sum of Residuals	0
Sum of Squared Residuals	8.67322
Predicted Residual SS (PRESS)	10.47806

The REG Procedure
Model: MODEL1
Dependent Variable: nocapture nocapture

Number of Observations Read	28
Number of Observations Used	28

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	1.14317	1.14317	0.39	0.5397
Error	26	76.96397	2.96015		
Corrected Total	27	78.10714			

Root MSE	1.72051	R-Square	0.0146
Dependent Mean	2.32143	Adj R-Sq	-0.0233
Coeff Var	74.11425		

The REG Procedure
Model: MODEL1
Dependent Variable: nocapture nocapture

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	Intercept	1	2.70753	0.70124	3.86	0.0007
trapnight	trapnight	1	-0.07066	0.11370	-0.62	0.5397

The REG Procedure
Model: MODEL1
Dependent Variable: nocapture nocapture

Output Statistics

Obs	Dependent Variable	Predicted Value	Std Error Mean Predict	Residual	Std Error Residual	Student Residual	-2-1 0 1 2	Cook's D
1	3.0000	2.6369	0.6028	0.3631	1.611	0.225	| | |	0.004
2	3.0000	2.5662	0.5108	0.4338	1.643	0.264	| | |	0.003
3	2.0000	2.4956	0.4292	-0.4956	1.666	-0.297	| | |	0.003
4	4.0000	2.4249	0.3653	1.5751	1.681	0.937	| |* |	0.021
5	6.0000	2.3542	0.3294	3.6458	1.689	2.159	| |**** |	0.089
6	3.0000	2.2836	0.3308	0.7164	1.688	0.424	| | |	0.003
7	0	2.2129	0.3691	-2.2129	1.680	-1.317	| **| |	0.042
8	1.0000	2.1423	0.4346	-1.1423	1.665	-0.686	| *| |	0.016
9	2.0000	2.0716	0.5171	-0.0716	1.641	-0.0436	| | |	0.000

Obs	Dependent Variable	Predicted Value	Std Error Mean Predict	Residual	Std Error Residual	Student Residual	-2-1 0 1 2	Cook's D
10	5.0000	2.0009	0.6097	2.9991	1.609	1.864	|***	0.249
11	2.0000	2.6369	0.6028	-0.6369	1.611	-0.395	|	0.011
12	2.0000	2.5662	0.5108	-0.5662	1.643	-0.345	|	0.006
13	3.0000	2.4249	0.3653	0.5751	1.681	0.342	|	0.003
14	2.0000	2.3542	0.3294	-0.3542	1.689	-0.210	|	0.001
15	1.0000	2.2836	0.3308	-1.2836	1.688	-0.760	*|	0.011
16	5.0000	2.2129	0.3691	2.7871	1.680	1.659	|***	0.066
17	4.0000	2.1423	0.4346	1.8577	1.665	1.116	|**	0.042

The REG Procedure
Model: MODEL1
Dependent Variable: nocapture nocapture

Output Statistics

Obs	Dependent Variable	Predicted Value	Std Error Mean Predict	Residual	Std Error Residual	Student Residual	-2-1 0 1 2	Cook's D
18	1.0000	2.0716	0.5171	-1.0716	1.641	-0.653	*|	0.021
19	1.0000	2.0009	0.6097	-1.0009	1.609	-0.622	*|	0.028
20	0	2.6369	0.6028	-2.6369	1.611	-1.636	***|	0.187
21	3.0000	2.5662	0.5108	0.4338	1.643	0.264	|	0.003
22	6.0000	2.4956	0.4292	3.5044	1.666	2.103	|****	0.147
23	1.0000	2.4249	0.3653	-1.4249	1.681	-0.848	*|	0.017
24	1.0000	2.3542	0.3294	-1.3542	1.689	-0.802	*|	0.012
25	1.0000	2.2836	0.3308	-1.2836	1.688	-0.760	*|	0.011
26	1.0000	2.2129	0.3691	-1.2129	1.680	-0.722	*|	0.013
27	1.0000	2.1423	0.4346	-1.1423	1.665	-0.686	*|	0.016
28	1.0000	2.0009	0.6097	-1.0009	1.609	-0.622	*|	0.028

Sum of Residuals	0
Sum of Squared Residuals	76.96397
Predicted Residual SS (PRESS)	88.89128

The TTEST Procedure

Variable: capture (capture)

acc	N	Mean	Std Dev	Std Err	Minimum	Maximum
After	22	0.3182	0.5679	0.1211	0	2.0000
Before	6	0.6667	0.5164	0.2108	0	1.0000
Diff (1-2)		-0.3485	0.5584	0.2572		

acc	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
After		0.3182	0.0664	0.5700	0.5679	0.4369	0.8116
Before		0.6667	0.1247	1.2086	0.5164	0.3223	1.2665
Diff (1-2)	Pooled	-0.3485	-0.8771	0.1801	0.5584	0.4397	0.7652
Diff (1-2)	Satterthwaite	-0.3485	-0.9022	0.2052			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	26	-1.36	0.1870
Satterthwaite	Unequal	8.6191	-1.43	0.1870

The TTEST Procedure

Variable: capture (capture)

Equality of Variances

Method	Num DF	Den DF	F Value	Pr > F

Folded F	21	5	1.21	0.9105

The TTEST Procedure

Variable: nocapture (nocapture)

acc	N	Mean	Std Dev	Std Err	Minimum	Maximum
After	22	2.3636	1.8399	0.3923	0	6.0000
Before	6	2.1667	1.1690	0.4773	0	3.0000
Diff (1-2)		0.1970	1.7312	0.7973		

acc	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
After		2.3636	1.5479	3.1794	1.8399	1.4155	2.6294
Before		2.1667	0.9398	3.3935	1.1690	0.7297	2.8672
Diff (1-2)	Pooled	0.1970	-1.4420	1.8359	1.7312	1.3634	2.3725
Diff (1-2)	Satterthwaite	0.1970	-1.1413	1.5352			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	26	0.25	0.8068
Satterthwaite	Unequal	12.662	0.32	0.7551

The TTEST Procedure

Variable: nocapture (nocapture)

Equality of Variances

Method	Num DF	Den DF	F Value	Pr > F

Folded F	21	5	2.48	0.3185