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# An Evaluation of Trap-Neuter-Release Practices for Free-Roaming Cat Populations

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# AN EVALUATION OF TRAP-NEUTER-RELEASE PRACTICES FOR FREE-ROAMING CAT POPULATIONS

being

A Thesis Presented to the Graduate Faculty
of the Fort Hays State University
in Partial Fulfillment of the Requirements for
the Degree of Master of Science

by

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This Thesis for

The Master of Science Degree

By

Brian James Gaston

has been approved

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# PREFACE

This thesis is written in the style of the *Journal of Mammalogy*, to which it will be submitted for publication.

# ABSTRACT

As of 2002, estimates of free-roaming domestic cat (*Felis catus)* populations exceeded 100 million individuals, throughout the United States. Many lost or abandoned cats will revert to living outdoors as free-roaming individuals. To try to control the abundance of free-roaming cats, trap-neuter-release (TNR) programs have been implemented across the United States. The goal of many TNR programs is to reduce cat populations by sterilizing the individuals to prevent breeding, while also providing food and water to the unconfined colony. However, wildlife conservationists question the effectiveness of TNR programs. The objectives of my study were to: determine the population size and apparent survival of free-roaming cats in areas managed by a TNR program, determine population size and apparent survival of free-roaming cats in areas not managed by a TNR program, and compare the population sizes of TNR managed populations to those of unmanaged cat populations. Between September 2011 and September 2012, free-roaming cats were trapped and marked at two sites managed by a TNR program, and at two unmanaged sites. Population estimates indicated seasonal population changes in the unmanaged sites as well as TNR site 1, but not TNR site 2. TNR site 1 had a lower proportion of neuter cats (<50% neutered) while TNR site 2 had a much higher proportion of neutered individuals (~90% neutered). Population estimates of the unmanaged sites and TNR site 1 increased in the spring and decreased through the winter months. Population estimates for TNR site 2 remained constant throughout the year. This study showed TNR programs will need to maintain a high proportion of neutered individuals to prevent population increases and that a highly neutered colony is managed for a seasonally stable population of cats as opposed to a decreasing population.

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# INTRODUCTION

Domesticated animals which return to a semi-feral state, have a potential to reach high abundances in urban landscapes (Devillard et al. 2003; Guttilla and Stapp 2010; Liberg 1980). A "feral" animal is a previously domesticated animal that has reverted to its wild state and is independent of human help to survive, including shelter and food (Tennent et al. 2009). A "free-roaming" individual still uses human structures for shelter or is provided supplemental feeding, but these individuals can be either an abandoned animal or a pet, which is allowed outdoors (Calhoon and Haspel 1989; Schmidt et al. 2007; Slater 2002).

In the United States, there are over 70 million owned domestic cats (*Felis catus*) (Levy et al. 2003; Lord 2008; Loyd and Miller 2010b; Schmidt et al. 2007; Slater 2002), and an estimated 50-75 million free-roaming domestic cats (Jessup 2004; Loyd and Miller 2010b; Mahlow and Slater 1996; Schmidt et al. 2007). Humans have transported domestic cats throughout the world (Guttilla and Stapp 2010; Schmidt et al. 2007). Many of these cats are often abandoned or lost and revert to living outdoors as free-roaming individuals. The ever-increasing population of free-roaming cats has concerned two major groups of stakeholders here in the United States: animal welfare programs and wildlife conservationists (Castillo and Clark 2003).

The primary concern for animal welfare groups working with free-roaming cats is the welfare of the cats (Loyd and Miller 2010a). This welfare consists of providing individuals with water, food, shelter, and vaccinations. With a rise in animal welfare groups, trap-neuter-release (TNR) programs have been implemented across the United States to try to control the growing populations of free-roaming cats (Castillo and Clark

2003; Guttilla and Stapp 2010; Loyd and Miller 2010a; Schmidt et al. 2007). Proponents of TNR state that the sterilization will prevent new offspring, which will lead to a decrease in the population size (Levy et al. 2003; Tennent et al. 2009). Along with the sterilization, supplemental feeding is used to deter the cats from hunting nearby wildlife. Some animal welfare groups, such as the No Kill Advocacy Center, state that TNR is the only acceptable and humane method to manage free-roaming cat populations (Longcore et al. 2009).

TNR programs consist of trapping stray cats, sterilizing them, and then returning them to a managed colony (Castillo and Clark 2003; Guttilla and Stapp 2010; Longcore et al. 2009; Loyd and Miller 2010b). The management of the colony is often carried out by a network of volunteers. Management of the colony consists of providing food, water, vaccinations, and housing in most cases (Levy et al. 2003). Due to the abundance of food and shelter, new cats are drawn to the colony or are abandoned by owners, who no longer want them (Levy and Crawford 2004). Volunteers must then trap and sterilize the new individuals and provide more food and shelter to accommodate the growing, sterile population. In residential areas, colonies often have owned cats that frequent the areas for food and then return to their homes.

Sterilizing an individual, typically by performing a hysterectomy on a female and a vasectomy on a male, results in the inability of that individual to produce offspring (Gunther and Terkel 2002; Tennent et al. 2009). The surgical sterilization of animals commonly is referred to as neutering (Castillo and Clark 2003; Longcore et al. 2009), whereas a non-surgical sterilization interrupts pregnancy through the use of chemicals, which can be fed and eliminate the need to trap individuals (Remfry 1996; Tennent et al.

2009). Proponents of sterilization claim it is useful in preventing increases in a population of an organism, eventually leading to a population decline (Levy et al. 2003; Longcore et al. 2009; Zaunbrecher and Smith 1993). However, recent research suggests that sterilization efforts alone are an ineffective way to control populations because of the immigration of new individuals into the population and the difficulty in sterilizing all individuals (Castillo and Clark 2003; Guttilla and Stapp 2010; Loyd and Miller 2010a; Winter 2004). One study modeled a population of free-roaming cats and concluded a minimum of 70% of the females would need to be sterilized in order for any significant reduction in population growth (Gunther and Terkel 2002).

Wildlife conservationists are concerned with free-roaming cats having a negative effect on native wildlife (Guttilla and Stapp 2010; Loyd and Miller 2010a; Schmidt et al. 2007). Researchers estimate cats annually kill 1.3-4.0 billion birds and 6.3-22.3 billion mammals in the United States (Loss et al. 2013). Wildlife conservationists oppose the argument that supplemental feeding will prevent predation on wildlife by cats.

One study observed that an individual free-roaming cat's diet was 90% comprised of black-vented shearwaters (Keitt et al. 2002). Research has shown that cat predation on many bird species, such as the black-vented shearwater (*Puffinus opisthomelas*) (Keitt et al. 2002) and the Leach's storm petrel (*Oceanodroma leucorhoa*) can lead to local population extinctions on islands (McChesney and Tershy 1998). Even game bird species, such as the California quail (*Callipepla californica*) went locally extinct in areas of high cat densities (Hawkins et al. 1999). Wildlife conservationists also contest the effectiveness of TNR programs in quickly reducing free-roaming cat populations. Even accounting for a 75-80% sterilization rate and intensive adoption, it might take over a decade before free-roaming cat populations reach zero individuals (Guttilla and Stapp 2010).

Diseases, which can be carried by and transmitted from cats to humans, are a growing issue in many urban areas (Barrows 2004; Longcore et al. 2009; Patronek 1998). In 2001, there were 270 reported cases of rabid cats in the United States (Levy and Crawford 2004). By 2008, the number of rabies cases in cats was nearly four times the number of cases in dog (*Canis lupus familiaris*) (Blanton et al. 2009; Gerhold 2011). Even cats, which previously were vaccinated, can still contract the virus from other host species (Murray et al. 2009). Free-roaming cats are the definitive hosts for diseases and parasites such as toxoplasmosis, intestinal worms, and fleas, which can also be passed to humans or livestock on farms (Gerhold 2011; Levy and Crawford 2004; Tennent et al. 2009). These parasites and diseases also are destructive to wildlife as they can be passed to other species, such as bobcat (*Lynx rufus*) (Gerhold 2011; Jessup 2004).

Due to the concerns surrounding free-roaming cats in human communities, I investigated four populations of free-roaming cats. I selected two populations which had TNR programs for managing free-roaming cats and two populations without TNR programs. The objectives of my study were to: (1) determine the population size and apparent survival of free-roaming cats in areas managed by a TNR program, (2) determine population size and apparent survival of free-roaming cats in areas not managed by a TNR program, and (3) compare the population sizes of TNR-managed populations to those of unmanaged cat populations

## MATERIALS AND METHODS

*Study sites.*—The study area included four separate sites within or around the city of Hays, Kansas (Fig. 1). Each study site was located in primarily residential zones of the city, with the greatest distance between any two sites being three kilometers and the shortest distance being about 800 meters. Hays is located in northwestern Kansas with a population of approximately 20,000 residents, and includes the campus of Fort Hays State University (FHSU), which has an enrollment of approximately 5,000 on-campus students. TNR Site 1 was located on the FHSU campus, which is located in the southwestern corner of Hays. A TNR program had been instituted on the FHSU campus three years prior to the study and was unable to neuter more than 50% of the free-roaming cats. The TNR program was managed by an animal welfare group called the Western Kansas Cat Program, which consisted of student volunteers and staff from FHSU. The Western Kansas Cat Program focused on neutering both male and female cats. The volunteers provided approximately one cup of food per neutered cat and also would leave small amounts for other mesocarnivores, such as raccoon (*Procyon lotor*), Virginia opossum (*Didelphis virginiana*), and striped skunk (*Mephitis mephitis*). The campus animal welfare group also provided small wooden boxes for shelters. Big Creek flowed through the campus and was near the primary feeding station for the cats, providing shelter in the riparian zone.

TNR Site 2 was managed for over seven years prior to my study by animal control officers working for the city of Hays and had an estimated 90% of both sexes, neutered. This site was located in southern Hays on private property in a residential neighborhood and included a single-story storage building to provide shelter for the cats. The supplemental feeding for the TNR program was provided by a homeowner, who provided a half-cup of dry food per neutered cat and removed all unconsumed food in the early afternoon. No food was intentionally left for any wildlife species, but shelter was provided due to the building being left open for cats.

The third and fourth study sites were not managed by TNR programs. Unmanaged Site 1 was at Meadow Acres Mobile Home Park, located north of FHSU. This was a residential mobile home park located near agricultural fields with Big Creek along the southern border of the park. This riparian habitat provided cover in addition to the shelter under the trailer homes. Garbage dumpsters were a food source as well as several residents in the mobile home park provided food to the free-roaming cats. Unmanaged Site 2 was at Colonial Gardens Mobile Home Park, located in southern Hays. This mobile home park was surrounded by residential and commercial buildings, with Highway 183-Bypass providing a southern border to the community. Residents provided food and water to the free-roaming cats and additional food was available in open garbage dumpsters. The most common shelters available were underneath the trailers and porches of the mobile homes.

*Trapping.*—Within the TNR sites, ten large Havahart live traps (91cm x 25cm x 30cm) were placed near feeding stations and in traveling corridors. In the unmanaged sites, traps were placed throughout the study sites. Sardines or canned cat food was used as bait. Traps were left open from 0700 to 1900 from September through March. From April through September, traps were left open from 1900 to 0700. These times were selected to decrease potential mortality due to extreme temperatures. Trap-nights were counted as a single trap remaining open or successfully capturing a cat. If a trap was closed and empty or contained bycatch, then it was counted as a half trap-night. Each study site was trapped for a period of one week per month and the trapping field season continued for a period of 12 months.

*Marking.*—Trapped cats were marked with a distinctive pattern using Clairol® Nice ‘n Easy hair dye unless distinctive pelage patterns were available to identify individuals. In previous studies, hair dye has been used to identify individuals of Columbian ground squirrel (*Urocitellus columbianus*) (Hare 1991), Richardson’s ground squirrel (*Urocitellus richardsonii*) (Hare et al. 2004), and woodchuck (*Marmota monax*) (Maher 2009). Individuals were photographed, checked for ear clippings, which indicated if they were captured for a TNR program, and then released near where they had been captured. Blonde marks were given to individuals with dark pelage and black marks were given to individuals with light pelage. In instances where marks faded or caused slight hair loss, other characteristics were used to identify that individual if I could not reapply hair dye to the marked individual.

*Resightings.*—A resighting period was conducted at each study site two weeks after each trapping period. Resightings were conducted twice per week for two weeks. This two-week resighting period was considered the secondary sampling period, during which the population had demographic and geographic closure. Closure is required for the Poisson-log normal modeling. During this resighting period, no new marks were added. Resightings consisted of counting both unmarked and marked cats and identifying each marked cat. The data were used to estimate population size for each month at each site.

*Population modeling.*—Population size estimates were calculated with Program MARK by using a full-likelihood robust design Poisson-log normal mark-resight model. The robust design Poisson-log normal model is used when the number of marked individuals in the population is unknown (McClintock and White 2009). With the potential for the hair dye to fade over time or the occurrence of unknown mortalities, the number of marked individuals is unknown, and so this type of modeling was the best option for the study. This modeling required demographic closure with no births, deaths, immigration, or emigration, but only during secondary sampling periods. Therefore, it did not require geographic closure during the full primary sampling period or between primary sampling periods (McClintock and White 2009). This procedure also required individuals to be marked and individually identifiable (McClintock and White 2009).

Program MARK uses phi-dot notation in its modeling. Greek or uppercase letters are used to denote modeled parameters. For mark-resight models, these parameters are: mean resighting rate ($\alpha$), individual heterogeneity ($\sigma$), population size (U), survival ($\varphi$), and movement ($\gamma'$) ($\gamma''$). Each parameter was either held constant (.) or varied with time (t) with the exception of the movement parameters, which were given a value of zero or one to calculate no movement models. Program Mark utilizes Akaike Information Criterion (AIC) to select between each of the different models. Estimates for population size and apparent survival were produced by using the best supported model, as indicated by AIC.

*Statistical analyses.*—I used an analysis of variance (ANOVA) to compare population size estimates among all four populations. If the ANOVA indicated that population size differed among the sites, then a Tukey’s parametric HSD test was used to identify sites that differed. I then also ran an ANOVA using monthly changes in population size, from month x to month x+1, among sites to determine if population size changes differed.

## RESULTS

*Trap success.*—I trapped and marked 86 cats during a total of 3,085.5 trap-nights between September 2011 and September 2012. I had a combined trap success of 3% across all four study sites. Within TNR Site 1, I trapped and marked 23 cats and had a trap success of 3% across a total of 753.5 trap-nights (Table 1). In addition to the cats captured at TNR Site 1, bycatch included: raccoon (n=50), Virginia opossum (n=26), and striped skunk (n=16). In TNR Site 2, I trapped and marked 10 cats and had a trap success of 1% across 797 trap-nights (Table 1). Bycatch at TNR Site 2 included: raccoon (n=7), Virginia opossum (n=1), and striped skunk (n=1). I trapped and marked 28 cats in Unmanaged Site 1 and had a trap success of 4% across a total of 763.5 trap-nights (Table 1). Bycatch at Unmanaged Site 1 included: raccoon (n=26), Virginia opossum (n=9), striped skunk (n=6), and domestic dog (n=1). Within Unmanaged Site 2, I trapped and marked 25 cats and had a trap success of 3% across a total of 771.5 trap-nights (Table 1). Bycatch at Unmanaged Site 2 included: raccoon (n=10), Virginia opossum (n=9), striped skunk (n=1), and domestic dog (n=13). Only the cats received hair dye marks at sites.

*Population modeling.*—The best supported model for TNR Site 1, compared to the full set of candidate models, was a no movement model that only varied population size over time while holding all other variables constant ($w$ = 0.94, K = 14, AICc = 378.92) (Table 2). To ensure there were no concerns with individual heterogeneity, a null heterogeneity model ($\sigma$=0) was run against the most supported model and no difference was detected ($\Delta$AICc = 0), which suggested there were no complications from individual heterogeneity. Population size estimates for TNR Site 1 ranged between 11 and 26 individuals for each month (Table 3) with a constant apparent survival of 81%

(φ=0.81) over one year. The 24 models applied to TNR Site 2 had a best supported no movement model that only varied population size over time and held all other variables constant (*w* = 0.84, K = 14, AICc = 261.34) (Table 4). A null heterogeneity model also was run against the most supported model to ensure no problems resulted from individual heterogeneity, and no difference was detected (ΔAICc = 0), which suggested there were no complications from individual heterogeneity. Population size estimates for TNR Site 2 ranged between 6 and 14 individuals for each month (Table 5) with a constant apparent survival of 89% (φ=0.89) over one year.

The best supported model for Unmanaged Site 1 was a no movement model that varied only in population size over time and held all other variables constant (*w* = 0.80, K = 14, AICc =409.42) (Table 6). A null heterogeneity model also was run against the most supported model to ensure no problems resulted from individual heterogeneity, and no difference was detected (ΔAICc = 0), which suggested there were no complications from individual heterogeneity. Population size estimates for Unmanaged Site 1 ranged between 27 and 49 individuals for each month (Table 7) with a constant apparent survival of 80% (φ=0.80) over one year. The best supported model for Unmanaged Site 2 was a no movement model that varied only in population size over time and held all other variables constant (*w* = 0.79, K = 14, AICc =356.25) (Table 8). A null heterogeneity model also was run against the most supported model to ensure no problems resulted from individual heterogeneity, and no difference was detected (ΔAICc = 0), which suggested there were no complications from individual heterogeneity. Population size estimates for Unmanaged Site 2 ranged between 15 and 37 individuals for each month (Table 9) with a constant apparent survival of 82% (φ=0.82) over one year. A line graph was produced by using population sizes for each site for each month to examine monthly and seasonal trends (Fig. 2). From the beginning of the study in October, the graph shows a decline in population size for all four study sites until the lowest size in February, corresponding to the fall and winter seasons. All four populations showed an increase in March, which corresponds with the beginning of the spring season.

*Statistical analyses*.—I performed an ANOVA by using each site's population size standard errors to determine if sites differed in population size. According to the ANOVA, population sizes at the four sites differed (F=118.099, df=3, 44, $p<0.05$). A Tukey's HSD post-hoc test indicated significant differences among population size at all four sites. I then performed an ANOVA by using change in population size for each site, from month x to month x+1, to determine if sites differed in changes to population size over time. The ANOVA indicated no significant differences among sites in monthly changes of population size. These data suggested there might be similar population trends at all the four sites.

## DISCUSSION

At the end of the study, only TNR Site 2 had a population size smaller than its estimated size at the beginning of the study (Table 5). The lack in decrease of population sizes might be explained by the relative short study period of just one year; however, a similar study, which examined a 10-year period, saw no decrease in cat population size in San Diego, California (Foley et al. 2005). One study, using population modeling, suggests that in order to reduce a population of free-roaming cats in urban environments, a program would either need to euthanize >50% of the colony or neuter >70% of the colony (Andersen et al. 2004). The required effort needed to reach these goals could prove difficult based on my trap success of around 3%.

Based on my study, trapping in an urban environment presented multiple difficulties, ranging from bycatch to traps being stolen. Free-roaming cats tend to be trap-wary, and a similar study in California had a low trapping success of 2.7% over 3 years (Guttilla and Stapp 2010). Raccoon was the most common bycatch at 3 of the 4 study sites, with domestic dog being the most common bycatch at Unmanaged Site 2. Raccoon, Virginia opossum, and striped skunk were all seen at the feeding stations at TNR Sites 1 and 2. TNR Site 1 also had the largest total bycatch (n=92), which was likely a result of the large quantities of food provided daily by the TNR program. The opposite also is likely at TNR Site 2, which provided lower quantities of food and removed unconsumed food in the afternoon, which might have resulted in fewer mesocarnivores and less bycatch.

All four sites had the same best supported model as indicated by indicated by AICc. In the best supported four models for every study site, the mean resighting rate (α) was always constant. Due to the design of the study, each study site had two resightings per week for two weeks and these were often kept three or four days apart. With this type of design, a few cats were seen many times while most others were seen few times. This might have caused similar resighting rates across the duration of the study and resulted in a constant resighting rate. Further investigation is needed to determine whether the few individuals were dominant and excluded others from resighting, or if it is due to some individuals being bolder around human presence.

Individual heterogeneity (σ) also was constant in the best supported four models for every study site. While there is much debate in regards to modeling individual heterogeneity, some studies have shown individual heterogeneity might only have small effects on survival estimates (Abadi et al. 2013). Individual heterogeneity is the additional variance caused by individual differences in life history traits. Individual encounter heterogeneity is an important parameter because failure to account for it might result in underestimates of abundance and overestimates of precision, due to a negative bias in the modeling (McClintock et al. 2013). This results in accounting for individuals with high encounter probabilities which tend to appear in the sample at a greater frequency than they appear in the population. However, none of the models with a constant individual heterogeneity showed any signs of concern when run against a null model. This could be due to the availability of food, water, and shelter resources being in relatively-constant supply which allows for many individuals to be more often encountered rather than dispersing in search of food, water, and shelter. The impact of socialization to humans of an already-domesticated animal could also play a part of the individual encounter heterogeneity, due to living in an urban area with resources provided to the animals. Future studies should look at effects of individual encounter heterogeneity of both domesticated animals and non-domesticated species.

Population size (U) was the only parameter which varied over time in the most supported model for each study site. This was because I chose this parameter to vary monthly instead of producing a single population size estimate for the entire year. No models were run with population size being kept constant, as population variation was the focus of my year-long study.

Apparent survival (φ) was constant across the entire year in the most supported model for each study site. All study sites had an apparent survival between 80-89%, which suggested cats, at non-TNR sites were proficient at finding food and shelter. A high survival rate will prevent a population size from reducing quickly unless a management change, such as removing food, can be made. A similar study in Caldwell, Texas found free-roaming cats, which were fed by volunteers, had a survival rate of 90% and feral cats, which never received food, had a survival rate of 56% (Schmidt et al. 2007). Since all four sites had at least one volunteer providing food on a daily or weekly basis, it is possible that not providing food could result in the reduction of the cat population sizes.

Even without the availability of human-supplied food, it is unclear how immediate of an impact food reduction would have on cat population size. One study indicated that free-roaming cats are sedentary and will occupy their home ranges for 10 months or longer (Edwards et al. 2001). In my study, some cats at both TNR Sites 1 and 2 persisted for the entire length of the study. According to volunteers at both TNR programs in my study, it was common for individuals to live 3+ years. Future studies should explore the impacts of the quality and quantity of supplemental nutrition as well as immigration and emigration on survival of free-roaming cats.

Three different types of movement models were used in my study: no movement, random movement, and Markovian movement. In the random movement model, the probability of being in the study area during the current resighting session is the same for those animals in and out of the study area during the previous session. In a Markovian movement model, the previous resighting session affects the probability of the individual being seen at the next resighting session. A no movement model assumes that observable individuals remain observable across all resighting sessions and unobservable individuals remain unobservable across all resighting sessions. The most supported model for each study site was a no movement model ($\gamma''(0)\gamma'(0)$). The lack of movement indicated in the model possibly was explained by the behavior of free-roaming cats, where some individuals were warier of humans and remain out of sight, while other individuals were less fearful of humans. Possibly, foraging behaviors by cats who have found a consistent food resource have changed, resulting in cats dispersing less.

Despite the statistical differences between all site’s population sizes, the monthly changes in population size for each site appeared to be similar, with no significant differences between sites. This can be seen in the seasonal fluctuations in the population size (Fig. 2) of the unmanaged sites as well as TNR Site 1. Each population size decreased through the late fall and winter months. Then the population size of all four sites increased in March, with some sites nearly doubling in population size. During March new kittens were seen for the first time at the Unmanaged Sites and TNR Site 1. No kittens were seen during resightings at TNR Site 2, but a previously owned house-cat was abandoned and then adopted by the property owners as a free-roaming individual. While the population sizes at the Unmanaged Sites and TNR Site 1 fluctuated in the months following March, the population size at TNR Site 2 remained relatively stable.

With population size increases at similar times in the TNR sites and Unmanaged Sites, TNR programs in Hays, Kansas did not appear to be reducing cat population sizes. Rather, TNR programs appeared to be supporting either a stable population size or an increasing population size. TNR Site 1 had less than 50% of their cats neutered, which explained why breeding was still taking place and with the addition of new immigrants, the population size was increasing. The immigration of these new individuals was probably due to the attraction of food, potential mates at the TNR site, or could have been released there.

In TNR Site 2, little breeding was occurring due to >90% of the cats being neutered, although there were still new cats immigrating to the site to obtain food or shelter or could have been released there. The limited food and the removal of excess food might have limited the site's carrying capacity. New individuals could join the colony only with the death or emigration of a resident cat. TNR programs, which neuter most individuals, to prevent breeding, are managing for stable population size, as opposed to reducing population size towards zero. Many TNR programs attempt to neuter most individuals, but lack the resources to keep up with the increasing population, resulting in an increasing cat population size.

The high survival rates and few, if any, decreases in population size found in my study suggested TNR programs did not appear to be reducing free-roaming cat populations contrary to assertions by animal advocacy groups in Hays, Kansas. This corroborates what other studies have found nationwide (Foley et al. 2005). The most common reason TNR programs are not as successful as commonly stated is due to the goals of the TNR programs. The definition of a successful TNR program often differs between TNR advocates and wildlife conservationists. Rapid colony reduction and the reduction of negative effects on wildlife are rarely ever included in the goals of a TNR organization. For TNR advocates, a successful TNR colony is one that focuses on improving the welfare of the cats and incidentally includes maintaining a constant, stable population. In contrast, wildlife conservationists determine success by how soon the colony is eliminated.

While animal welfare is a priority for TNR programs, many individual cats experience mortality during the winter months (Fig. 2). During these months, cats often congregate into condensed shelters where contact with other cats is likely. With a high concentration of cats in one area, internal parasites and diseases such as distemper, feline leukemia, and rabies might spread. As a result, animal welfare could actually worsen in the colonies where there is a greater chance to come into contact with a sick or infected individual. This also is true for wildlife, such as raccoons, skunks, and opossums that are attracted to the colonies for the same resources. Disease transmission between mesocarnivores and cats, vaccinated or not, has been documented in various studies (Gerhold, 2011; Murray et al. 2009). With a total of 93 raccoons, 45 Virginia opossums, 24 striped skunks and 14 domestic dogs captured during my study, possibly disease was a major factor in the winter decline of all four population sizes.

Management of free-roaming cats is often determined by local city, county, or even state laws. Often, these regulations occur at a local level where environmental impacts are not measured before the implementation of a management policy. This again stems from TNR programs being perceived as an animal welfare issue as opposed to an environmental problem. This lack of input from environmental officials and professionals adds into the problem of what makes TNR an unsuccessful technique. My results and those of other researchers have documented the limited effects of TNR on reducing cat population size. Previous studies have presented numerous management techniques that use a combination of trapping, adoption, and euthanasia, to reduce free-roaming cat populations and should be considered in the place of TNR programs (Castillo and Clark 2003; Winter 2004). Additionally, cooperative efforts between stakeholders, biologists, and animal advocates should focus on research of current TNR populations as well as better policies at each governmental level.

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TABLE 1.—The trapping success and number of cats trapped per each Trap-Neuter-Release Site (TNR) and Unmanaged Site and the overall total of all the sites combined. Total Cats is the total number of individuals trapped and marked for each site. Original trap-nights did not account for any bycatch or closed traps. Half trap-nights accounted for traps, which had bycatch or were closed but empty. Total trap-nights factored in the half trap-nights. Trap success was calculated by using total trap-nights.

| Site | Total Cats | Original Trap-Nights | Half Trap-Nights | Total Trap-Nights | Trap Success |
|---|---|---|---|---|---|
| TNR Site 1 | 23 | 840 | 173 | 753.5 | 3% |
| TNR Site 2 | 10 | 840 | 86 | 797 | 1% |
| Unmanaged Site 1 | 28 | 840 | 153 | 763.5 | 4% |
| Unmanaged Site 2 | 25 | 840 | 137 | 771.5 | 3% |
| **Total** | 86 | 3,360 | 549 | 3085.5 | 3% |

TABLE 2.—All 24 models used for Trap-Neuter-Release Site 1. The parameters include: α (mean resighting rate), σ (individual heterogeneity), U (population size), φ (apparent survival), γ" (probability of transitioning from observable state to unobservable state), and γ' (probability of remaining in unobservable state). The variables for modeling the parameters include: period (parameter constant over time), *t* (parameter varied over time), and a 0 or 1 (parameter fixed with zeros or ones). Different types of movement models include: γ"= γ' represents a random emigration model, γ"≠ γ' represents a Markovian movement model, and γ"(0) γ'(1) represents a no movement model. AICc values were used to determine the most supported model with the most supported listed model being the best fit. Delta AICc is the change from the most supported model to the listed model. AICc weight (*w*) describes the weight of evidence for a particular model. K represents the number of parameters used in the model.

| Model | AICc | Delta AICc | AICc Weight | K |
|---|---|---|---|---|
| α(.)σ(.)U(t)φ(.)γ"(0)γ'(1) | 378.9162 | 0.0000 | 0.94070 | 14 |
| α(.)σ(.)U(t)φ(.)γ"(.)=γ'(.) | 384.4903 | 5.5741 | 0.05795 | 16 |
| α(.)σ(.)U(t)φ(t)γ"(0)γ'(1) | 392.3302 | 13.4140 | 0.00115 | 24 |
| α(.)σ(.)U(t)φ(t)γ"(.)=γ'(.) | 395.8511 | 16.9349 | 0.00020 | 25 |
| α(.)σ(t)U(t)φ(.)γ"(0)γ'(1) | 412.4501 | 33.5339 | 0.00000 | 26 |
| α(t)σ(.)U(t)φ(.)γ"(0)γ'(1) | 412.5566 | 33.6404 | 0.00000 | 26 |
| α(t)σ(t)U(t)φ(.)γ"(.)=γ'(.) | 416.1548 | 37.2386 | 0.00000 | 27 |
| α(t)σ(.)U(t)φ(.)γ"(.)=γ'(.) | 416.1637 | 37.2475 | 0.00000 | 27 |
| α(.)σ(.)U(t)φ(.)γ"(t)=γ'(t) | 416.8092 | 37.8930 | 0.00000 | 26 |
| α(.)σ(.)U(t)φ(.)γ"(t)γ'(t) | 436.9276 | 58.0114 | 0.00000 | 35 |
| α(.)σ(.)U(t)φ(t)γ"(t)=γ'(t) | 436.9276 | 58.0114 | 0.00000 | 35 |
| α(t)σ(t)U(t)φ(t)γ"(0)γ'(1) | 437.4329 | 58.5167 | 0.00000 | 36 |
| α(t)σ(.)U(t)φ(t)γ"(.)=γ'(.) | 437.4498 | 58.5336 | 0.00000 | 36 |
| α(t)σ(.)U(t)φ(t)γ"(0)γ'(1) | 437.4533 | 58.5371 | 0.00000 | 36 |
| α(t)σ(t)U(t)φ(t)γ"(.)=γ'(.) | 442.3681 | 63.4519 | 0.00000 | 37 |
| α(.)σ(.)U(t)φ(t)γ"(t)γ'(t) | 446.6833 | 67.7671 | 0.00000 | 37 |
| α(t)σ(t)U(t)φ(.)γ"(t)=γ'(t) | 459.6335 | 80.7173 | 0.00000 | 37 |
| α(t)σ(.)U(t)φ(.)γ"(t)=γ'(t) | 459.6717 | 80.7555 | 0.00000 | 37 |
| α(t)σ(.)U(t)φ(t)γ"(t)=γ'(t) | 495.0836 | 116.1674 | 0.00000 | 46 |
| α(t)σ(t)U(t)φ(t)γ"(t)=γ'(t) | 501.9859 | 123.0697 | 0.00000 | 47 |
| α(t)σ(t)U(t)φ(.)γ"(t)γ'(t) | 501.9875 | 123.0713 | 0.00000 | 47 |
| α(t)σ(.)U(t)φ(.)γ"(t)γ'(t) | 502.0218 | 123.1056 | 0.00000 | 47 |
| α(t)σ(t)U(t)φ(t)γ"(t)γ'(t) | 516.6745 | 137.7583 | 0.00000 | 49 |
| α(t)σ(.)U(t)φ(t)γ"(t)γ'(t) | 532.5463 | 153.6301 | 0.00000 | 51 |

TABLE 3.—Trap-Neuter-Release Site 1 population size (N) estimates with the listed standard errors and 95% confidence intervals for each month.

| | | | 95% Confidence Interval | |
|---|---|---|---|---|
| Month | N | Standard Error | Lower | Upper |
| October 2011 | 19.3 | 2.37 | 15.21 | 24.56 |
| November 2011 | 16.2 | 2.50 | 12.04 | 21.92 |
| December 2011 | 16.4 | 2.24 | 12.58 | 21.41 |
| January 2012 | 12.9 | 2.09 | 9.40 | 17.69 |
| February 2012 | 10.6 | 1.94 | 7.41 | 15.10 |
| March 2012 | 22.9 | 2.44 | 18.59 | 28.18 |
| April 2012 | 24.2 | 3.06 | 18.93 | 31.00 |
| May 2012 | 22.2 | 2.62 | 17.59 | 27.92 |
| June 2012 | 25.8 | 3.31 | 20.10 | 33.15 |
| July 2012 | 21.9 | 2.96 | 16.84 | 28.51 |
| August 2012 | 22.1 | 2.74 | 17.33 | 28.13 |
| September 2012 | 26.0 | 3.11 | 20.56 | 32.83 |

TABLE 4.—All 24 models used for Trap-Neuter-Release Site 2. AICc values were used to determine the best fit model with the most supported listed model the best fit. The parameters include: $\alpha$ (intercept (on a log scale) for mean resighting rate), $\sigma$ (individual heterogeneity level (on a log scale)), U (population size), $\varphi$ (apparent survival), $\gamma''$ (probability of transitioning from an observable state to an unobservable state), and $\gamma'$ (probability of remaining in an unobservable state). The variables for modeling the parameters include: a period (parameter constant over time), a *t* (parameter varied over time), and a 0 (parameter fixed with zeros). Different types of movement models include: $\gamma''= \gamma'$ represents a random emigration model, $\gamma''\neq \gamma'$ represents a Markovian movement model, and $\gamma''(0)$ $\gamma'(0)$ represents a no movement model. Model Likelihood indicates the strength of evidence of this model relative to other models in the set of models considered.

| Model | AICc | Delta AICc | AICc Weight | K |
|---|---|---|---|---|
| $\alpha(.)\sigma(.)U(t)\varphi(.)\gamma''(0)\gamma'(1)$ | 261.3372 | 0.0000 | 0.84321 | 14 |
| $\alpha(.)\sigma(.)U(t)\varphi(.)\gamma''(.)=\gamma'(.)$ | 264.7019 | 3.3647 | 0.15678 | 15 |
| $\alpha(.)\sigma(.)U(t)\varphi(t)\gamma''(0)\gamma'(1)$ | 287.8294 | 26.4922 | 0.00000 | 24 |
| $\alpha(.)\sigma(.)U(t)\varphi(t)\gamma''(.)=\gamma'(.)$ | 293.0611 | 31.7239 | 0.00000 | 25 |
| $\alpha(t)\sigma(.)U(t)\varphi(.)\gamma''(0)\gamma'(1)$ | 298.9837 | 37.6465 | 0.00000 | 25 |
| $\alpha(t)\sigma(t)U(t)\varphi(.)\gamma''(0)\gamma'(1)$ | 298.9837 | 37.6465 | 0.00000 | 25 |
| $\alpha(t)\sigma(.)U(t)\varphi(.)\gamma''(.)=\gamma'(.)$ | 304.4837 | 43.1465 | 0.00000 | 26 |
| $\alpha(t)\sigma(t)U(t)\varphi(.)\gamma''(.)=\gamma'(.)$ | 304.4837 | 43.1465 | 0.00000 | 26 |
| $\alpha(.)\sigma(.)U(t)\varphi(.)\gamma''(t)=\gamma'(t)$ | 307.6019 | 46.2647 | 0.00000 | 25 |
| $\alpha(.)\sigma(.)U(t)\varphi(.)\gamma''(t)\gamma'(t)$ | 338.5611 | 77.2239 | 0.00000 | 32 |
| $\alpha(.)\sigma(.)U(t)\varphi(t)\gamma''(t)=\gamma'(t)$ | 355.3353 | 93.9981 | 0.00000 | 34 |
| $\alpha(.)\sigma(.)U(t)\varphi(t)\gamma''(t)\gamma'(t)$ | 355.3353 | 93.9981 | 0.00000 | 34 |
| $\alpha(t)\sigma(t)U(t)\varphi(t)\gamma''(0)\gamma'(1)$ | 355.7222 | 94.3850 | 0.00000 | 35 |
| $\alpha(t)\sigma(.)U(t)\varphi(t)\gamma''(0)\gamma'(1)$ | 355.7222 | 94.3850 | 0.00000 | 35 |
| $\alpha(t)\sigma(t)U(t)\varphi(t)\gamma''(.)=\gamma'(.)$ | 365.5843 | 104.2471 | 0.00000 | 36 |
| $\alpha(t)\sigma(.)U(t)\varphi(t)\gamma''(.)=\gamma'(.)$ | 365.5843 | 104.2471 | 0.00000 | 36 |
| $\alpha(t)\sigma(.)U(t)\varphi(.)\gamma''(t)=\gamma'(t)$ | 380.3458 | 119.0086 | 0.00000 | 36 |
| $\alpha(t)\sigma(t)U(t)\varphi(.)\gamma''(t)=\gamma'(t)$ | 380.3458 | 119.0086 | 0.00000 | 36 |
| $\alpha(t)\sigma(.)U(t)\varphi(.)\gamma''(t)\gamma'(t)$ | 459.7222 | 198.3850 | 0.00000 | 43 |
| $\alpha(t)\sigma(t)U(t)\varphi(.)\gamma''(t)\gamma'(t)$ | 459.7222 | 198.3850 | 0.00000 | 43 |
| $\alpha(t)\sigma(t)U(t)\varphi(t)\gamma''(t)=\gamma'(t)$ | 498.7222 | 237.3850 | 0.00000 | 45 |
| $\alpha(t)\sigma(t)U(t)\varphi(t)\gamma''(t)\gamma'(t)$ | 498.7222 | 237.3850 | 0.00000 | 45 |
| $\alpha(t)\sigma(.)U(t)\varphi(t)\gamma''(t)=\gamma'(t)$ | 498.7222 | 237.3850 | 0.00000 | 45 |
| $\alpha(t)\sigma(.)U(t)\varphi(t)\gamma''(t)\gamma'(t)$ | 498.7222 | 237.3850 | 0.00000 | 45 |

TABLE 5.—Trap-Neuter-Release Site 2 population size (N) estimates with the listed standard errors and 95% confidence intervals for each month.

| | | | 95% Confidence Interval | |
|---|---|---|---|---|
| Month | N | Standard Error | Lower | Upper |
| October 2011 | 8.2 | 2.14 | 4.95 | 13.57 |
| November 2011 | 14.3 | 2.34 | 10.44 | 19.70 |
| December 2011 | 9.2 | 1.34 | 6.89 | 12.18 |
| January 2012 | 10.9 | 1.72 | 8.01 | 14.81 |
| February 2012 | 5.6 | 1.37 | 3.48 | 8.97 |
| March 2012 | 11.6 | 1.71 | 8.70 | 15.45 |
| April 2012 | 8.0 | 1.40 | 5.70 | 11.26 |
| May 2012 | 7.4 | 1.25 | 5.35 | 10.32 |
| June 2012 | 6.9 | 1.09 | 5.03 | 9.33 |
| July 2012 | 6.2 | 1.24 | 4.23 | 9.15 |
| August 2012 | 7.5 | 0.91 | 5.90 | 9.50 |
| September 2012 | 6.3 | 0.89 | 4.75 | 8.27 |

TABLE 6.—All 24 models used for Unmanaged Site 1. AICc values were used to determine the best fit model with the most supported listed model being the best fit. The parameters include: α (intercept (on a log scale) for mean resighting rate), σ (individual heterogeneity level (on a log scale)), U (population size), φ (apparent survival), γ" (probability of transitioning from an observable state to an unobservable state), and γ' (probability of remaining in an unobservable state). The variables for modeling the parameters include: a period (parameter constant over time), a *t* (parameter varied over time), and a 0 (parameter fixed with zeros). Different types of movement models include: γ"= γ' represents a random emigration model, γ"≠ γ' represents a Markovian movement model, and γ"(0) γ'(0) represents a no movement model. Model Likelihood indicates the strength of evidence of this model relative to other models in the set of models considered.

| Model | AICc | Delta AICc | AICc Weight | K |
|---|---|---|---|---|
| α(.)σ(.)U(t)φ(.)γ"(0)γ'(1) | 409.4183 | 0.0000 | 0.79550 | 14 |
| α(.)σ(.)U(t)φ(.)γ"(.)=γ'(.) | 412.1362 | 2.7179 | 0.20439 | 15 |
| α(.)σ(.)U(t)φ(t)γ"(0)γ'(1) | 427.8583 | 18.4400 | 0.00008 | 24 |
| α(.)σ(.)U(t)φ(t)γ"(.)=γ'(.) | 431.2934 | 21.8751 | 0.00001 | 25 |
| α(t)σ(.)U(t)φ(.)γ"(0)γ'(1) | 432.4636 | 23.0453 | 0.00001 | 25 |
| α(t)σ(t)U(t)φ(.)γ"(0)γ'(1) | 432.4636 | 23.0453 | 0.00001 | 25 |
| α(t)σ(.)U(t)φ(.)γ"(.)=γ'(.) | 435.9857 | 26.5674 | 0.00000 | 26 |
| α(t)σ(t)U(t)φ(.)γ"(.)=γ'(.) | 435.9857 | 26.5674 | 0.00000 | 26 |
| α(.)σ(.)U(t)φ(.)γ"(t)=γ'(t) | 442.6355 | 33.2172 | 0.00000 | 25 |
| α(t)σ(t)U(t)φ(t)γ"(0)γ'(1) | 461.0678 | 51.6495 | 0.00000 | 35 |
| α(t)σ(.)U(t)φ(t)γ"(.)=γ'(.) | 465.6765 | 56.2582 | 0.00000 | 36 |
| α(t)σ(.)U(t)φ(t)γ"(0)γ'(1) | 465.7142 | 56.2959 | 0.00000 | 36 |
| α(.)σ(.)U(t)φ(t)γ"(t)=γ'(t) | 466.5646 | 57.1463 | 0.00000 | 34 |
| α(.)σ(.)U(t)φ(t)γ"(t)γ'(t) | 466.5646 | 57.1463 | 0.00000 | 34 |
| α(t)σ(t)U(t)φ(t)γ"(.)=γ'(.) | 470.4226 | 61.0043 | 0.00000 | 37 |
| α(.)σ(.)U(t)φ(.)γ"(t)γ'(t) | 471.0434 | 61.6251 | 0.00000 | 35 |
| α(t)σ(.)U(t)φ(.)γ"(t)=γ'(t) | 476.8223 | 67.4040 | 0.00000 | 36 |
| α(t)σ(t)U(t)φ(.)γ"(t)=γ'(t) | 476.8223 | 67.4040 | 0.00000 | 36 |
| α(t)σ(t)U(t)φ(t)γ"(t)=γ'(t) | 520.3560 | 110.9377 | 0.00000 | 46 |
| α(t)σ(t)U(t)φ(t)γ"(t)γ'(t) | 520.3560 | 110.9377 | 0.00000 | 46 |
| α(t)σ(.)U(t)φ(t)γ"(t)=γ'(t) | 520.3560 | 110.9377 | 0.00000 | 46 |
| α(t)σ(.)U(t)φ(t)γ"(t)γ'(t) | 520.3560 | 110.9377 | 0.00000 | 46 |
| α(t)σ(.)U(t)φ(.)γ"(t)γ'(t) | 520.3560 | 110.9377 | 0.00000 | 46 |
| α(t)σ(t)U(t)φ(.)γ"(t)γ'(t) | 526.9037 | 117.4854 | 0.00000 | 47 |

TABLE 7.—Unmanaged Site 1 population size (N) estimates with the listed standard errors and 95% confidence intervals for each month.

| | | | 95% Confidence Interval | |
|---|---|---|---|---|
| Month | N | Standard Error | Lower | Upper |
| October 2011 | 44.0 | 5.96 | 33.77 | 57.29 |
| November 2011 | 47.0 | 6.63 | 35.69 | 61.88 |
| December 2011 | 40.1 | 5.97 | 30.04 | 53.63 |
| January 2012 | 37.3 | 5.51 | 27.96 | 49.75 |
| February 2012 | 26.5 | 4.72 | 18.77 | 37.47 |
| March 2012 | 46.1 | 6.18 | 35.46 | 59.86 |
| April 2012 | 39.9 | 5.58 | 30.39 | 52.42 |
| May 2012 | 44.8 | 6.15 | 34.24 | 58.52 |
| June 2012 | 48.8 | 6.38 | 37.78 | 62.95 |
| July 2012 | 47.4 | 6.22 | 36.68 | 61.21 |
| August 2012 | 44.1 | 6.19 | 33.58 | 58.04 |
| September 2012 | 44.4 | 6.56 | 33.26 | 59.20 |

TABLE 8.—All 24 models used for Unmanaged Site 2. AICc values were used to determine the best fit model with the top listed model being the best fit. The parameters include: α (intercept (on a log scale) for mean resighting rate), σ (individual heterogeneity level (on a log scale)), U (population size), φ (apparent survival), γ" (probability of transitioning from an observable state to an unobservable state), and γ' (probability of remaining in an unobservable state). The variables for modeling the parameters include: a period (parameter constant over time), a *t* (parameter varied over time), and a 0 (parameter fixed with zeros). Different types of movement models include: γ"= γ' represents a random emigration model, γ"≠ γ' represents a Markovian movement model, and γ"(0) γ'(0) represents a no movement model. Model Likelihood indicates the strength of evidence of this model relative to other models in the set of models considered.

| Model | AICc | Delta AICc | AICc Weight | K |
|---|---|---|---|---|
| α(.)σ(.)U(t)φ(.)γ"(0)γ'(1) | 356.2500 | 0.0000 | 0.78856 | 14 |
| α(.)σ(.)U(t)φ(.)γ"(.)=γ'(.) | 358.8985 | 2.6485 | 0.20976 | 15 |
| α(.)σ(.)U(t)φ(t)γ"(0)γ'(1) | 368.9028 | 12.6528 | 0.00141 | 24 |
| α(.)σ(.)U(t)φ(t)γ"(.)=γ'(.) | 372.1762 | 15.9262 | 0.00027 | 25 |
| α(t)σ(.)U(t)φ(.)γ"(0)γ'(1) | 384.8207 | 28.5707 | 0.00000 | 26 |
| α(.)σ(.)U(t)φ(.)γ"(t)=γ'(t) | 387.7168 | 31.4668 | 0.00000 | 25 |
| α(t)σ(.)U(t)φ(.)γ"(.)=γ'(.) | 388.2753 | 32.0253 | 0.00000 | 27 |
| α(t)σ(t)U(t)φ(.)γ"(.)=γ'(.) | 388.8999 | 32.6499 | 0.00000 | 28 |
| α(.)σ(.)U(t)φ(t)γ"(t)=γ'(t) | 405.3195 | 49.0695 | 0.00000 | 34 |
| α(.)σ(.)U(t)φ(t)γ"(t)γ'(t) | 405.3195 | 49.0695 | 0.00000 | 34 |
| α(t)σ(.)U(t)φ(t)γ"(0)γ'(1) | 407.3709 | 51.1209 | 0.00000 | 36 |
| α(t)σ(t)U(t)φ(.)γ"(0)γ'(1) | 407.8142 | 51.5642 | 0.00000 | 33 |
| α(.)σ(.)U(t)φ(.)γ"(t)γ'(t) | 409.4682 | 53.2182 | 0.00000 | 35 |
| α(t)σ(.)U(t)φ(t)γ"(.)=γ'(.) | 411.7554 | 55.5054 | 0.00000 | 37 |
| α(t)σ(t)U(t)φ(t)γ"(.)=γ'(.) | 415.3398 | 59.0898 | 0.00000 | 38 |
| α(t)σ(t)U(t)φ(t)γ"(0)γ'(1) | 418.1246 | 61.8746 | 0.00000 | 39 |
| α(t)σ(t)U(t)φ(.)γ"(t)=γ'(t) | 424.0815 | 67.8315 | 0.00000 | 37 |
| α(t)σ(.)U(t)φ(.)γ"(t)=γ'(t) | 427.5241 | 71.2741 | 0.00000 | 37 |
| α(t)σ(.)U(t)φ(.)γ"(t)γ'(t) | 436.5950 | 80.3450 | 0.00000 | 41 |
| α(t)σ(t)U(t)φ(.)γ"(t)γ'(t) | 459.1898 | 102.9398 | 0.00000 | 47 |
| α(t)σ(.)U(t)φ(t)γ"(t)=γ'(t) | 462.5957 | 106.3457 | 0.00000 | 47 |
| α(t)σ(.)U(t)φ(t)γ"(t)γ'(t) | 462.7300 | 106.4800 | 0.00000 | 47 |
| α(t)σ(t)U(t)φ(t)γ"(t)=γ'(t) | 465.3878 | 109.1378 | 0.00000 | 48 |
| α(t)σ(t)U(t)φ(t)γ"(t)γ'(t) | 471.3348 | 115.0848 | 0.00000 | 49 |

TABLE 9.—Unmanaged Site 2 population size (N) estimates with the listed standard errors and 95% confidence intervals for each month.

| | | | 95% Confidence Interval | |
|---|---|---|---|---|
| Month | N | Standard Error | Lower | Upper |
| October 2011 | 29.2 | 4.87 | 21.08 | 40.38 |
| November 2011 | 23.5 | 3.77 | 17.16 | 32.11 |
| December 2011 | 18.3 | 3.32 | 12.89 | 26.09 |
| January 2012 | 17.8 | 2.57 | 13.43 | 23.57 |
| February 2012 | 14.8 | 3.13 | 9.80 | 22.27 |
| March 2012 | 27.6 | 3.89 | 21.01 | 36.37 |
| April 2012 | 30.2 | 4.45 | 22.64 | 40.22 |
| May 2012 | 31.7 | 4.67 | 23.83 | 42.30 |
| June 2012 | 26.7 | 5.05 | 18.53 | 38.59 |
| July 2012 | 28.2 | 4.48 | 20.68 | 38.41 |
| August 2012 | 28.0 | 4.29 | 20.78 | 37.75 |
| September 2012 | 37.4 | 6.14 | 27.15 | 51.45 |

FIGURE 1.—A map of all four study site locations around the city of Hays, Kansas. Trap-Neuter-Release Site 1 is marked with a triangle and is located on Fort Hays State University campus. Trap-Neuter-Release Site 2 is marked with a square and is located on a private residence. Unmanaged Site 1 is marked with a diamond and is located at Meadow Acres Mobile Home Park. Unmanaged Site 2 is marked with a circle and is located at Colonial Gardens Mobile Home Park.

FIGURE 2.—Estimates of population size, for each site per month, obtained from Program MARK. Population trends suggest seasonal fluctuations in both Unmanaged Sites 1 and 2, and Trap-Neuter-Release Site 1. Trap-Neuter-Release Site 2 remained relatively stable across seasons.