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Immobilization of Small Mammals and Occupancy, Seasonal Food Habits, and Parasites of Allegheny Woodrats in the Cumberland Mountains, Tennessee

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To the Graduate Council:

I am submitting herewith a thesis written by William Teague Parker entitled "Immobilization of Small Mammals and Occupancy, Seasonal Food Habits, and Parasites of Allegheny Woodrats in the Cumberland Mountains, Tennessee." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife and Fisheries Science.

Lisa Muller, Major Professor

We have read this thesis and recommend its acceptance:

Reid Gerhardt, Edward Ramsay, Arnold Saxton

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Edward Ramsay

Arnold Saxton

Acceptance for the Council:

Anne Mayhew
Vice Chancellor and
Dean of Graduate Studies

(Original signatures are on file with official student records)

IMMOBILIZATION OF SMALL MAMMALS AND OCCUPANCY, SEASONAL FOOD HABITS, AND PARASITES OF ALLEGHENY WOODRATS IN THE CUMBERLAND MOUNTAINS, TENNESSEE

A Thesis
Presented for the
Master of Science Degree
The University of Tennessee, Knoxville

William Teague Parker
August 2006

DEDICATION

I dedicate this thesis to all the fuzzy woodrats that endured the poking and prodding to further our knowledge in the name of science. Hopefully this information will help in their management and keep them here for a while longer to fill their niche in the large expanse of wildlife species in Tennessee.

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Finally, I would like to thank my family for the support and encouragement they have given me throughout my college career. I greatly appreciate the love and support of my wife Kristen. I am looking forward to the start of our new careers together.

ABSTRACT

Allegheny woodrats (*Neotoma magister*) occur throughout the Appalachians north of the Tennessee River. Declines have occurred in the northern and western parts of their range, prompting the need for more information about the species in areas where they are rare. The purpose of this study was to gain more information on the Allegheny woodrat in the Cumberland Mountains of Tennessee. The main objectives were to (1) evaluate isoflurane anesthesia to immobilize woodrats and other small mammals for biological sample collection and (2) determine percent occupancy, food habits, and external parasite species of Allegheny woodrats at likely candidate sites in eastern Tennessee.

I evaluated a chamber and nose cone method of isoflurane delivery for immobilizing eastern gray squirrels (*Sciurus carolinensis*; summer $n = 43$, winter $n = 48$) and Allegheny woodrats (summer $n = 24$, winter $n = 13$) respectively. Time to induction for squirrels did not differ between summer (3.24 min) and winter (3.13 min) or by sex. Squirrels awoke more quickly in the summer (1.47 min) than in the winter (3.66 min) after removal of the nose cone and their pulse was higher in the winter, whereas body temperature and respiration were lower. I administered the nose cone for 0.5 min for all woodrats since it was not possible to determine induction time because the animals were being manually restrained. There were no differences by season or sex for timing of effects or physiological parameters in Allegheny woodrats. Woodrats awoke in 4.22 min in the summer and 4.06 min in the winter following the final dose of isoflurane. Both methods resulted in rapid induction, quick recovery times, and acceptable physiological parameters in both summer and winter.

Data for occupancy, food habits, and external parasites for Allegheny woodrats were collected from November 2003 to August 2005 in Royal Blue Wildlife Management Area (RBWMA) and Big South Fork National River and Recreation Area (BSFNRRA), Tennessee, USA. We determined if food availability including percent forbs (FORB) and number of mast producing trees (MAST), trap effort measured by the number of traps (N_TRAP), or location of trapping (AREA) explained detection probability (p) while occupancy (ψ) was kept constant. I evaluated the following habitat variables for their effect on occupancy: FORB (determine if woodrats preferred areas with green forage over habitats without green forage), MAST (evaluate preference of hard mast crops during the winter and habitat selection of hard mast producing trees), AREA (geographic location), and the combination of FORB and MAST (determine if woodrats occupied areas with both green vegetation and hard mast over areas with only one or none of these food items). Site occupancy models calculated from presence-apparent absence data indicated detection probabilities were best predicted by the two areas (AREA). The detection probabilities obtained from model averaging were $p = 0.49$ (SE = 0.13) and 0.74 (SE = 0.07) for BSFNRRA and RBWMA, respectively. Using detection probabilities explained by AREA, model selection results suggested that occupancy was constant for selected habitat variables examined. The model constraining occupancy as a function of FORB also seemed useful for model inference but the slope of this function bounded 0, indicating low predictive value. Using model averaging, the proportion of the trapping locations occupied by woodrats was 0.79 (SE = 0.12 SE) and 0.79 (SE = 0.13) for RBWMA and BSFNRRA, respectively.

I also described food habits for the summer (n = 14) and winter (n = 13) seasons in Tennessee using microhistological analysis of fecal material. The main food types in the summer were forbs, shrubs, fungus, and soft mast. The winter diet was primarily composed of fungus, forbs, shrubs, and hard mast. External parasites were collected from 26 Allegheny woodrats and included 2 woodrat fleas (*Epitedia cavernicola*), 63 of the woodrat specific flea *Orchopeas pennsylvanicus,* and 5 female woodrat ticks (*Ixodes woodi*).

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PART I

INTRODUCTION

INTRODUCTION

The Allegheny woodrat (*Neotoma magister)* is a medium-sized rodent that utilizes rock outcrops, caves, boulders, talus fields, and occasionally abandoned human structures. Allegheny woodrats historically ranged throughout the Appalachians from southern New York to northern Alabama and northwestern Georgia (Poole 1940). The southern border is the Tennessee River and has been used to distinguish between the Allegheny and eastern woodrat (*Neotoma floridana*; Whitaker and Hamilton 1998). Analysis of mitochondrial DNA and morphological variation has distinguished the Allegheny woodrat as a separate species from the eastern woodrat (Hayes and Harrison 1992, Hayes and Richmond 1993).

Home ranges for adult Allegheny woodrats are approximately 2 ha located in intact deciduous forest (Castleberry et al. 2001). Home ranges do not typically differ between sexes, although home ranges for males can be up to 3 times larger in some areas (Castleberry 2000). Reproduction in woodrats can occur throughout the year depending on available resources (Mengak 2002). The average litter size in the wild has been estimated at 2.3 and in captivity has been observed to be 3 (Poole 1936, Mengak 2002). Gestation of young is usually between 30 and 36 days (Poole 1936).

Declines have occurred in most areas of the Allegheny woodrat’s distribution. Castleberry et al. (2002*b*) noted that Allegheny woodrats were deemed endangered, threatened, or of concern in every state of their range. Population declines have mainly occurred in the northern and western parts of the Allegheny woodrat’s range (Balcom and Yahner 1996, Whitaker and Hamilton 1998). Populations of woodrats have been extirpated from New York and Connecticut (Balcom and Yahner 1996). Many declines in the north have been attributed to the raccoon roundworm (*Baylisascaris procyonis*; LoGiudice 2003). Infection occurs when woodrats eat seeds found in raccoon fecal material infected with roundworm eggs. Once ingested, the parasite is fatal to woodrats (LoGiudice 2000). Other theories of decline include predation by great horned owls (*Bubo virginianus*), reduced hard mast production due to the elimination of American chestnut (*Castanea dentata*) from chestnut blight (*Cryphonectria parasitica*), infestations in oak (*Quercus* spp.) by gypsy moth (*Lymantria dispar*), and habitat fragmentation (Hall 1985, Balcom and Yahner 1996, Castleberry 2000).

The core region of the Allegheny woodrat distribution in Virginia and West Virginia has been the focus of most studies. Food habits (Castleberry et al. 2002*a*), reproduction (Mengak 2002), demography and genetic structure (Manjerovic 2004), habitat (Wood 2001), external parasites (Castleberry et al. 2003), and conservation and management (Castleberry 2000) have all been examined in this region. However, little research has been conducted along the southern boundary of the Allegheny woodrat's range.

The purpose of this research was to gain more information on the Allegheny woodrat in the Cumberland Mountains of Tennessee. The main goals of the project were to:

1. Evaluate isoflurane anesthesia to immobilize woodrats and other small mammals for biological sample collection.
2. Determine percent occupancy of Allegheny woodrats at likely candidate sites in eastern Tennessee.

3. Determine the food habits of Allegheny woodrats in eastern Tennessee.
4. Determine the external parasitic species infecting Allegheny woodrats in eastern Tennessee.

LITERATURE REVIEW

Immobilization

Small mammals often need to be restrained and anesthetized for research purposes. The type of restraint method depends on the purpose for which the animals are being captured. Manual restraint with cloth bags, canvas cones, or by hand is useful for quick procedures that do not cause significant stress to the animal. Determining age, sex, weight, and placing ear tags may be accomplished with manual restraint in most small mammals (Arenz 1997). Manual restraint is efficient and cost effective. Douglass et al. (2000) determined that bleeding nonanesthetized wild rodents did not affect handling mortality or recapture. However, the chance of researchers being bitten and discomfort to the animals was greater (Douglass et al. 2000).

Immobilization with injectable drugs is useful for research procedures that may cause a lot of stress to the animal and that require more time to complete. Ketamine (ketamine hydrochloride) has been used to immobilize fox squirrels (*Sciurus niger*), bushy-tailed woodrats (*Neotoma cinerea*), and yellow-bellied marmots (*Marmota falviventris*) for taking blood samples (Frase and Vuren 1989, Arenz 1997). *Neotoma* spp. and *Peromyscus* spp. have been immobilized using ketamine and medetomidine (medetomidine hydrochloride; Hahn et al. 2005). The main advantages of injectable drugs are that induction times are fast, the animal remains immobilized for a long period of time, and some drugs are reversible. Antagonists may be used to decrease the amount of time for recovery in some cases. Atipamezole was used to reverse the medetomidine component of a ketamine/medetomidine mixture in rodents. Recovery times were between 4 and 13 minutes after atipamezole administration (Hahn et al. 2005). The main disadvantage of injectable drugs is that many are nonreversible and have long recovery times. Arenz (1997) found that induction for fox squirrels was only 2 – 4 minutes, while recovery time to the point of release was over 2 hours without an antagonist.

Inhalation anesthetics are useful for immobilizing animals for procedures that are short but can cause stress to the animal. Inhalation anesthetics have been used to aid in collecting blood, attaching radiocollars, marking animals, and taking basic physiological data (Patton et al. 1976, Anstee and Needham 1997, McColl and Boonstra 1999, Wimsatt et al. 2005). Isoflurane, halothane, methoxyflurane, and sevoflurane are common inhalant anesthetics that have been used in small mammals (McColl and Boonstra 1999, Breck and Gaynor 2003). McColl and Boonstra (1999) determined that isoflurane and halothane had the fastest induction and recovery times compared to methoxyflurane. Inhalation anesthetics reduced the time for bleeding procedures by half compared to using manual restraint alone. Isoflurane is the preferred choice for anesthesia of exotic species in veterinary practice due to its low cost, rapid induction and recovery, and low incidence of side effects (Edling 2003). One disadvantage is that isoflurane decreases the heart rate and respiratory frequency as the dose of anesthetic is increased (Imai et al. 1999). However, isoflurane allows precise control over the depth of anesthesia and physiological depression that occurs during use due to its low blood gas partition coefficient (Seeler et al. 1988). Anesthetics that have a low blood gas partition coefficient are less soluble in the blood, causing the tension of anesthetic in the arterial blood to rise quickly (Muir et al. 2000). This allows the user to control the depth of anesthesia and physiological depression through the amount and duration of drug given. Portable induction masks and anesthesia chambers have been developed to aid in the delivery of inhalant anesthetics to small mammals in the field (Heidt 1973, Anstee and Needham 1997, Lewis 2004).

Occupancy

Occupancy is the proportion of an area inhabited by a target species (MacKenzie et al. 2005). Occupancy estimates using presence-apparent absence data can provide information about the range of a species, the likelihood of extinction, and abundance (MacKenzie et al. 2005). Presence-apparent absence data has been widely used in wildlife management to monitor population distribution and determine relationships between wildlife and habitat (Gu and Swihart 2004, MacKenzie 2005). Presence of a species is easily determined if the animal is captured in an area.

The main problem with presence-absence data is when a target species is present but goes undetected during sampling (MacKenzie et al. 2003, Gu and Swihart 2004, Wintle et al. 2005). Detectability is not constant in time or space for a species or individual (Vojta 2005). Ignoring this variation in detectability leads to biased estimates of presence, site occupancy, colonization, and extinction probabilities (MacKenzie et al. 2003, Vojta 2005). Determining information about detection probabilities for the target species can allow unbiased estimates to be produced (MacKenzie 2005).

MacKenzie et al. (2002) demonstrated that detection probabilities could be calculated from detection and nondetection data collected at sites during revisits. Using the calculated detection probabilities, occupancy rates could be estimated using a maximum likelihood estimate model (MacKenzie et al. 2002). Vojta (2005) noted that low detection probabilities present problems with occupancy modeling and can lead to biased estimates of occupancy rate. Stanley and Royle (2005) further showed that indirect detection indices could be used with the model described by MacKenzie et al. (2002) to estimate occupancy when capture-recapture methods are unavailable or not practical.

Researchers have used the methods described by Mackenzie et al. (2002) to calculate occupancy models for many species. Finley et al. (2005) estimated the population size and occupancy rates for the threatened swift fox (*Vulpes velox*) in Colorado. Finley et al. (2005) was able to determine a relationship between occupancy of swift foxes and short-grass prairie habitat and designed an occupancy monitoring system to detect declines in the species. Pellet and Schmidt (2005) estimated occupancy rates and detection probabilities using anuran call surveys for a monitoring program of amphibian species. Moore and Swihart (2005) used occupancy models to determine which forest rodent species were adversely affected by forest fragmentation and patch isolation.

Food Habits

Allegheny woodrat food habits have not been examined thoroughly throughout their range. Castleberry et al. (2002*a*) described the food habits of Allegheny woodrats in their core distribution of the Central Appalachians in West Virginia. Hard mast, soft mast, and fungi were important food sources in this area (Castleberry et al. 2002*a*). Acorns (*Quercus* spp.) were significantly consumed even in areas where oak forests were rare (Castleberry et al. 2002*a*).

Food habits for eastern woodrats have been examined through several experiments and observations (McMurry et al. 1993, Herrera and McDonald 1997, Wagle and Feldhamer 1997). Wagle and Feldhamer (1997) found that hard mast and herbaceous material comprised the greatest percentage in eastern woodrat diets in southern Illinois. Hickory nuts (*Carya* spp.), Virginia creeper (*Parthenocissus quinquefolia*), spicebush (*Lindera benzoin*), and sedge (*Carex* spp.), were the most consumed species in the area (Wagle and Feldhamer 1997). Wagle and Feldhamer (1997) also noted that woodrats ration cached food resources to maintain quality foods until the end of winter and beginning of spring. In a controlled experiment by Williams et al. (2000), eastern woodrats willingly consumed northern bobwhite (*Colinus virginianus*) carcasses when present. This suggested that woodrats may include meat in their diet when other food resources become limited (Williams et al. 2000). Maternal diets also influence the type of foods that are cached and eaten by juvenile woodrats (Post et al. 1998).

Several small mammals consume significant amounts of fungi in their diet. Herrera and McDonald (1997) found that eastern woodrats consume foods that are highly infected with fungi. When given a choice, the woodrats would choose items highly infected over ones with intermediate amounts of fungi (Herrera and McDonald 1997). Castleberry et al. (2002*a*) also found significant amounts of fungi present in Allegheny woodrat diets. The fungi seen in the diet could be from the consumption of mushrooms, michorrizae, or from food items infected with fungal growth (Castleberry et al. 2002*a*). Pyare and Longland (2001) looked at consumption of fungi by small mammals in the Sierra Nevada. Spores of fungi were found in the feces of northern flying squirrels (*Glaucomys sabrinus*) and Douglas squirrels (*Tamiasciurus douglassi*). Mitchell (2001) determined that fungi and lichens were primary items in the diet of northern flying squirrels in West Virginia. In the southern Appalachians, fungi are an important food item for southern red-backed voles (*Clethrionomys gapperi*) throughout the year (Orrock and Pagels 2002). Stienecker and Browning (1970) found that fungi, acorns, and forb leafage were important items in the diet of western gray squirrels (*Sciurus griseus*).

Oaks are the most abundant and widely distributed genus of hardwood trees in the temperate zone (Van Dersal 1940). Samples from southern Appalachian oak stands have shown acorns to be a very valuable although inconsistent food source for wildlife (Beck 1977). Acorn production varies each year and also varies by the oak species (Beck 1977). Acorn yield increases as trees mature. Few oak trees less than 20 years old produce acorns while the largest production is in trees between 40 and 99 years of age (Goodrum et al. 1971). The amount of acorns produced is related to the crown size and bole diameter (Goodrum et al. 1971). Acorns are high in nutrient content with carbohydrates and fat important for animals during the winter (Goodrum 1959). Hickories and walnuts (*Juglans* spp.) are also high in fat and are more digestible than other hard mast species (Short and Epps 1976). Hard mast is an important food source for many wildlife species. Van Dersal (1940) showed that acorns are utilized by several birds and mammals including northern bobwhite, wild turkey (*Meleagris gallopavo*), ruffed grouse (*Bonasa umbellus*), black bear (*Ursus americanus*), white-tailed deer

(*Odocoileus virginianus*), elk (*Cervus elaphus*), eastern chipmunk (*Tamias striatus*), white-footed mouse (*Peromyscus leucopus*), gray squirrel (*Sciurus carolinensis*), and Allegheny woodrat. Acorns, hickory nuts (*Carya* spp.), and pine seeds (*Pinus* spp.) were important food sources for gray squirrels in the southeast (Davison 1964, Spritzer 2002).

Optimal foraging theory suggests that animals should choose foods that maximize energy intake and minimize the time to acquire and consume the item (Pyke et al. 1977). Eastern woodrats exhibited opportunistic foraging and selected forb items in relation to their abundance in manipulated habitats (McMurry et al. 1993). Selective foraging was occasionally observed in eastern woodrats in response to food items that were more palatable or had increased nutrient quality (McMurry et al. 1993).

Species that regularly cache food have a more diverse diet than animals that do not exhibit a caching behavior (Reichman and Fay 1983). Squirrels were shown to consistently consume acorns of high perishability and store acorns of low perishability (Hadj-Chikh et al. 1996). Post and Reichman (1991) also showed that eastern woodrats consumed more perishable food items when foraging and cached less perishable items. Eastern woodrats collected nearby items over distant items and cached dry items over wet items presumably due to perishability (Post and Reichman 1991). Horne et al. (1998) noted that eastern woodrats often only obtain a few primary items of high quality to store in their cache due to what food items are located within their home range size. Post (1992) found that the nutrient content of cached materials decreases with time and that woodrats need to store several types of food in order to have some high quality items left at the end of the dormant season.

External Parasites

Several studies have documented the flea fauna associated with woodrats in the southeastern United States. Castelberry et al. (2003) collected parasites from Allegheny woodrats and found almost all were *Orchopeas pennsylvanicus*. The exception was a single male *Epitedia cavernicola*. *Orchopeas pennsylvanicus* and *E. cavernicola* have also been discovered as parasites of eastern woodrats in Tennessee, South Carolina, and Indiana (Pfitzer 1950, Cudmore 1986, Durden and Kollars 1997, Durden et al. 1999). Both *O. pennsylvanicus* and *E. cavernicola* have been documented as host specific parasites of *Neotoma* species in the southeast United States (Lewis 1974, Lewis 1975). In addition to the previous two species, *Polygenis gwyni* and *O. howardi* have been collected from eastern woodrats in South Carolina and Georgia (Durden et al. 1997, Durden et al. 1999).

Most early research was conducted before the distinction between Allegheny and eastern woodrat was made. Allegheny woodrats may have a higher degree of flea host specificity compared to eastern woodrats due to their specific habitat requirements (Castleberry et al. 2003). Allegheny woodrats have less contact with other small mammals reducing the chance of transmission. Eastern woodrats also build large stick nests that harbor other rodents that may facilitate transfer of fleas (Castleberry et al. 2003). These nests are reused each year. Fleas often choose specific hosts that build nests (Benton 1980). After a blood meal, fleas lay their eggs on the host and the eggs eventually fall into the nest. After the eggs mature, the fleas can be transmitted to the host's offspring in the nest (Benton 1980). This adaptation results in a flea-host specificity.

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PART II

EVALUATION OF ISOFLURANE FOR IMMOBILIZATION OF SMALL MAMMALS

INTRODUCTION

Immobilization of small mammals in the field presents several problems for researchers. When immobilizing animals, researchers have to weigh the mortality risk associated with anesthesia against the advantages of reducing stress and pain during animal procedures (Animal Care and Use Committee 1998). Immobilization of animals allows easier handling when performing procedures that cause pain or stress. Frase and Van Vuren (1989) noted that while using manual restraint, animals could harm themselves or the handler while trying to escape when samples were collected. Douglass et al. (2000) also noted that proper use of anesthesia reduces the chance of bite wounds for handlers. This is very important when dealing with animals that may harbor zoonotic diseases.

Anesthesia reduces discomfort from punctures or cuts and allows blood and tissue samples to be collected more easily (McColl and Boonstra 1999, Douglass et al. 2000, Hahn et al. 2005). Disease surveillance requires blood to be collected for serology and has been useful for many rodent species. Douglass et al. (2000) noted that blood could be collected from *Peromyscus* sp. to survey for hantavirus. Blood samples have also been collected from squirrels for La Crosse encephalitis virus surveillance (Scheffel 2006). This type of data allows researchers to assess disease risk, examine transmission routes, and develop a plan to prevent the spread of certain diseases.

The ideal immobilization drug should have short induction and recovery times, a wide safety margin, have no adverse effects, and be safe for the user and the animal (Miller et al. 2003). Many injectable drugs have short induction times; however, the recovery times can be from 2 to 6 hours (Arenz 1997, Belant 2004). Inhalation drugs allow quick induction and recovery times. Inhalation drugs with low blood gas partition coefficient like isoflurane and sevoflurane are less soluble in the blood, causing the tension of anesthetic in the arterial blood to rise quickly (Muir et al. 2000). This allows precise control over the depth of anesthesia and physiological depression (Seeler et al. 1988). Researchers need anesthesia delivery systems that allow collection of samples while reducing stress and risk of injury to the animal. Some rodents such as the Allegheny woodrat (*Neotoma magister)* are endangered, threatened, or in need of management throughout their range (Castleberry et al. 2002) and require techniques that are safe and have little margin for error.

Isoflurane is an inhalation anesthetic that is commonly used in veterinary practices (Edling 2003). In the laboratory, isoflurane is administered with oxygen to prevent hypoxemia. Carrying cylinders of oxygen in the field presents significant practical problems (Lewis 2004). Heidt (1973) developed a portable anesthesia chamber from plastic that allowed animals to be immobilized using ether. This setup required the animal to be transferred from the trap to the anesthesia chamber and was only large enough for mice and rats (Heidt 1973). Anstee and Needham (1997) developed a small anesthesia chamber that would fit over a mouse’s head and allow air to be pushed into the chamber across cotton balls containing isoflurane using a syringe. This method was very useful to allow the correct fitting of radio collars (Anstee and Needham 1997). The method required isoflurane to be applied to the cottonballs through a small hole in the base of the nose cone using a 1-ml syringe (Anstee and Needham 1997), while a 5-ml syringe was used to push air across the cottonballs. Refinements to the technique are needed before being used in the field.

The main purpose of this research was to evaluate isoflurane and refine anesthesia administration to immobilize small mammals in the field. We administered isoflurane using a chamber or nose cone depending on the tractability of the species.

STUDY AREAS

Gray squirrel (*Sciurus carolinensis*) trapping occurred in Karns, Knox County, Tennessee (N35°59 W-84°08) and Maryville, Blount County, Tennessee (N35°44 W-83°57; Figures 1 and 2, all figures and tables are located in the Appendix). Trapping sites were located in mixed hardwood stands.

Allegheny woodrats were trapped at the Royal Blue Wildlife Management Area (RBWMA) and the Big South Fork National River and Recreation Area (BSFNRRA) in Tennessee. The RBWMA is located in the Cumberland Mountain region (N36°20 W-84°17) comprising 20,235 ha in Scott and Campbell Counties, Tennessee (Figure 3). The BSFNRRA is located on the Cumberland Plateau (N36°29 W-84°41) along the Tennessee and Kentucky state border (Figure 4). Both areas are comprised of mixed hardwood forests and temperate climates (Smalley 1984, National Park Service 2005).

METHODS

Isoflurane Chamber Method for Immobilizing Eastern Gray Squirrels

Eastern gray squirrels were trapped with Tomahawk live traps (TL201, [40.6 x 12.7 x 12.7 cm, 16 x 5 x 5 in] and TL202, [48.3 x 15.2 x 15.2 cm, 19 x 6 x 6 in]

Tomahawk Live Trap, Tomahawk, Wisconsin, USA) using animal procedures approved by the University of Tennessee Institutional Animal Care and Use Committee (UT-IACUC 1255). At each location, 50 traps were baited with black oil sunflower seeds and placed in line transects near sites of observed squirrel activity. Trapping sites were located at the base of trees and downed logs in mixed-oak forests and along edge borders. Each site was trapped 3 days per season in the summer (May – June) and winter (November – January). Each trap was checked every 2-4 hours during the day. After retrieving captures, squirrels remained in the traps up to 1 hour before being immobilized. Cloth sheets were placed over the traps to keep the animals calm.

The anesthesia chamber was composed of a clear plastic box (57.9 x 42.4 x 34.5 cm, 60 qt) with a snap-on lid and a petri dish containing 5 cotton balls. Fifteen ml of isoflurane (Abbott Laboratories, North Chicago, Illinois, USA) were added to the petri dish approximately 10 minutes before animals were placed in the box. Once gray squirrels were captured, the entire Tomahawk live trap was placed inside the anesthesia chamber and the lid was placed on the box. The squirrels were observed for breathing, blinking, and loss of righting reflex. Once the squirrels were unable to right themselves, they were removed from the trap using a leather glove.

Blood samples were taken from the ventral tail vein at 1 min post immobilization (Sjoberg and Odberg 2003). Approximately 30-50μl of blood was collected from squirrels using a Nobuto® blood filter strip (Advantec MFS, Pleasanton, California USA). Additional doses of isoflurane were given using a nose cone consisting of a 50-ml centrifuge tube with 3 cotton balls containing 5 ml of isoflurane as needed, such as if the animal showed signs of waking or struggling. Between 5 – 10 minutes after immobilization, a digital thermometer coated with lubricant (K-Y Jelly, McNeil-PPC, Skillman, New Jersey, USA) was used to take the rectal temperature, pulse was measured by auscultation, and respiration was measured by observing the diaphragm and body movement for 15 seconds. The animals were marked with 2 uniquely numbered aluminum ear tags (1005-1, National Band and Tag Co., Newport, Kentucky, USA).

Induction was defined as the time beginning when the cage was placed into the chamber until the squirrel could be removed. Time for additional dose was the time between required additional isoflurane doses using the nose cone. Down time was the time from induction until the animal was alert and standing. Recovery was the time from the end of the last anesthesia dose until the animal was alert and standing. Time was measured in seconds using a stopwatch. All time results were reported in minutes.

Isoflurane Nose Cone Method for Immobilizing Allegheny Woodrats

Allegheny woodrat trapping was conducted on 19 different sites located in RBWMA and BSFNRRA between November 2003 and August 2005 (Table 1, Figures 5 and 6) using animal procedures approved by the University of Tennessee Institutional Animal Care and Use Committee (UT-IACUC 1200). Trapping sites were located along rock bluffs, boulder structures, and abandoned human structures with current or historic woodrat sign. Woodrat sign included food caches, communal latrines, and middens. Tomahawk live traps (TL201) were used to capture Allegheny woodrats. Tomahawk traps were placed at 10-meter intervals along the base of the rock bluffs and along the perimeter of boulder structures. Traps were placed within abandoned vehicles and buildings and set at 10-meter intervals along the perimeter of the structures. Live traps were baited with sliced apples and black oil sunflower seeds. Cotton or polyester stuffing was used as bedding material in all traps.

Each site was trapped once during winter (November to March) and summer (April to August). Approximately 10 to 20 Tomahawk live traps were set at each site depending on the length of the rock outcrop or number of boulders or human structures. Each trap was pre-baited and wired open at least 2 days prior to trapping. Traps were then set and checked in the morning for 2 to 3 consecutive days. Traps were set each morning and left open all day. Allegheny woodrats are nocturnal and none were caught during the day.

Once Allegheny woodrats were captured, they were placed in cloth pillow cases and weighed to the nearest 5 g using a spring scale. The woodrats were restrained by hand while in the cloth bag by scruffing the fur along the neck with a leather glove. The head of the woodrat was then uncovered and a nose cone consisting of a 50-ml centrifuge tube with 3 cotton balls containing 5 ml of the inhalation anesthetic isoflurane was used for immobilization. Induction time was defined from when the nose cone was placed over the mouth until the woodrat lost reflexes. Additional doses of isoflurane were given using a nose cone consisting of a 50-ml centrifuge tube with 3 cotton balls containing 5 ml of isoflurane as needed, such as if the animal showed signs of waking or struggling. Time for additional dose, down time, and recovery times were measured as for the squirrels. Time was measured in seconds using a stopwatch. All time results were reported in minutes.

Blood samples were taken from the marginal ear vein, ventral tail vein, or saphenous vein at 1 min post immobilization (Sjoberg and Odberg 2003). Approximately

30µl of blood was collected using a 100µl microcapillary tube. Between 5 – 10 minutes after immobilization, rectal temperature, pulse, and respiration were measured. The animals were marked with a uniquely numbered aluminum ear tag.

Statistical Analysis

Data analysis for both delivery methods of isoflurane was performed using SAS 9.1 (SAS Institute, Cary, North Carolina, USA). A completely randomized design (CRD) model was used to analyze the data. Seven dependent variables were measured (induction, time for additional dose, down time, recovery time, body temperature, pulse, and respiration) and used in the analysis. Natural log and square root transformations were used on some variables to achieve normality and equal variance. Back transformed means were reported in the results. Analysis of variance (ANOVA) was performed on the data using SAS (PROC MIXED, SAS Institute, Cary, North Carolina, USA).

RESULTS

Isoflurane Chamber Method for Eastern Gray Squirrels

A total of 48 squirrels were trapped in the winter (December 2004) and 43 in the summer (May 2005). Mean time to induction was 3.2 min and did not differ by season or sex. The amount of time required for squirrels to awake and begin moving after the last dose of isoflurane (recovery) differed by season (Table 2). Squirrels recovered more quickly in the summer (1.47 min) than in the winter (3.66 min) after removal of the nose cone (Table 2). Physiological parameters also differed by season (Table 2). Pulse was higher in the winter, where as body temperature and respiration were lower (Table 2). There were no differences by sex for timing of effects or physiological parameters.

Two squirrel fatalities occurred during the study. Necropsy reports for cause of death were inconclusive. One fatality occurred during the winter while the last squirrel was being processed. The squirrel showed no problems until procedures were finished and the animal was placed back in the cage. The animal showed slower respiration and died shortly afterwards. The second fatality occurred during the summer. The squirrel was very aggressive and was injured while trying to escape from the trap. The animal died during induction while in the immobilization chamber.

Isoflurane Nose Cone Method for Allegheny Woodrats

A total of 13 woodrats were captured in the winter and 24 in the summer from November 2003 to August 2005. All woodrat induction times were less than 0.5 minutes. We administered the nose cone for 0.5 minutes for all woodrats since it was difficult to determine the exact point of induction because the animals were being manually restrained for anesthesia administration. There were no differences by season or sex for timing of effects or physiological parameters in Allegheny woodrats immobilized with the isoflurane nose cone delivery method (Table 3).

DISCUSSION

The chamber and nose cone isoflurane delivery methods were both effective in immobilizing small mammals. Short induction time is important when immobilizing animals. Shorter induction times reduce handling stress and the chance of injury to the animal. The chamber method was very useful for squirrels since the entire trap could be placed inside the chamber. This allowed for less handling before immobilization which was important since squirrels were more aggressive and stressed in the traps than woodrats. We were able to watch squirrels in the immobilization chamber and determine when loss of reflexes occurred.

When performed correctly, nose cone induction has been shown to decrease stress level and reduce induction time in animals (Edling 2003). Woodrats stopped moving and closed their eyes when the nose cone was placed over their mouth. We administered the nose cone for 0.5 minutes for all woodrats since it was difficult to determine the exact timing of induction. The nose cone worked well for the docile woodrats that were easily manipulated by manual restraint and showed minimal stress when captured.

Isoflurane allows reasonably good control over the depth of anesthesia in the animal (Seeler et al. 1988). We were able to give additional doses of isoflurane as needed to keep squirrels and woodrats immobilized during sampling. Additional doses were usually applied prior to and during bleeding if the animal began to show reflex signs or movement.

Recovery time is also an important aspect when immobilizing animals. Quick recovery time decreases the chances of the animal being injured or captured as prey once released. Both squirrels and woodrats recovered within minutes following the final dose of isoflurane and were alert and fully coordinated before release. Squirrels were aroused more quickly after removal of isoflurane administration in the summer (1.47 min) than in the winter (3.66 min).

Squirrels showed a decrease in respiration and temperature and an increase in pulse during the winter. Since isoflurane is primarily eliminated by the lungs, decreased respiration causes the gas to be washed from the lungs more slowly and results in longer recovery times (Muir et al. 2000). The decrease in body temperature may be a side effect of anesthesia. Although not significant, woodrats also exhibited lower temperatures during winter (p = 0.08). Small mammals can rapidly lose heat when anesthetized (Edling 2003). This becomes more important in winter when the ambient temperatures are near freezing. Animals may need to be wrapped in a towel or add a heating pad during sampling procedures to reduce the amount of heat loss. The increase in heart rate of squirrels during the winter may be a response to heat loss. The heart rate increases to circulate blood to the extremities and to keep the core body temperature warm.

Both methods of immobilization were cost efficient. Isoflurane was purchased in 250 ml bottles from the University of Tennessee College of Veterinary Medicine for $27.50. The cost of isoflurane (5 ml) using the nose cone was $0.55 per woodrat. During this study, new cotton balls and new isoflurane was used for each woodrat for consistency. However, the nose cone could be used more than once if multiple woodrats were captured in the same trapping area. Immobilization cost using 20 ml of isoflurane in the chamber method was $2.20 per animal. Costs could be reduced by using the chamber multiple times before adding additional isoflurane and keeping the chamber lid closed unless inserting or removing a trap.

The immobilization methods for delivery of isoflurane used in this study provided efficient immobilization of squirrels and woodrats. Both methods resulted in quick induction and recovery times and were safe for the animals and handlers. The chamber method seems more useful for animals that are aggressive and difficult to remove from traps before being anesthetized. The nose cone is useful for animals that can be easily removed from traps and manually restrained before administration of the isoflurane. Therefore, both methods are recommended for small mammals when taking samples that cause stress or pain to the animal.

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PART III

OCCUPANCY, FOOD HABITS, AND PARASITES OF ALLEGHENY WOODRATS IN THE CUMBERLAND MOUNTAINS

INTRODUCTION

The Allegheny woodrat (*Neotoma magister*) is a medium-sized rodent that utilizes rock outcrops, caves, boulders, fissures, and occasionally abandoned human structures. Historically, Allegheny woodrats ranged throughout the Appalachians from southern New York to northern Alabama and northwestern Georgia (Poole 1940). The southern extent of the range is limited by the Tennessee River (Whitaker and Hamilton 1998). These woodrats have been extirpated from New York and Connecticut, and have experienced population declines in the northern and western parts of their range (Balcom and Yahner 1996, Whitaker and Hamilton 1998).

Allegheny woodrats are deemed endangered, threatened, or of concern in every state of their range (Castleberry et al. 2002). Declines have been attributed to several factors including parasitism, predation, and reduced food availability. The raccoon roundworm (*Baylisascaris procyonis*) resulted in declines in the northern part of the Allegheny woodrat range (LoGiudice 2003). Eggs of raccoon roundworm are contained in raccoon feces and are 100% fatal if ingested by woodrats (LoGiudice 2000). Woodrats often collect feces while foraging and store the feces in communal food caches. This behavior exposes the entire community of woodrats to possible infections from fecal parasites.

Decline of Allegheny woodrats in Pennsylvania has been attributed primarily to predation by great horned owls (*Bubo virginianus*) and exposure to raccoon roundworms (Balcom and Yahner 1996). Reduced hard mast production due to the elimination of American chestnut (*Castanea dentata*) from chestnut blight (*Cryphonectria parasitica*) and infestations in oak (*Quercus* spp.) by gypsy moth (*Lymantria dispar*), have also been hypothesized as reasons for woodrat declines (Hall 1985, Castleberry 2000*b*). Habitat fragmentation has also been detrimental in certain areas of the woodrat's range (Balcom and Yahner 1996).

The purpose of this research was to gain more information on the Allegheny woodrat in the southern end of the range in the Cumberland Mountains of Tennessee. The main goals of the project were to:

1. Determine percent occupancy of Allegheny woodrats at likely candidate sites in eastern Tennessee.
2. Determine the food habits of Allegheny woodrats in eastern Tennessee.
3. Determine the external parasitic species infecting Allegheny woodrats in eastern Tennessee.

STUDY AREAS

The Royal Blue Wildlife Management Area (RBWMA) is located in the Cumberland Mountain region and is comprised of 20,235 ha in Scott and Campbell Counties, Tennessee (Figure 3, all figures and tables are located in the Appendix). The Tennessee Wildlife Resources Agency (TWRA) owns the surface rights to RBWMA and manages the area for wildlife, forestry, and recreational resources. Hunting, fishing, and all terrain vehicle (ATV) use occur year round on RBWMA. The Tennessee Valley Authority (TVA) owns the mineral rights and there are several surface and deep mines present in the RBWMA area (Tennessee Valley Authority 1981).

The elevation in RBWMA ranges from 400 to 1070 m. Slopes were generally between 20% and 60%, but occasionally were as great as 100% (Smalley 1984). Soils are derived from bedrock, shale, and sandstone and are loamy, friable, and acidic (Smalley 1984).

Tennessee Wildlife Resources Agency (2000) described the area as dominated by 87% mixed mesophytic forest, with 2% openings, and only 1% cropland. Soil and site characteristics are related to the type of trees and tree reproduction (Smalley 1984). Yellow-poplar (*Liriodendron tulipifera*) is common in drainages, while northern red oak (*Quercus rubra*), white oak (*Quercus alba*), and chestnut oak (*Quercus montana*) are found on upper and lower northern slopes and some upper southern slopes. Sugar maple (*Acer saccharinum*)-basswood (*Tilia americana*)-buckeye (*Aesculus flava*) communities are also present along middle elevations. Shortleaf pine (*Pinus echinata*) and Virginia pine (*Pinus virginiana*) are occasionally located along spur ridges (Smalley 1984).

The climate of RBWMA is humid with mild winters and warm to hot summers. The annual temperature in 2003 was 13.1°C with a high of 32.8°C in August and a low of -17.2°C in January (National Oceanic and Atmospheric Administration 2003). In 2004, the annual temperature was 13.6°C with a high of 31.7°C in August and a low of -14.4°C in December (National Oceanic and Atmospheric Administration 2004). The mean temperatures during the summer trapping seasons were 22.4°C and 22.2°C in 2004 and 2005, respectively (National Oceanic and Atmospheric Administration 2004, 2005). During the winter trapping seasons, the mean temperatures were 6.5°C and 3.8°C in 2003 and 2004, respectively (National Oceanic and Atmospheric Administration 2003, 2004).

Annual precipitation was 171.2 cm (40.4 cm above mean) in 2003. In 2004, the annual precipitation was 147.4 cm and 16.7 cm above the mean.

The Big South Fork National River and Recreation Area (BSFNRRA) is located on the Cumberland Plateau along the Tennessee and Kentucky state borders (Figure 4). Woodrat research was conducted in the Tennessee portion of BSFNRRA within Fentress, Scott, Morgan, and Pickett Counties. The 41,680 ha park is owned and managed by the U.S. Department of the Interior, National Park Service (NPS). The BSFNRRA permits hunting, fishing, and trapping within the area. The main purpose of the park is to preserve and interpret the cultural, historical, geological, archeological, fish and wildlife, scenic, and recreation values of the area (National Park Service 2005).

Elevations in BSFNRRA range from 210 to 550 m. The slope is generally between 5% and 50%, but can be much greater along the cliffs and river gorges (National Park Service 2005). Soils in the BSFNRRA are derived from sandstone and shales from weathered bedrock and are generally thin, acidic and stony (National Park Service 2005).

The BSFNRRA’s general forest type is mixed-oak with pockets of mixed-mesophytic stands (National Park Service 2005). Red maple (*Acer rubrum*) is found on upland sites in damp flats while Virginia pine is located on dry upland ridges. Mixed oaks and hickory are found at middle to lower elevations. The ravines are dominated by beech (*Fagus grandifolia*), sugar maple, and yellow birch (*Betula alleghaniensis*) communities. Streams are bordered by hemlock (*Tsuga canadensis*) with river birch (*Betula nigra*) and sycamore (*Platanus occidentalis*) communities extending into the floodplains (National Park Service 2005).

The BSFNRRA also has a temperate climate that is humid with mild winters and moist summers. The BSFNRRA's location on the Cumberland Plateau causes it to have a lower mean seasonal temperature and higher annual precipitation than surrounding areas (National Park Service 2005). The mean temperature in 2003 was 12.3°C with a high of 32.8°C in August and a low of -17.8°C in January (National Oceanic and Atmospheric Administration 2003). In 2004, the mean temperature was 12.9°C with a high of 31.1°C in September and a low of -17.2°C in December (National Oceanic and Atmospheric Administration 2004). The mean temperature was 6.1°C during the winter and 21.4°C in the summer trapping season. The annual precipitation was 161.1 cm in 2003 and 154.0 cm in 2004.

METHODS

Trapping Procedures

Allegheny woodrat trapping was conducted on 19 different sites located in RBWMA and BSFNRRA between November 2003 and August 2005 (Figure 5 and 6). We examined sites that had historical documentation or personal observations of woodrat sign from researchers and managers working in the area. All trapping and animal procedures were approved by the University of Tennessee Institutional Animal Care and Use Committee (UT-IACUC 1200). Trapping sites were located along rock bluffs, boulder structures, and abandoned human structures with current or historic woodrat sign. Woodrat sign included food caches, communal latrines, and middens. Tomahawk live traps (TL201, [40.6x12.7x12.7 cm, 16x5x5 in] Tomahawk Live Trap, Tomahawk, Wisconsin, USA) were used to capture Allegheny woodrats. Tomahawk traps were placed at 10-meter intervals along the base of the rock bluffs and along the perimeter of boulder structures. Traps were placed within abandoned vehicles and buildings and set at 10-meter intervals along the perimeter of the structures. Live traps were baited with sliced apples and black oil sunflower seeds. Cotton or polyester stuffing was used as bedding material in all traps. Cloth catchsheets were placed under each trap for fecal collection. A handheld Garmin global positioning system (GPS) receiver (Garmin International, Olathe, Kansas, USA) was used to mark the latitude and longitude (WGS 1984 map datum) for the center of each trapping location (Table 1).

Each site was trapped once during winter (November to March) and summer (April to August). Approximately 10 to 20 Tomahawk live traps were set at each site depending on the length of the rock outcrop or number of boulders or human structures. Each trap was pre-baited and wired open at least 2 days prior to trapping. Traps were then set and checked in the morning for 2 to 3 consecutive days. The number of traps, new captures, recaptures, empty and tripped traps, and site location were recorded for each trap night.

Animal Procedures

Once Allegheny woodrats were captured, they were placed in cloth pillowcases and weighed to the nearest 5 g. The woodrats were restrained by hand while in the cloth bag by scruffing the fur along the neck with a leather glove. The head of the woodrat was then uncovered and a nose cone consisting of a 50-ml centrifuge tube with 3 cotton balls containing 5 ml of the inhalation anesthetic isoflurane (Abbott Laboratories, North Chicago, Illinois, USA) was used for immobilization. Once anesthetized, woodrats were marked with a uniquely numbered aluminum ear tag (1005-1, National Band and Tag Co., Newport, Kentucky, USA).

Between 5 – 10 minutes after immobilization, a digital thermometer coated with lubricant (K-Y Jelly, McNeil-PPC, Skillman, New Jersey, USA) was used to take the rectal temperature, pulse was measured by auscultation, and respiration was measured by observing the diaphragm and body movement for 15 seconds. Reproductive condition was examined externally by looking for juvenile condition, lactating females, or palpation of testes on males while the animal was in hand (Mengak 2002). Captured animals were aged based on a combination of reproductive condition, weight (juveniles ≤ 175 g and adults > 175g), and pelage color (Mengak 2002).

Vegetation Sampling

Vegetation sampling was conducted during the summer months at all trapping sites for use with occupancy calculations. Vegetation plots (2 – 3) were set up within 200 m of the rock bluff, boulders, or human structures at each trapping location. A handheld Garmin GPS unit was used to mark the latitude and longitude (WGS 1984 map datum) of plot center for each vegetation plot (Table 4).

Sampling of vegetation was performed at each plot as described by James and Shugart (1970) and modified by Manjerovic (2004). Plot center was established and 11.3 m belt transects were measured in the 4 cardinal directions to create a 0.04 ha circular plot. All trees greater than 8 cm diameter at breast height (DBH) within the circular plot were identified to species, counted, and placed into size classes (8 to 15 cm, 15 to 30 cm, 30 to 45 cm, and greater than 45 cm DBH). For occupancy calculations, hard mast trees greater than 15 cm were classified as mast producing trees.

Groundcover measurements were also conducted along the belt transects. Five stations were marked along each transect for a total of 20 observation sites. At each station, an ocular tube was used to determine what type of ground cover was present at each observation site. The ocular tube was held perpendicular to the ground at waist height and the user looked straight down to determine the type of ground cover present in the crosshairs of the tube. Ground cover was tallied into cover types including forbs, grass, fern, leaf litter, shrub cover, greenbrier, woody debris, rock, bare ground, water, and moss (Manjerovic 2004). Each tally for canopy cover and ground cover represented 5 percent of the total ground or canopy cover for the plot. Each group was totaled to determine the percent ground cover of each cover type.

Occupancy models were constrained as a function of percent forbs and hard mast. Other ground cover types were used to determine basic vegetation cover of woodrat trapping sites.

Occupancy Estimation

Analyses for percent occupancy (ψ) and detection probability (p) were performed using Program MARK (White and Burnham 1999). Presence-apparent absence trapping data for each location was used in the analysis. Occupancy is the proportion of an area inhabited by a target species (MacKenzie et al. 2005). The main problem with presence-absence data is when a target species is present but goes undetected during sampling (MacKenzie et al. 2003, Gu and Swihart 2004, Wintle et al. 2005). Ignoring this variation in detectability leads to biased estimates of presence, site occupancy, colonization, and extinction probabilities (MacKenzie et al. 2003, Vojta 2005). Therefore, we first determined which variables best explained detection probability (Schmidt and Pellet 2005). The information theoretic method of Akaike's Information Criteria (AIC_c) and ΔAIC_c (change in AIC_c between 2 sequential models) were examined to determine which model best explained the variation in the data while using the least number of parameters (Anderson and Burnham 1999). Akaike's Information Criteria is a way to achieve balance between model fit and precision. The AIC value is calculated as negative 2 times the natural log of the model likelihood plus 2 times the number of parameters. Models with lowest AIC_c with $\Delta AIC_c < 2$ were given approximately equal weight for inference selection (Cooch and White 2006). We determined if food availability including percent forbs (FORB) and number of mast producing trees (MAST), trap effort measured by the number of traps (N_TRAP), or location of trapping (AREA) explained detection probability while occupancy was kept constant.

After selecting the model that best explained detection probability, we examined hypotheses concerning occupancy. We evaluated FORB to determine if woodrats preferred areas with green forage over habitats without green forage, MAST to evaluate preference of hard mast crops during the winter and habitat selection of hard mast producing trees (Castleberry et al. 2002), and geographic location (AREA). We tested the combination of FORB and MAST to see if woodrats occupied areas with both green vegetation and hard mast over areas with only one or none of these food items.

The goodness-of-fit of the occupancy models was evaluated using parametric bootstrap simulations in Program MARK (White and Burnham 1999, MacKenzie and

Bailey 2004). The observed deviance of the most general model without covariates divided by the deviance generated from the bootstrap simulations (simulated deviance) was used to produce a variance inflation factor or ĉ (Moore and Swihart 2005). Occupancy and detection probabilities were calculated for the best-fit model using site occupancy models developed by MacKenzie et al. (2002).

Fecal Sampling and Food Habit Analysis

Cloth sheets were placed under all traps to catch any fresh scat and prevent contamination from surrounding vegetation (Castlebery et al. 2002). Feces touching plant material were discarded and not used in the food habit analysis. Fresh Allegheny woodrat feces were collected each season from newly captured animals when available. Collected feces were stored in plastic containers and frozen.

All fecal samples for the summer and winter seasons were sent to the Washington State Wildlife Habitat and Nutrition Laboratory (Pullman, Washington, USA) to determine diet composition through microhistological analysis described by Davitt and Nelson (1980). Plants were identified to genus and species when possible. In some cases, plants were pooled by genera due to similarities in cellular structure. Each fecal sample was examined using 1 slide of 50 views. Fifty views were used to decrease the chance of missing forage plants that were less prominent in the diet (Davitt and Nelson 1980). Results were reported as percent diet composition. Reference slides were used to make comparisons and aid in identification. Washington State Wildlife Habitat and Nutrition Laboratory prepared reference slides for this geographic area from previous studies by Castleberry et al. (2002) and Lupardus (2005).

Parasite Collection and Identification

External parasites were collected from Allegheny woodrats during immobilization. All parasites observed on woodrats were collected using forceps. The fur was combed back and all visible parasites were collected and stored in labeled vials containing 70% ethanol (Castleberry et al. 2003, Durden et al. 2004).

Flea specimens were mounted onto slides using saline mounting solution and identified using a high-power microscope. Keys for the fleas of the eastern United States were used to identify specimens (Fox 1940, Benton 1983). Larger external parasites were placed in petri dishes and identified using a dissecting microscope.

Statistical Analysis

Data analysis for Allegheny woodrat food habits was performed using SAS 9.1 (SAS Institute, Cary, North Carolina, USA). A completely randomized design (CRD) model was used to analyze the data. Eight different plant groups were identified (fern, forb, shrub, berry, fungus, hard mast, soft mast, and insect) and used in the analysis. Square root transformations were used on some variables to achieve normality and equal variance and back transformed means were reported. After attempting transformation, ranked data was used for other variables since the data was not normally distributed and had unequal variance (PROC RANK, SAS Institute, Cary, North Carolina, USA). The ranked data was analyzed using the CRD model with season, sex, and season cross-classified with sex as fixed effects. Body weight was also used as a covariate. Analysis of variance (ANOVA) was performed on the data using SAS (PROC MIXED, SAS Institute, Cary, North Carolina, USA).

RESULTS

Occupancy

Trapping occurred on 5 sites in BSFNRRA and 10 sites in RBWMA. During winter of 2003-2004, 4 sites were trapped in BSFNRRA and 2 sites were trapped in RBWMA. During the summer of 2004, 5 sites were trapped in BSFNRRA and 2 sites in RBWMA. During 2005, no trapping was conducted in BSFNRRA. In RBWMA, 5 sites were trapped during the winter of 2004-2005 and 10 sites were trapped in the summer 2005. We detected Allegheny woodrats at 11 out of 15 sites (naïve site occupancy = 0.73). We estimated $\hat{c} = 0.94$ for the most general model without covariates, indicating adequate fit of the model and no evidence of overdispersion. Since $\hat{c}$ was less than 1, we did not adjust $\hat{c}$ for model selection (Cooch and White 2006). The model that best fit the data included AREA for detection probability (Table 5). However, detection constant and MAST provided reasonable explanation for detection when comparing the ΔAIC_c (Table 5). When the difference in AIC_c between two models (ΔAIC_c) is less than 2, then both models have approximately equal weight for model inference (Cooch and White 2006). Percent FORB was not a useful predictor of p. Model averaging of detection probability estimated $p = 0.49$ ($SE = 0.13$) and 0.74 ($SE = 0.07$) for BSFNRRA and RBWMA, respectively.

Using AREA in the detection probability, the model containing a constant occupancy rate and constraining occupancy as a function of FORB exhibited higher selection than the models containing MAST, AREA, and FORB + MAST (Table 5).

Model-averaging estimated occupancy of Allegheny woodrats was 0.79 (SE = 0.13) and 0.79 (SE = 0.12) for BSFNRRA and RBWMA, respectively.

Food Habit Analysis

Woodrat fecal samples were examined for the summer (*n* = 14) and winter (*n* = 13) seasons. The percentage of hard mast in the diet was greater in the winter (5.7%) than the summer (0.3%; Table 6). No differences were seen by season for other plant groups (Table 6). The percentage of soft mast was neared significance ($P = 0.052$), with greater amounts consumed in the diet during the summer (9.7%) than the winter (0%). There were no differences between sexes for any plant group consumed by woodrats. There was also no significant interaction between season and sex for any plant groups ($P > 0.35$). The covariate, body weight, was also not important in the amount of each plant group in the diet ($P > 0.07$).

The summer diet of Allegheny woodrats was primarily composed of forbs (41.1 %). Shrubs (15.2 %), fungus (12.7 %), and soft mast (9.7 %; Table 6). Insects made up 5.3 % of the diet. Hard mast (0.26 %) was the least consumed plant group.

The winter diet shifted slightly and fungus (26.1%) was the main food in the diet (Table 6). Forbs (22.1%) and shrubs (19.4%) again made the top three foods in the diet (Table 6). Insects also made up 5.3% of the diet as in the summer. Hard mast was consumed more heavily and comprised 5.7% of the diet in the winter.

Vegetation data was collected at 29 locations to relate habitat variables to Allegheny woodrat diet in addition to the occupancy estimation. There were 2.03 (SE = 0.59) hard mast trees less than 12 inches and 1.39 (SE = 0.26) greater than 12 inches located at each site. The main ground cover was leaf litter (42.50 %, SE = 3.00), shrub cover (9.82 %, SE = 2.16) and forbs (9.64 %, SE = 1.78). Rock (9.64 %, SE = 1.65), woody debris (9.46 %, SE = 1.29), and ferns (8.03 %, SE = 2.08) were also prominent ground cover types.

Parasites

Between November 2003 and August 2005, 63 fleas and 5 ticks were collected from 26 out of 40 Allegheny woodrats. Except for 2 female woodrat fleas (*Epitedia cavernicola)*, all were the common woodrat specific flea *Orchopeas pennsylvanicus* (Table 7). The mean number of fleas on each woodrat was 2.4 fleas. All 5 ticks were collected from a single woodrat in winter and identified as female woodrat ticks (*Ixodes woodi*, 2 adult, 3 nymph; Table 7).

DISCUSSION

Occupancy

We used site occupancy models to determine what factors affect Allegheny woodrat occurrence in the Cumberland Mountains, Tennessee. Model selection results from Program MARK showed that the detection probability was best explained by AREA (Table 5). Our detection probabilities for BSFNRRA (0.49) and RBWMA (0.74) were adequate to allow unbiased estimates of occupancy rates. Using detection probabilities explained by AREA, model selection results suggested that occupancy was constant (Table 5). The model constraining occupancy as a function of FORB also seemed useful for model selection. However, since the beta estimates for FORB bound 0, they were not considered statistically or biologically significant (Cooch and White 2006), suggesting that the amount of green vegetation around the area did not appear to affect whether the site was occupied or not (Table 5).

The proportion of the trapping locations occupied by woodrats was 0.79 in both the BSFNRRA and RBWMA. These data may provide a useful baseline to monitor potential changes in occupancy of woodrats in the Cumberland Mountains of Tennessee over time. We examined sites that had historical documentation or personal observations of woodrat sign from researchers and managers working in the area. All rock outcrops were not examined. Therefore our data was likely biased to successful trapping efforts. Further data collection should include additional rock outcrops and additional habitat variables to clarify conditions that may affect occupancy in Allegheny woodrats.

Food Habits

The Allegheny woodrat is a generalist herbivore that can adapt feeding habits to local conditions. Allegheny woodrats cache food for use during the dormant season when food may be scarce or hard to locate. The use of cached food can minimize seasonal food trends compared to mammals that do not cache food resources (Caslteberry et al. 2002). Woodrats consume more perishable items when foraging and cache less perishable items for long-term use (Post and Reichman 1991).

Small mammals often use herbaceous vegetation during the summer and spring months. Castleberry (2000*a*) found woodrats appear to use green vegetation as a buffer food during the fall and winter when the mast crop is low. Forbs were present in large amounts in the summer (41.1%) and winter (26.1%) diets in the Cumberland Mountains, Tennessee. Shrubs were also highly used (19.4%) in the winter. Forbs (9.64 %) and shrubs (9.82 %) also made up substantial portions of the ground cover seen around trapping sites. We suspect that these food items were used to conserve the amount of hard mast stored for the dormant season.

Hard mast is important for many wildlife species during winter in the southeastern United States. Hard mast is used by white-tailed deer, elk, eastern chipmunks, white-footed mice, eastern gray squirrels, and Allegheny woodrats (Van Dersal 1940, Lupardus 2005). Acorns, hickory nuts, and walnuts are high in nutrient content and provide carbohydrates and fat required by animals during the winter (Goodrum 1959, Short and Epps 1976). Hard mast trees were located at each trapping site, with some large enough (> 12 inches) to produce viable mast. Hard mast composed only 5.7% of the winter diet for woodrats in the Cumberland Mountains. However, this was probably an important part of their diet due to the nutritional value.

Fungus was present in the diet in high amounts in both summer (12.7%) and winter (26.1%) in the Cumberland Mountains. Fungi can be high in protein and carbohydrates, making it a high quality food item in times of low mast crops (Short and Epps 1976). Fungi has been found to be a primary food item for southern red-backed voles and northern flying squirrels in the Appalachians (Mitchell 2001, Orrock and Pagels 2002). Castleberry et al. (2002) also found significant amounts of fungi in the diets of Allegheny woodrats in central Appalachians. Herrera and McDonald (1997) found that woodrats often choose items highly infected with fungi over items with intermediate infection. More research is needed to understand whether fungus is being inadvertently eaten while consuming other food items or if it is an important food source for woodrats in the Cumberland Mountains.

Parasites

Ectoparasites of woodrats have been documented in the southeast United States. *Orchopeas pennsylvanicus* and *E. cavernicola* are host specific ectoparasites of *Neotoma* species in the southeast United States (Lewis 1974, Lewis 1975). Both *O. pennsylvanicus* and *E. cavernicola* have also been documented as parasites of eastern woodrats in Tennessee, South Carolina, and Indiana (Pfitzer 1950, Cudmore 1986, Durden and Kollars 1997, Durden et al. 1999) and of Allegheny woodrats in West Virginia (Castleberry et al. 2003). Our results were very similar to those documented by Castleberry et al. (2003) in West Virginia, where most Allegheny woodrats were host to *O. pennsylvanicus* while only one *E. cavernicola* was documented.

Castleberry et al. (2003) suggested that Allegheny woodrats may have a higher degree of flea host specificity compared to eastern woodrats due to their specific habitat requirements. Allegheny woodrats are isolated due to their habitat preference for rock bluffs. This habitat requirement reduces contact with other mammals and may decrease the chance of transmission of parasites. Allegheny woodrats also build nests that are reused every year. Fleas choose nest-building type species since the fleas are easily transmitted within the nest (Benton 1980). This flea adaptation can lead to certain flea-host relationships as seen with the Allegheny woodrat.

Castleberry et al. (2003) documented one tick species (*Ixodes angustus*) when collecting parasites from Allegheny woodrats in West Virginia. Clark et al. (2001)

documented several tick species on eastern woodrats in South Carolina. The hard tick, *Ixodes minor*, was strongly associated with eastern woodrats (Clark et al. 2001). Eastern woodrats have also been shown to be hosts for several immature ticks in the southeast United States (Clark et al. 1998). Allegheny woodrats in Tennessee may be host to other species of ticks including *Ixodes woodi*.

MANAGEMENT IMPLICATIONS

Habitat changes are occurring in the Cumberland Mountains of Tennessee. Landscape changes due to mining may lead to habitat loss or destruction in areas where woodrats are currently located. Allegheny woodrats are habitat specialists that usually require rock bluffs, outcrops, or talus fields for den sites. Castleberry et al. (2001) found that Allegheny woodrats cannot disperse and re-establish new territories easily without relocation to other rock outcrops or suitable habitat. Because of this limitation, disturbance surrounding woodrat dens could cause local population declines or extirpation if the woodrats are unable to find other rock outcrops. Management decisions involving mining should try to reduce the amount of disturbance surrounding rock outcrops containing woodrats.

Reduction of hard mast trees surrounding dens may also have adverse effects on local woodrat populations. Management decisions should focus on maintaining hard mast trees and fungi surrounding rock outcrops. Prescribed burning could be used to promote growth and regeneration of oak species. Prescribed burning may also promote forbs and green vegetation that is used year round by Allegheny woodrats (Van Lear and Waldrop 1990).

The population of Allegheny woodrats could be monitored using occupancy models. Trapping data could be obtained and used to determine if occupancy rates are stable or decreasing due to mining and other resource management practices in the area. We examined sites that had historical documentation or personal observations of woodrat signs from researchers in the field. We did not examine all rock outcrops in the study areas. Further research in this area should focus on additional rock outcrops and indicators of habitat quality to monitor potential changes in woodrat status.

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APPENDIX

Table 1. Plot center locations of Allegheny woodrat trapping sites (WGS84 map datum), November 2003 to August 2005, Royal Blue Wildlife Management Area (RBWMA) and Big South Fork National River and Recreation Area (BSFNRRA), Tennessee, USA.

Trapping Site #	Location	Longitude	Latitude
1	BSFNRRA	-84°43.654	36°21.200
2	BSFNRRA	-84°37.902	36°23.322
3	BSFNRRA	-84°45.942	36°31.869
4	BSFNRRA	-84°45.144	36°31.521
5	BSFNRRA	-84°37.534	36°27.478
6	RBWMA	-84°17.463	36°21.637
7	RBWMA	-84°18.171	36°21.663
8	RBWMA	-84°17.500	36°21.482
9	RBWMA	-84°16.726	36°18.125
10	RBWMA	-84°19.884	36°25.405
11	RBWMA	-84°19.671	36°24.830
12	RBWMA	-84°19.730	36°25.455
13	RBWMA	-84°16.392	36°24.194
14	RBWMA	-84°16.421	36°24.201
15	RBWMA	-84°16.479	36°24.132

Table 1. Continued.

Trapping Site #	Location	Longitude	Latitude
16	RBWMA	-84°13.993	36°18.449
17	BSFNRRA	-84°43.043	36°31.901
18	RBWMA	-84°15.705	36°25.228
19	RBWMA	-84°37.534	36°27.478

Table 2. Mean time to induction, necessity of additional isoflurane doses (administered by nose cone method), recovery time (animal standing and alert after last dose of isoflurane), down time (time from induction until animal was standing and alert), and physiological parameters by season for eastern gray squirrels anesthetized with isoflurane (chamber method) in Karns and Maryville, Tennessee, USA.

	Winter (*n* = 48)		Summer (*n* = 43)		
Parameters	**Mean**	**SE**	**Mean**	**SE**	***P*-value**[a]
Induction (min)	3.24	0.22	3.13	0.22	0.83
Additional Dose (min)	1.25	0.12	1.10	0.09	0.30
Recovery (min)	3.66	0.21	1.41	0.21	< 0.001
Down Time (min)	8.41	0.21	7.99	0.21	0.62
Temperature (°C)	39.2	0.1	39.7	0.1	0.005
Pulse (beats/min)	370.6	14.5	323.7	11.8	0.014
Respiration (beats/min)	115.6	7.1	144.1	5.7	0.002

[a] *P*-values for differences between seasons for physiological parameters.

Table 3. Mean time to induction, necessity of additional isoflurane doses (administered by nose cone method), recovery time (animal standing and alert after last dose of isoflurane), down time (time from induction until animal was standing and alert), and physiological parameters by season for Allegheny woodrats anesthetized with isoflurane (nose cone method) in Royal Blue Wildlife Management Area (RBWMA) and Big South Fork National River and Recreation Area (BSFNRRA), Tennessee, USA.

	Winter ($n = 13$)		**Summer ($n = 24$)**		
Parameters	**Mean**	**SE**	**Mean**	**SE**	***P*-value**[a]
Induction (min)	0.5 [b]	0	0.5 [b]	0	[b]
Additional Dose (min)	2.27	0.20	2.63	0.15	0.15
Recovery (min)	4.06	0.81	4.22	0.62	0.88
Down Time (min)	18.00	2.50	14.09	1.86	0.22
Temperature (°C)	35.7	0.4	36.6	0.3	0.08
Pulse (beats/min)	358.9	32.9	347.9	19.7	0.78
Respiration (beats/min)	81.6	9.0	78.4	6.0	0.77

[a] *P*-values for differences between seasons for physiological parameters.

[b] We administered the nose cone for 0.5 minutes for all woodrats since it was difficult to determine the exact timing of induction. Woodrats stopped moving and closed their eyes when the nose cone was placed over their mouth.

Table 4. Plot center locations of vegetation sampling sites (WGS84 map datum), November 2003 to August 2005, Royal Blue Wildlife Management Area (RBWMA) and Big South Fork National River and Recreation Area (BSFNRRA), Tennessee, USA.

Vegetation Site #	Trapping Site #	Location	Longitude	Latitude
1	1	BSFNRRA	-84°43.670	36°21.253
2	1	BSFNRRA	-84°43.649	36°21.245
3	1	BSFNRRA	-84°43.643	36°21.226
4	1	BSFNRRA	-84°43.646	36°21.159
5	2	BSFNRRA	-84°38.001	36°23.361
6	2	BSFNRRA	-84°37.963	36°23.343
7	2	BSFNRRA	-84°37.916	36°23.317
8	3	BSFNRRA	-84°45.950	36°31.906
9	3	BSFNRRA	-84°45.955	36°31.856
10	4	BSFNRRA	-84°45.153	36°31.510
11	4	BSFNRRA	-84°45.132	36°31.525
12	5	BSFNRRA	-84°37.593	36°27.480
13	5	BSFNRRA	-84°37.558	36°27.472
14	6	RBWMA	-84°17.443	36°21.622
15	6	RBWMA	-84°17.458	36°21.645
16	7	RBWMA	-84°18.166	36°21.703

Table 4. Continued.

Vegetation Site #	Trapping Site #	Location	Longitude	Latitude
17	7	RBWMA	-84°18.164	36°21.657
18	8	RBWMA	-84°17.528	36°21.455
19	8	RBWMA	-84°17.504	36°21.481
20	9	RBWMA	-84°16.730	36°18.123
21	9	RBWMA	-84°16.753	36°18.146
22	13	RBWMA	-84°16.395	36°24.197
23	14	RBWMA	-84°16.418	36°24.196
24	15	RBWMA	-84°16.475	36°24.132
25	10	RBWMA	-84°19.850	36°25.414
26	10	RBWMA	-84°19.835	36°25.420
27	12	RBWMA	-84°19.717	36°25.447
28	11	RBWMA	-84°19.669	36°24.812

Table 5. Model selection results for Program MARK models of Allegheny woodrat detection probability (p) and occupancy (ψ) in Royal Blue Wildlife Management Area (RBWMA) and Big South Fork National River and Recreation Area (BSFNRRA), Tennessee, USA.

Model[a]	AIC_c	ΔAIC_c	AIC_c weights	Deviance	# Par
p(AREA) ψ(.)	84.5	0.0	0.25	76.3	3
p(AREA) ψ(FORB)	85.2	0.7	0.14	73.2	4
p(.) ψ(.)	85.8	1.3	0.13	80.8	2
p(MAST) ψ(.)	85.9	1.4	0.13	76.7	3
p(AREA) ψ(MAST)	86.6	2.1	0.07	74.6	4
p(N_TRAPS) ψ(.)	87.0	2.5	0.07	78.8	3
p(AREA) ψ(AREA)	88.0	3.5	0.04	76.0	4
p(AREA + N_TRAPS) ψ(.)	88.0	3.5	0.04	76.0	4
P(AREA) ψ(FORB + MAST)	88.3	3.8	0.03	71.6	5
p(FORB) ψ(.)	89.0	4.5	0.03	80.8	3
p(t) ψ(t)	171.3	86.8	0.00	57.1	11

[a] AREA = the two geographic locations RBWMA and BSFNRRA

FORB = percent forbs

MAST = number of mast producing trees

N_TRAPS = number of Tomahawk live traps

t = trap occasion

AIC = -2 ln(model likelihood) + 2(number of parameters)

Table 6. Mean percent of plant groups by season in the diet of Allegheny woodrats in Royal Blue Wildlife Management Area (RBWMA) and Big South Fork National River and Recreation Area (BSFNRRA), Tennessee, USA. Diet composition determined by microhistological analysis of plant material found in feces and expressed as percent of total diet ± SE.

	Winter (*n* = 13)		**Summer (*n* = 14)**		
Plant Group	0	**SE**	0	**SE**	***P*-value**[a]
Fern	1.8	0.8	1.0	1.0	0.23
Forb	22.1	6.7	41.1	7.9	0.08
Shrub	19.4	5.9	15.2	6.1	0.63
Berry	0.5	0.5	2.5	1.5	0.15
Fungus	26.1	6.6	12.7	5.4	0.13
Hard Mast	5.7	2.0	0.3	0.5	0.007
Soft Mast	0	5.2	9.7	6.1	0.052
Insect	5.3	3.1	5.3	3.6	0.77

[a] *P*-values for differences between seasons for plant groups consumed.

Table 7. External parasites collected from Allegheny woodrats from November 2003 to August 2005 in Royal Blue Wildlife Management Area (RBWMA) and Big South Fork National River and Recreation Area (BSFNRRA), Tennessee, USA.

Woodrat ID	Capture Date	Flea / Tick Species	# Male	# Female	Total #
426	25 Nov 2003	*Ixodes woodi*	0	5	5
426	25 Nov 2003	*Orchopeas pennsylvanicus*	1	1	2
427	2 Dec 2003	*Orchopeas pennsylvanicus*	1	3	4
427	2 Dec 2003	*Epitedia cavernicola*	0	1	1
430	25 Mar 2004	*Orchopeas pennsylvanicus*	0	7	7
431	14 July 2004	*Orchopeas pennsylvanicus*	1	1	2
432	14 July 2004	*Orchopeas pennsylvanicus*	3	0	3
433	16 July 2004	*Orchopeas pennsylvanicus*	1	0	1
434	29 July 2004	*Orchopeas pennsylvanicus*	0	1	1
428	10 Aug 2004	*Orchopeas pennsylvanicus*	0	1	1
435	7 Dec 2004	*Orchopeas pennsylvanicus*	1	1	2
436	7 Dec 2004	*Orchopeas pennsylvanicus*	0	1	1
437	7 Dec 2004	*Orchopeas pennsylvanicus*	1	2	3
437	8 Dec 2004	*Orchopeas pennsylvanicus*	0	1	1
437	8 Dec 2004	*Epitedia cavernicola*	0	1	1
439	11 Jan 2005	*Orchopeas pennsylvanicus*	0	1	1
429	11 Jan 2005	*Orchopeas pennsylvanicus*	1	1	2
428	11 Jan 2005	*Orchopeas pennsylvanicus*	1	1	2
441	30 May 2005	*Orchopeas pennsylvanicus*	0	5	5
442	30 May 2005	*Orchopeas pennsylvanicus*	0	1	1
443	30 May 2005	*Orchopeas pennsylvanicus*	1	1	2

Table 7. Continued

Woodrat ID	Capture Date	Flea / Tick Species	# Male	# Female	Total #
444	30 May 2005	*Orchopeas pennsylvanicus*	1	1	2
435	6 June 2005	*Orchopeas pennsylvanicus*	1	3	4
446	7 June 2005	*Orchopeas pennsylvanicus*	1	1	2
447	8 June 2005	*Orchopeas pennsylvanicus*	2	1	3
448	18 July 2005	*Orchopeas pennsylvanicus*	0	2	2
450	18 July 2005	*Orchopeas pennsylvanicus*	1	1	2
001	18 July 2005	*Orchopeas pennsylvanicus*	0	3	3
004	1 Aug 2005	*Orchopeas pennsylvanicus*	0	2	2

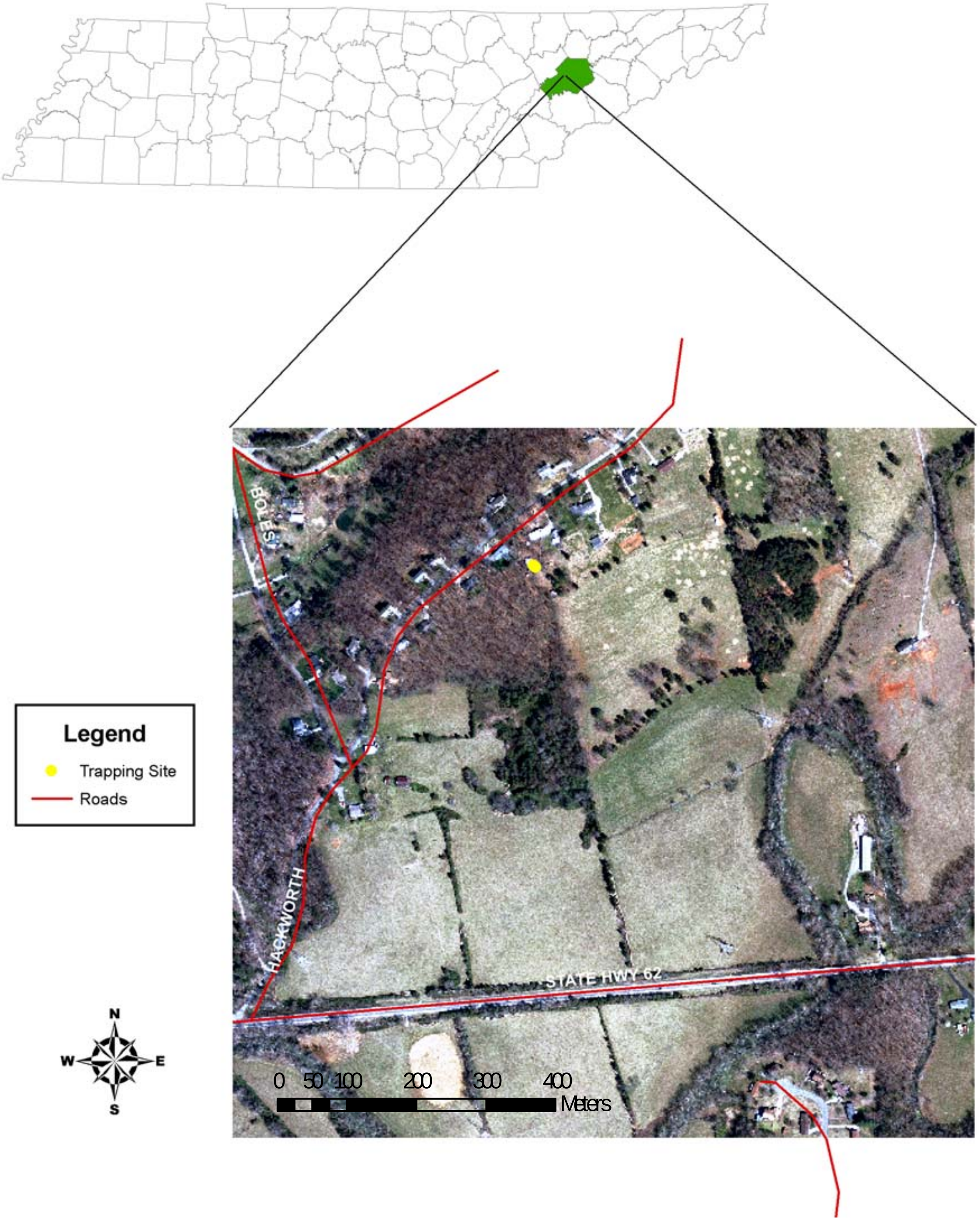

Figure 1. Small mammal trapping site location in Karns, Tennessee, USA from December 2004 to May 2005.

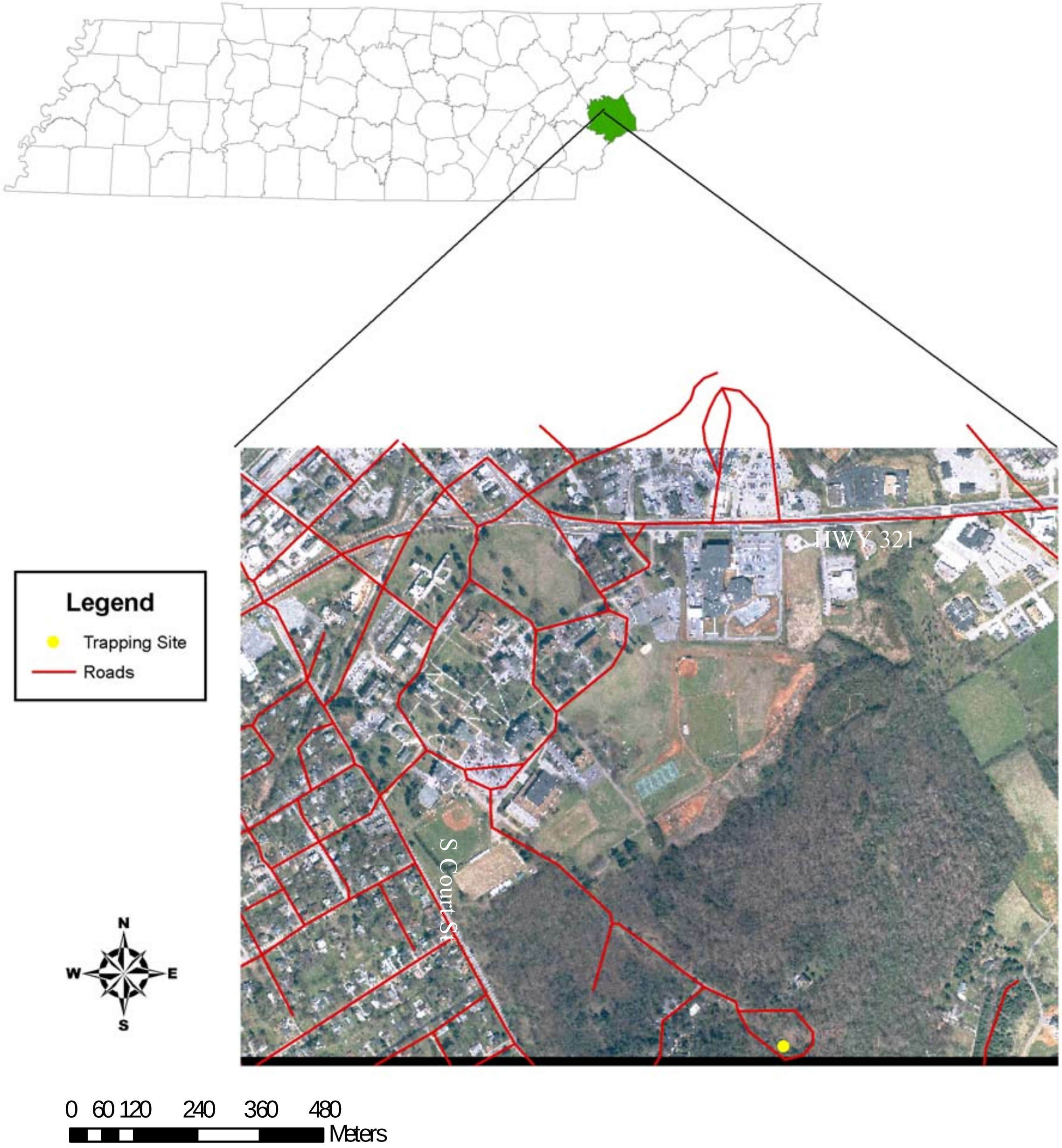

Figure 2. Small mammal trapping site location in Maryville, Tennessee, USA from December 2004 to May 2005.

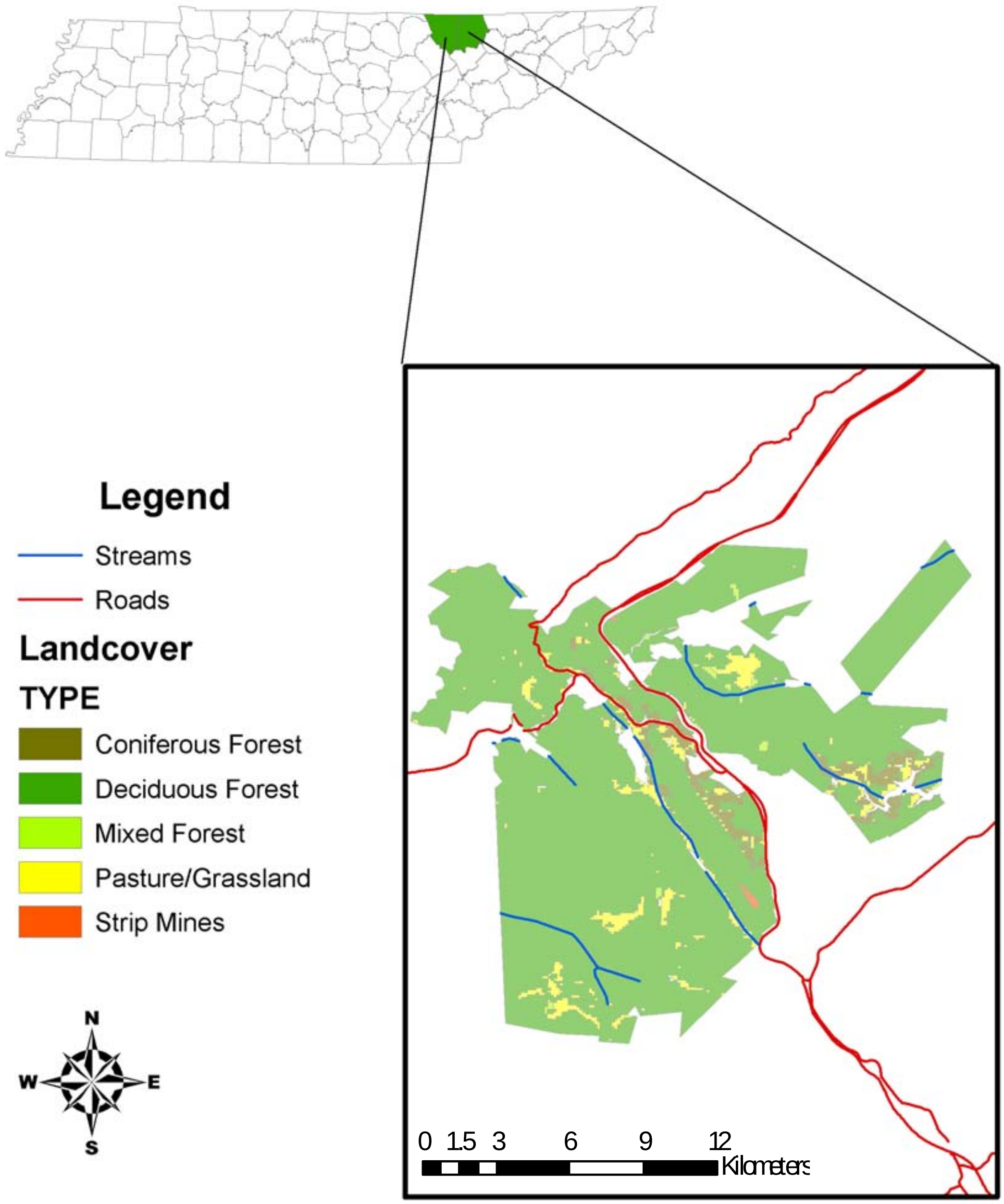

Figure 3. Location of Royal Blue Wildlife Management Area (RBWMA) in the Cumberland Mountains, Tennessee, USA.

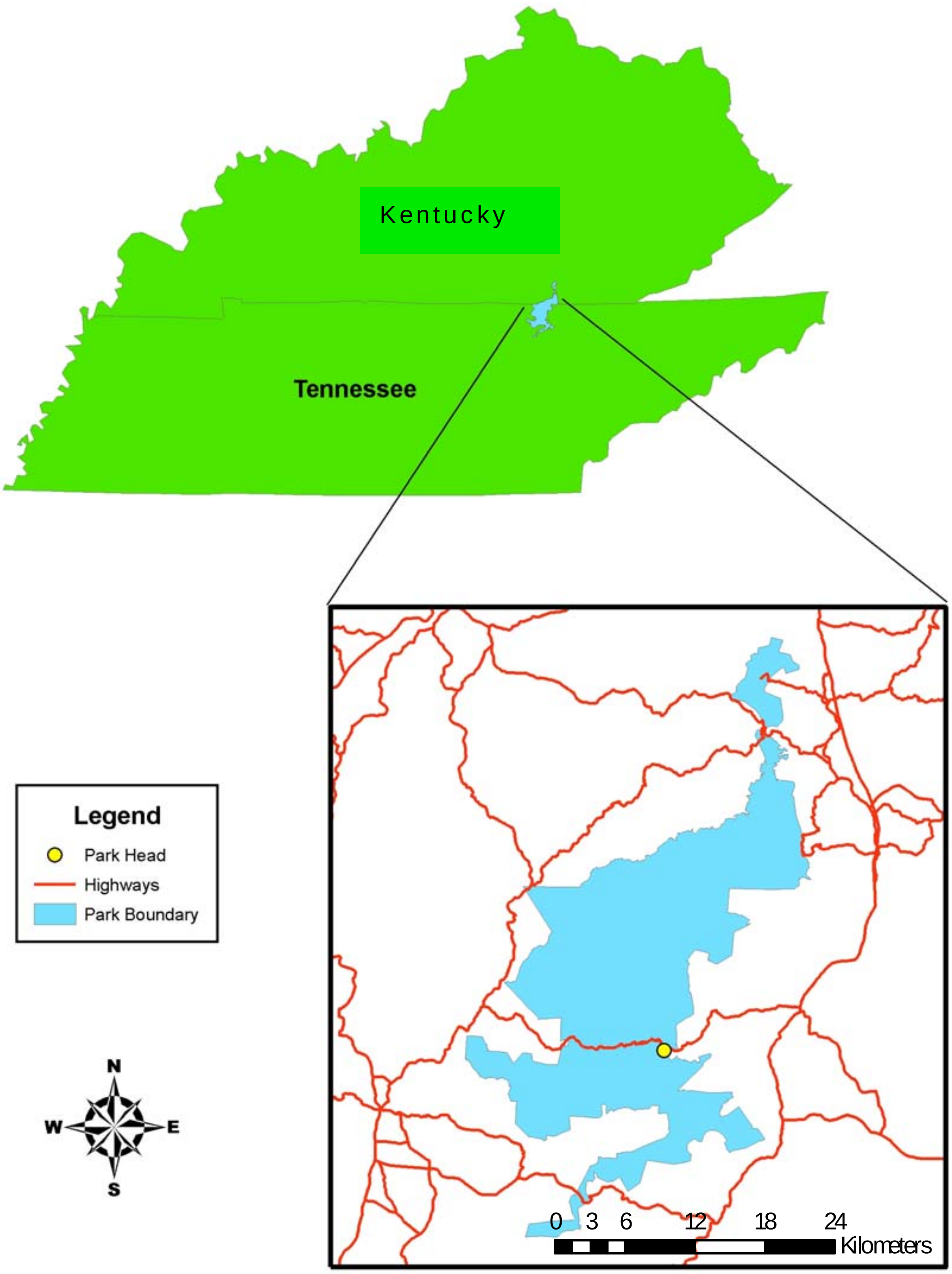

Figure 4. Location of Big South Fork National River and Recreation Area (BSFNRRA) in the Cumberland Mountains, Kentucky and Tennessee, USA.

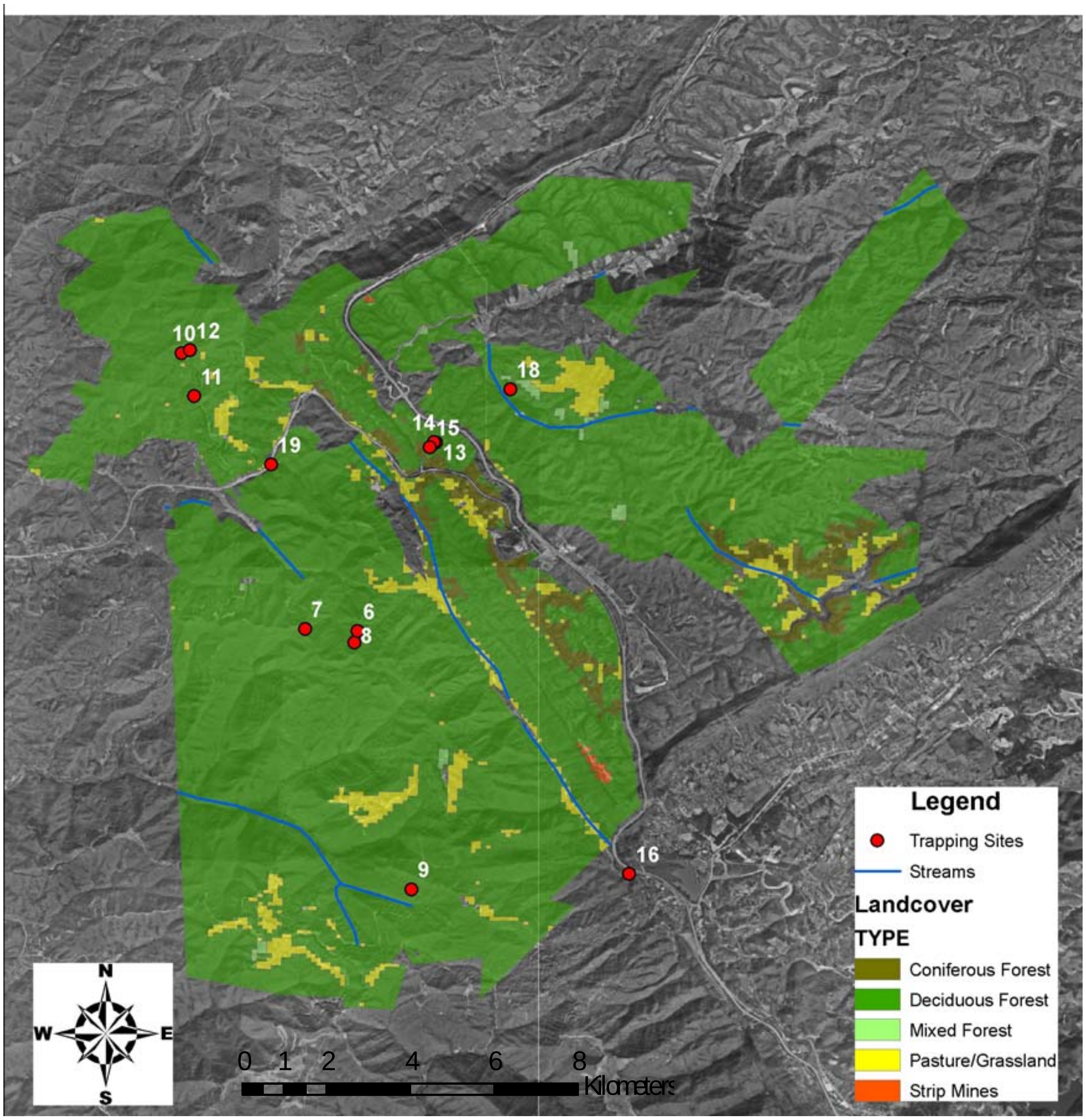

Figure 5. Allegheny woodrat trapping site locations in Royal Blue Wildlife Management Area (RBWMA), Tennessee, USA from November 2003 to August 2005.

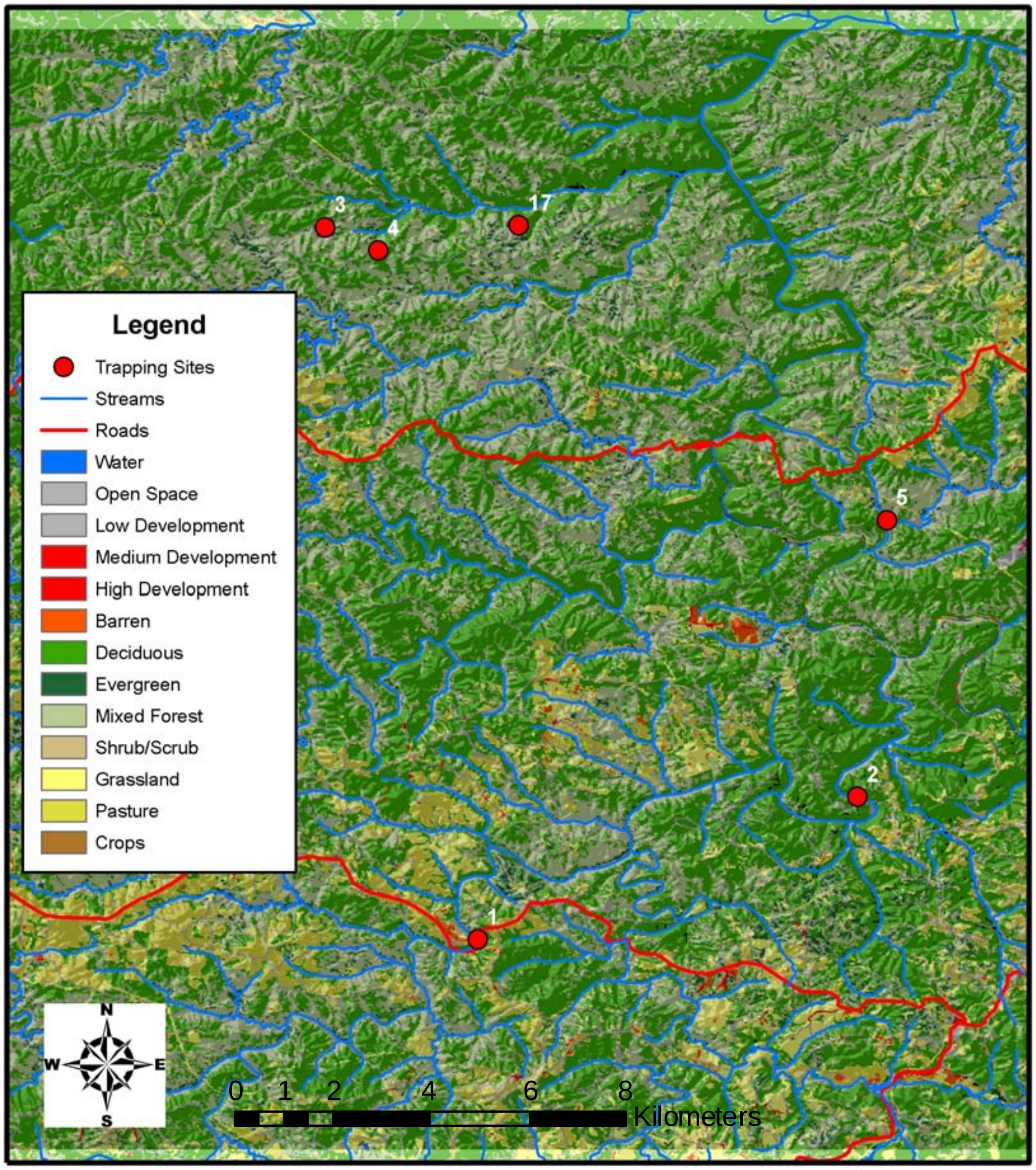

Figure 6. Allegheny woodrat trapping site locations in Big South Fork National River and Recreation Area (BSFNRRA), Tennessee, USA from November 2003 to August 2005.

VITA

William Parker was born in Wurzburg, Germany in November 1980 while his father was serving in the military. Shortly after, his family returned to the United States and they lived in Virginia and Louisiana before finally settling in western North Carolina. William attended elementary and high school in Canton, NC. He then attended the University of Tennessee, Knoxville to study mechanical engineering. After the first year of study, he switched majors and pursued a B.S. degree in wildlife and fisheries sciences with a minor in forestry in 2003. He then decided to work with small mammals and nongame species and received his M.S. in wildlife sciences at the University of Tennessee, Knoxville. He is now married to Dr. Kristen Parker and living in Georgia.