Home Range, Dispersal, and Survival of the Ozark Pocket Gopher (*Geomys bursarius ozarkensis*)

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Project Overview

In 2000, the Ozark pocket gopher (*Geomys bursarius ozarkensis*) was identified as a new subspecies of the plains pocket gopher (*Geomys bursarius*) inhabiting north-central Arkansas. The most current survey estimated the population at about 3,500 individuals with a restricted range in the Ozark Mountains limited to Izard County, Arkansas. The conservation status of the Ozark pocket gopher is of concern due to its isolation from other populations (nearest extant population is *G. bursarius missouriensis* which is ~300 km away near St. Louis, Missouri) and its status as an agricultural pest. These two factors have lead to concern because of the small population size, no source for recolonization, and the intentional killing by humans to reduce agricultural damage. Thus, we collected data on the home range, dispersal, and survival of the Ozark pocket gopher. Additionally, we developed techniques to efficiently trap and subsequently collect movement data along with the small mammal and herpetofaunal community assemblages within gopher habitat. A further understanding of these animals' territory use including home range and dispersal behavior may shed light on aspects of how to extend the population range or size or how to regulate the gophers that are deemed pests to the landowners. Ultimately, this data can be used to make conservation and/or managerial decisions regarding the Ozark pocket gopher.

Project Results

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2. Connior, M.B., and T. S. Risch. 2009. Benefits of subcutaneous implantation of radio transmitters in pocket gophers. Southwestern Naturalist: In Press. (**Thesis, Chapter III**).

3. Connior, M.B., and T. S. Risch. 2009. Live trap for pocket gophers. Southwestern Naturalist 54:102-105. (**Thesis, Chapter II**).

4. Connior, M. B., I. Guenther, T. S. Risch, and S.E. Trauth. 2008. Amphibian, reptile, and small mammal associates of Ozark pocket gopher habitat. Journal of the Arkansas Academy of Science 62:45-51. (**Thesis, Chapter VI**).

5. Connior, M.B, R.E. Medlin, A.A. Kershen, D.E. Elrod, D.B. Sasse, and T.S. Risch. Distribution and habitat affinities of an endemic pocket gopher. Ecoscience: *In Review.*

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HOME RANGE, DISPERSAL, AND SURVIVAL OF THE OZARK POCKET GOPHER (*GEOMYS BURSARIUS OZARKENSIS*)

By

Matthew Brett Connior

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AN ABSTRACT

Of

HOME RANGE, DISPERSAL, AND SURVIVAL OF THE OZARK POCKET GOPHER (*GEOMYS BURSARIUS OZARKENSIS*)

The Ozark pocket gopher (*Geomys bursarius ozarkensis*) has recently been described as a new subspecies of the plains pocket gopher (*G. bursarius*) inhabiting north-central Arkansas with an estimated population of 3,500 individuals. Ozark pocket gophers are considered a "species of greatest conservation need" in Arkansas; therefore, research on spatial use and life-history characteristics are warranted. Being fossorial, pocket gophers are difficult to study using conventional techniques. Thus, I designed new techniques to collect spatial data and population attributes. I developed a new live trap with minimal mechanical parts and modified a technique to collect long-term radio telemetry data. Home range size could be predicted by the females' body masses but not in males. Home ranges were significantly larger for females in the winter/early spring versus late spring/summer probably due to food availability and the concurrence of the reproductive season in spring. Pocket gophers had relatively high survival rates for rodents, but the majority of mortality occurred in the winter months. I documented mortality of pocket gophers from both predation and floods. Finally, subterranean burrows of pocket gophers provide protection for pocket gophers as well as other vertebrates. I recorded numerous amphibian, reptile, and small mammal species inhabiting pocket gopher habitat. Although pocket gophers are considered agricultural

pests, both conservationists and managers need to determine the Ozark pocket gopher's impact on the ecosystem's health and viability before managerial decisions are employed on this endemic subspecies.

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CHAPTER I

GENERAL INTRODUCTION

The Ozark pocket gopher (*Geomys bursarius ozarkensis*) has recently been described as a new subspecies of the plains pocket gopher (*Geomys bursarius*) inhabiting north-central Arkansas (Elrod et al. 1996, 2000). The most current survey estimated the population at about 3,500 individuals with a restricted range in the Ozark Mountains limited to Izard County, Arkansas (Kershen 2004). Pocket gophers of the genus *Geomys* are found throughout the Midwest and Southeast in North America (Elrod et al. 2000). Geomyids are solitary and subterranean in nature, which fosters genetic differentiation within populations due to restricted dispersal. The conservation status of the Ozark pocket gopher is of concern due to its isolation from other populations (nearest extant population is *G. bursarius missouriensis* which is ~300 km away near St. Louis, Missouri; Elrod et al. 2000) and its status as an agricultural pest (Witmer and Engeman 2007). These factors, along with small population size, no source for recolonization, and the intentional killing by humans to reduce agricultural damage under score the potential need of conservation of the Ozark pocket gopher. Although this subspecies is restricted to the sandy valleys and drainages of streams, it appears that not all suitable habitat found within its range is being occupied (Kershen 2004). A further understanding of these animals' territory use including home range and dispersal behavior may shed light on why vacant habitat exists within their range.

Dispersal patterns and survival rates are very important when making conservation and/or management decisions, but these parameters are unknown for the

Ozark pocket gopher. Dispersal is defined as movements of short distances away from the natal site (Endler 1977). These dispersal events alter the genetic structure and demographic processes of a population and can result in a stable population size over time due to emigration equaling immigration (Gaines and McClenaghan 1980). Evidence collected from several taxon of vertebrates suggests that a relationship exists between basic life-history characteristics (e.g. sociality and reproductive strategy) and dispersal patterns (Sutherland et al. 2000). Most species must use a dispersal mechanism based on their life-history, but the causal factors may be different depending on the ecological pressures exhibited by a particular life-history (Gaines and McClenaghan 1980). Thus, the ecological constraints, such as habitat requirements and social structure, on a species may lead to insight on the specific dispersal mechanism.

Mortality causes and predators may elucidate the current restricted range that these gophers occupy. Howard and Childs (1959) and Wilks (1963) estimated survival rates for other species of pocket gophers. Ozark pocket gophers are expected to suffer from the same basic mortality factors (e.g. starvation and disease) and predators as other species of pocket gophers.

Fossorial mammals, such as pocket gophers, present a unique challenge to study due to their underground lifestyle. Surface trapping and direct observation of behavior cannot be employed since they remain in closed underground burrows for most of their life. Previous studies have used a variety of live traps designed for pocket gophers; however, these live traps readily malfunction or require adjustment to capture varying sizes of pocket gophers. Therefore, I had to develop novel or improve field techniques in order to efficiently obtain data. The techniques that were used in this study can potentially be used for other fossorial mammals.

Pocket gophers cause topographical changes in the environment by moving soil within and around their burrows (Grinnell 1923, Inouye et al. 1997). They are also important in plant succession, plant distribution, nutrient cycling, soil aeration, and water drainage (Grinnell 1923, Grant et al. 1980, Williams and Cameron 1986, Inouye et al. 1987*a*, Inouye et al. 1987*b*, Huntly and Reichman 1994). They can potentially be ecosystem engineers since their burrows can be quite extensive underground and impact the overall lay of the ground (Huntly and Inouye 1988). This impact on the environment can lead to the distribution of other animal species present in the burrows and surrounding area. Several studies (Howard and Childs 1959, Vaughan 1961, Wilks 1963) have reported numerous vertebrate species (e.g. salamanders and snakes) from pocket gopher burrows and associated habitat. Thus, I additionally recorded data on the amphibian, reptile, and small mammal species that occupied Ozark pocket gopher habitat to determine the gophers' impact on associated vertebrates (Chapter VI).

The study area was located in the southern portion of Izard County, in north-central Arkansas. Izard County is a mixture of rocky mountain terrain and flood plains near streams and rivers. The majority of Izard County either has a slope higher than eight percent or contains rock outcroppings (United States Department of Agriculture 1984). Pocket gophers are not associated with rocky habitat because the topsoil is shallow and not conducive to digging. Due to their fossorial nature, pocket gophers need areas that have grassy fields or riparian areas with few trees and deep sandy or loamy soil so that their burrows will not collapse (Davis 1940). This provides habitat that is easy for pocket gophers to dig through to establish burrows and foraging areas due to the lack of large woody roots.

The purpose of this study was to elucidate population characteristics and behavioral attributes of the Ozark pocket gopher that influence home range, dispersal, survival, and community ecology. This study generated unique data describing the home range and dispersal behaviors of the newly described Ozark pocket gopher along with data about the subterranean community. These data can be used by managers to determine the best management practices for either controlling gophers in agricultural pest situations or conserving this unique subspecies. This research gives insight into the importance of conservation of this subspecies because of the relation with the subterranean community as well as limitations of control due to its dispersal behaviors and movement activities. Ultimately, this research provides information pertaining to the specific life history traits of this subspecies that has not been studied previously. Furthermore, specific objectives were as follows:

1. Refine capture and radio telemetry methods for the Ozark pocket gopher.
2. Determine home range for adult male and female Ozark pocket gophers using radio telemetry.
3. Determine survival rates and mortality causes of Ozark pocket gophers.
4. Determine dispersal patterns and distances of sub-adult Ozark pocket gophers using radio telemetry and drift fences.
5. Determine small mammal and herpetofaunal community in pocket gopher habitats in Izard County, Arkansas by collecting data with pitfall traps.

This thesis is broken into seven chapters. Each chapter is meant to be a standalone manuscript. Thus, each data chapter (*i.e.* Chapters II-VI) has an abstract, introduction, methods, results, and discussion, except Chapters II and III which do not have subheadings. Chapters I, IV, V, and VII are formatted using the guidelines of *Journal of Mammalogy*. Chapters II and III are formatted using the guidelines of *Southwestern Naturalist.* Chapter VI is formatted using the guidelines of *Journal of the Arkansas Academy of Science.* Chapter VII is the conclusion chapter and contains overall conclusions and managerial implications and suggestions for worthwhile future studies relating to this unique subspecies. Chapters II through VI are data chapters containing direct results and discussions pertaining to specific objectives of the study.

In Chapter II, I present a new live trap for pocket gophers and compared its effectiveness with the Baker and Williams (1972) live trap. I developed this box trap to alleviate the difficulties associated with numerous mechanical parts common in other live traps. When I analyzed this trap compared to the Baker and William trap, this trap was superior in some aspects, e.g., capture of heavier pocket gophers and males. My trap was user friendly and could equally capture all portions of a population of pocket gophers.

In Chapter III, I present a modified technique to subcutaneously implant radio transmitters for long term data collection in pocket gophers. This technique minimized time required and thus likely reduced the stress of surgery. I did not discover any signs of chronic trauma from the implantations on individuals. This technique worked well with pocket gophers suggesting why it would work with other similar species.

In Chapter IV, I present data on movements made by Ozark pocket gophers (*i.e.* home range and dispersal events). Area of home range encompassed by pocket gophers varied in size, but not necessarily with respect to mass, sex, or season. Home ranges of females could best be predicted with respect to mass and season. I present limited data on dispersal; however, I collected indirect evidence that Ozark pocket gophers disperse aboveground.

In Chapter V, I present data on survival of Ozark pocket gophers. Survival rates and specific mortality factors determine population demographics and size. Since the Ozark pocket gopher is a species of greatest conservation need, these mortality factors and rates can elucidate how to better conserve this endemic subspecies. Radio telemetry results indicated that individual survival rates are high in the spring but lower in the winter. Mark-recapture data suggests that turnover rates are fairly high in the studied population. This may be a result of either undetected mortality or dispersal events.

In Chapter VI, I present results of the associated herpetofaunal and small mammal community within Ozark pocket gopher habitat. Previous studies have shown that pocket gopher habitats are high in species richness and provide abundant cover for other species associates (Howard and Childs 1959, Vaughan 1961, Wilks 1963). Therefore, I collected and analyzed what community associates were present in pocket gopher habitat. Although these data present preliminary results as to the extent of the importance of pocket gopher burrows, many species are at least obligate associates of pocket gopher burrows.

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CHAPTER II

LIVE TRAP FOR POCKET GOPHERS

*****accepted in a modified version in the Southwestern Naturalist

ABSTRACT—I present a new trap for pocket gophers and compared its effectiveness with the Baker and Williams live trap. My box trap readily captured juveniles ≥44 g and adults ≥294 g. I had ≤50% capture success. In general, capture success was similar to the Baker and Williams live trap. However, analysis suggested that my trap was superior in some aspects, e.g., capture of heavier pocket gophers and males. My trap was user friendly and could be employed to equally capture all portions of a population of pocket gophers.

Previous research on live trapping small mammals has demonstrated differences in rates of capture related to size of trap (Kisiel, 1972; Slade et al., 1993), type of live trap (Holdenreid, 1954; Sealander and James, 1958; Jorgensen et al., 1994; O'Farrell et al., 1994; Hayes et al., 1996), and placement of trap (Witt, 1991; Risch and Brady, 1996). Being fossorial, pocket gophers are difficult to live trap and, thus, comparisons of trapping techniques are warranted. Several cylindrical (Scheffer, 1934; Ingles, 1949; Sargeant, 1966; Baker and Williams, 1972; Hart, 1973) and box-type live traps (Sherman, 1941; Howard, 1952) have been developed for pocket gophers, all of which use a trigger mechanism (plate). Herein, I describe a trap that has the ability to capture >1 individual at a time (i.e., juveniles in the natal burrow) and lacks a trigger plate. My design has several additional advantages over other trapping techniques for fossorial rodents, including ease of use and ability to capture juveniles. Thus, I include data on juveniles as well as on adults.

I conducted my evaluation of the effectiveness of the box trap on a population of Ozark pocket gophers (*Geomys bursarius ozarkensis*), a subspecies that has been described recently (Elrod et al., 2000). The paucity of records of captures of juveniles because of possible malfunction of the trigger mechanism led me to develop a more robust and simpler live trap. Although some studies have used bait inside traps (Scheffer, 1934; Howard and Childs, 1959; Wilks, 1963), bait is not required because pocket gophers respond to foreign objects or light in a burrow by plugging that burrow (Werner et al., 2005). Thus, this behavior facilitates use of unbaited traps.

The trap I describe is a modified box trap using a one-way hinged door that does not require a trigger mechanism (Fig. 2.1). I report capture success of my box trap in comparison to a standard Baker and Williams (1972) live trap. Additionally, I provide instructions on how to modify the door of the Baker and Williams (1972) live trap so that smaller pocket gophers (i.e., juveniles) can be successfully captured and discuss general trapping practices for juvenile fossorial mammals.

Length of the trap was ≥40.6 cm but ≤50.8 cm. The following specific measurements are for 40.6-cm length. The body of the trap was 12.7 by 40.6 cm and was made of plywood (1.3-cm thick), mesh hardware cloth (1.3-cm spacing), and 0.6-cm thick Plexiglas® (ATOFINA Chemicals, Inc., Philadelphia, Pennsylvania). Sides of the trap were made of plywood and were 10.2 by 40.6 cm. To build the trap, I attached the two sides with wood screws to the plywood back, which measured 10.2 by 12.7 cm.

After I assembled the sides and back, I attached the Plexiglas® top (12.7 by 37 cm) with wood screws and a fast-drying adhesive to the sides and flush with the back of the trap, leaving a space in the front to attach the door. I made the bottom using 1.3-cm-mesh hardware cloth 38 cm in length and stapled it, using wood staples, to the sides and back of the trap.

The door was made of plywood (1.3-cm thick), Plexiglas®, and a 2.5-cm metal hinge (Fig. 2.1-top). I assembled the door by using F-26 construction adhesive (Leech Products, Hutchinson, Kansas) to glue the 2.5 by 5.1-cm piece of plywood flush to the center of the front section (7.6 by 12.7 cm) of plywood. Next, I glued the hinge flush with the shorter side of the 9.5 by 11.4-cm piece of Plexiglas®. I mounted the hinge to the plywood top so that the Plexiglas® door opened toward the inside of the trap (Fig. 2.1-middle). I attached the door with wood screws to the front top of the body of the trap (Fig 2.1-bottom).

The Baker and Williams (1972) trap used a safety hasp as a door. Juveniles could escape by crawling between the polyvinyl chloride (PVC) pipe and the safety hasp door. Hence, I modified this hasp door by using a piece of aluminum flashing cut such that it covered the entrance when the trap is sprung. Then, I taped the aluminum flashing to the hasp so there was no open gap in the door when the trap is triggered.

I placed traps in burrows by first locating fresh mounds and digging into them until a tunnel was located. I placed the box trap inside the burrow, moving it back and forth until dirt came through the mesh floor. Dirt was then placed on the top of the trap to limit light. Additionally, it was useful to place a plywood cover over the trap to further reduce light in the burrow. Traps initially were checked after 1 h. Between checks, traps were left undisturbed and set unless a pocket gopher was captured or the trap has been plugged with dirt, in which case the dirt was emptied and the trap reset (checking every 30 min thereafter).

During January-April 2007, I conducted a comparison of live traps between my box trap and the Baker and Williams (1972) live trap (pipe trap) using Ozark pocket gophers in the southern portion of Izard County, Arkansas. I randomly selected a burrow system to receive either a box trap or pipe trap. Each time I checked the trap, I recorded one of three outcomes: no activity, plugged but no capture, or capture. I allowed ≤6 capture attempts (i.e., capture, triggered, or plugged but no capture) for each trap, after that, I concluded no capture success.

I recorded mass, reproductive condition, age (adult or juvenile), and gender of all individuals. I classified pocket gophers as adults if they had mass >100 g; all others were considered juveniles. Gender was determined by multiple external characteristics, including genitalia and mammae, to reduce the error in determining sex of individuals without necropsy (Witmer et al., 1996). This study coincided with the reproductive season, allowing for easier determination of gender.

I conducted two-sample *t*-tests (SAS, Inc. 1990) on adults for type of trap versus mass for males and females, and a Wilcoxon rank-sum test on genders combined. I used Minitab 14 (Minitab, Inc.2007) to conduct χ^2 and Fisher's exact test for type of trap versus capture success.

Additional trapping was conducted through June 2007 and during December 2007-March 2008. I captured 66 pocket gophers (range, 44-294 g) in my box trap a total of 82 times when combined with data from the comparison of live traps.

Additionally, I captured seven juveniles (44, 59, 65, 84, 89, 93, and 98 g) in my box traps, whereas juvenile Ozark pocket gophers were able to escape through the door of the Baker and Williams (1972) live trap. One juvenile (70 g) escaped from a Baker and Willliams (1972) trap on several occasions until I modified the door. After modifying the door, I was able to catch seven juvenile pocket gophers (54, 62, 64, 70, 70, 72, and 91 g) with pipe traps.

Although there was no significant difference ($P > 0.05$), adult males captured in box traps were heavier ($\bar{X}$ = 223.75 g, *SD* = 57.44, range = 152-294 g, $n = 8$) than males captured in pipe traps ($\bar{X}$ = 186.29 g, *SD* = 54.33, range = 106-292 g, $n = 14$). Mean masses of adult females were generally the same for individuals captured in box traps ($\bar{X}$ = 156.93 g, [*SD* = 26.55, range = 124-234 g, $n = 14$) and pipe traps ($\bar{X}$ = 150.88 g, *SD* 19.55, range = 110-182 g, $n = 24$) with no significant difference ($P > 0.05$) between samples, but females captured in box traps had a greater range of mass than males captured in box traps. A Wilcoxon rank-sum test did not reveal any significant difference ($P > 0.05$) for type of trap in relation to mass (all individuals captured). All groups were captured in box traps quicker than in pipe traps. However, pipe traps caught more individuals.

My box trap is effective at capturing differing sizes of Ozark pocket gophers of both genders. I was able to capture *Geomys* ≥44 g in our trap, whereas the smallest one captured previously weighed 66 g (Sargeant, 1966). A key feature of my trap was the absence of a trigger mechanism or treadle. Sherman (1941) reported problems with malfunctions of treadle mechanisms due to pocket gophers plugging the trap with soil. My trap was more robust due to a minimum of mechanical components, preventing malfunction due to wear or obstruction by soil. Conversely, the pipe trap has many components (trigger plate, rat trap, and wire) that could increase the likelihood of malfunction. It is my conviction that successful trapping of pocket gophers is affected by experience of trapper more than any other group of small mammals; thus, my trigger-less box trap is particularly useful for naïve trappers targeting these species. An additional strength of my box trap is that, like the trap of Howard (1952), traps can be checked without removing the trap. I did not have any injury or mortality with my trap; however, I did have one injury with the pipe trap when a pocket gopher became wedged behind the trigger plate.

One element of comparison that may have resulted in an unexpected bias in captures was the fact that I did not have paired traps in each burrow although I did have both trap types set at the same time but in different burrows. Jorgensen et al. (1994) and O'Farrell et al. (1994) had discrepancies between capture successes of small mammals due to experimental designs (paired traps versus alternating traps). I reduced any biases that may have been accrued unexpectedly due to experimental design of nonpaired traps by assigning randomly which type of trap would be used in each burrow before excavation.

Although box traps had similar success to pipe traps, the box trap appeared to be more effective at catching both smaller and larger pocket gophers (i.e., I captured the smallest, 44 g, and the largest, 294 g, in the box trap); thus, eliminating the need to modify traps. Modifications of traditional pipe traps are required to study juveniles. Previous live traps have needed minor modifications, including alterations in diameter of trap (Sargeant, 1966), adjustment of trigger mechanism (Sherman, 1941), and modifications of fasteners on the spring door (Ingles, 1949), to be effective at capturing all individuals of a population with respect to gender and mass. Hart (1973) stated that additional minor adjustments may need to be made depending on local behaviors of pocket gophers. Varying capture success due to sensitivity of trigger may be another potential bias of pipe traps. Indeed, Boonstra and Rodd (1982) reported biases caused by varying sensitivity of triggers along with a failure to catch larger animals in Longworth traps. In general, I had 25-50% capture success using my box trap.

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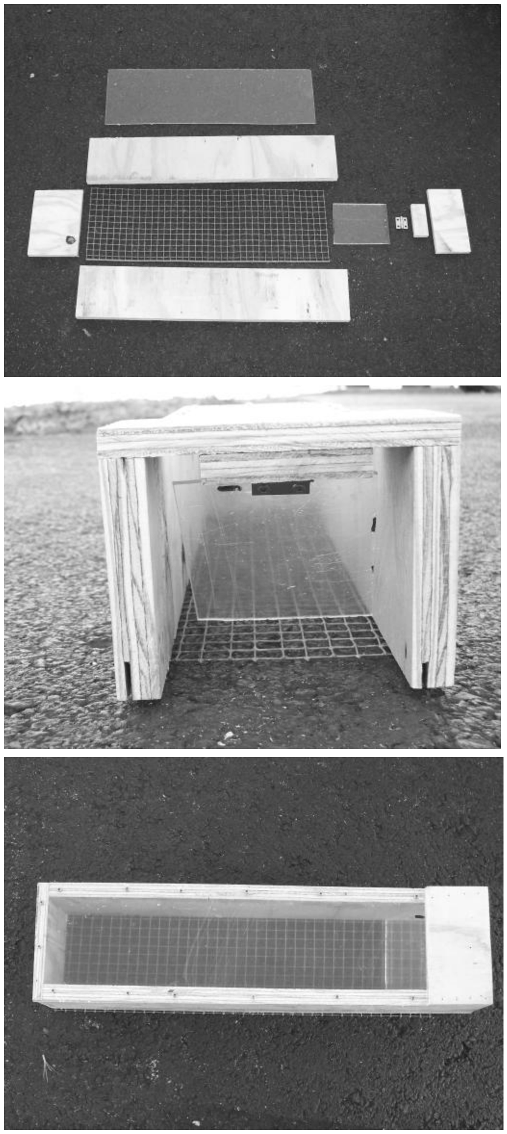

FIG. 2.1—Materials needed for construction of a live trap for pocket gophers (top); front view (middle) and top view (bottom) of assembled trap.

CHAPTER III

BENEFITS OF SUBCUTANEOUS IMPLANTATION OF RADIOTRANSMITTERS IN POCKET GOPHERS

*accepted in a modified version in the Southwestern Naturalist

ABSTRACT---Conventional attachment of radiotransmitters may not be feasible in pocket gophers due to their unique morphology and fossorial lifestyle. I implanted radiotransmitters subcutaneously in Ozark pocket gophers, *Geomys bursarius ozarkensis*, 3 March 2007-10 February 2008. Of the 72 implantations, 70 were successful. I recaptured 22 individuals (range, 20-325 days post-implantation) and recorded a mean change in mass from implantation to recapture for adult males, females, and juveniles of 1.1% (SD = 11.9), -1.6% (SD = 9.0), 17.3% (SD = 18.8), respectively. I suggest that subcutaneous implantation is the best method for pocket gophers and may be applicable for other small mammals.

Advantages and disadvantages of competing techniques in radiotelemetry should be considered so that the best radiotransmitter and method of attachment is chosen. Previous studies have shown high survivorship from intraperitoneal implants in pocket gophers (Zinnel and Tester, 1991; Benedix, 1994), yellow-bellied marmots (*Marmota flaviventris*; Van Vuren, 1989), American minks (*Neovison vison*), Franklin's ground squirrels (*Spermophilus franklinii*; Eagle et al., 1984), and other mammals (Koehler et al., 1987). Although intraperitoneal implants are successful in many mammalian species, other methods of attachment, such as subcutaneous implantation, may be more reliable, feasible, or both, for certain species.

Radiotransmitters have been placed on collars around the neck (Andersen and MacMahon, 1981; Witmer et al., 1996), in cheek pouches (Artmann, 1967), and in peritoneal cavities (Zinnel and Tester, 1991; Benedix, 1994) of pocket gophers. The short necks of pocket gophers may cause radiocollars to slip off, whereas insertion of radiotransmitters into cheek pouches may affect foraging and they can be removed by pocket gophers (Artmann, 1967). Surgical implantation in the peritoneal cavity is invasive, time consuming (often ≥20 min) and may cause additional stress or behavioral changes (Zinnel and Tester, 1991). Bandoli (1987) sutured radiotransmitters subcutaneously to the lateral aspect of the rump of pocket gophers. However, extended sedation for this ca. 45-min procedure may have caused unintentional stress. Cameron et al. (1988) took captured individuals to a screened enclosure where they placed radiotransmitters subcutaneously between scapulae. Individual pocket gophers were radiotracked in the field for 2 days after which animals were recaptured and radiotransmitters were removed. Because of the limitations of previous techniques for affixing radiotransmitters to subterranean mammals such as pocket gophers, I used a technique similar to Cameron et al. (1988). This technique allowed for quick implantation that could be carried out at the site of capture in ≤10 min when performed by two people.

During 3 March 2007-10 February 2008, I inserted radiotransmitters into 72 Ozark pocket gophers, *Geomys bursarius ozarkensis*, in Izard County, Arkansas. All surgical procedures followed guidelines of the American Society of Mammalogists (Gannon et al., 2007). I recorded mass of pocket gophers after capture (range = 41-274 g; n = 72) to determine appropriate size of radiotransmitter for each individual. I tested the technique of Cameron et al. (1988) by implanting radiotransmitters at the capture site and conducted long-term radiotracking using a Wildlife Materials TRX 1000S receiver (Wildlife Materials, Inc., Murphysboro, Illinois).

After capture, the pocket gopher was placed in a small plastic container and anesthetized via inhalation with Isoflurane (1-chloro-2,2,2-trifluoroethyl difluoromethyl ether, Webster Veterinary, Sterling, MA) (McColl and Boonstra, 1999). I placed all surgical equipment and the radio transmitter in a 1 normal (N) Iodine solution for sterilization. A small amount of 70 % Isopropyl rubbing alcohol was poured in between the gopher's scapulae to part the hair away from the skin. A small incision (~2 cm) was made in the skin between the scapulae with a #10 razor blade. I then placed a pair of forceps in the incision under the skin and pushed caudally to separate the skin from the muscle creating a pocket for the radio transmitter.

I activated each radio transmitter and checked the pulse and frequency before implantation. I placed the transmitter in the incision and slid it back under the skin into the pocket created with forceps. Incision was wiped clean with cotton swabs and then a fast-drying adhesive was used to close the incision. I returned the pocket gopher to its burrow after the adhesive dried and the pocket gopher was able to dig.

I left radiotransmitters inside pocket gophers for ≤9 months (range = 1-9 months), thereby greatly extending the 2-day period of Cameron et al. (1988). I returned each pocket gopher to its burrow within 1 h after implantation. I recaptured 22 individuals to examine any potential negative, long-term effects of subcutaneous implantation, including change in mass, infections, and restrained movements.

I classified female pocket gophers as adults if they had completed their first molt and had lost their pubic symphysis, and males were determined to be adults if they had completed their first molt and weighed ≥140 g (Wilks, 1963). I present data on adults by sex. Pocket gophers not meeting criteria to be considered as adults were classified as juveniles, and sexes in this age class were grouped together.

I implanted four sizes of radiotransmitters (SOPI-2038, SOPI-2070, and SOPI-2190, Wildlife Materials, Inc., Murphysboro, Illinois; PD-2H, Holohil Systems, Ltd., Carp, Ontario, Canada). Longevity of radiotransmitters was 3-9 months. The SOPI-2038 was 2.2 by 0.8 by 0.6 cm and weighed 1.8-2.2 g, the SOPI-2070 was 2.2 by 0.8 by 0.6 cm and weighed 2.0-3.0 g, the SOPI - 2190 was 2.2 by 1.3 by 0.7 cm and weighed 4.0-6.0 g, and the PD-2H was 2.3 by 1.2 by 0.9 and weighed 3.9 g. Pocket gophers were implanted with the largest radiotransmitter possible, provided it was not >5% of the mass of the pocket gopher.

Of the 72 surgeries, 70 were successful. One radiotransmitter was not retained after implantation in a female (188 g) likely due to insufficient closure of the incision. One old male (259 g) with worn teeth died during surgery, likely as a result of complications from the anesthesia.

Mean body mass for 20 adult males and 28 adult females was 206 g (*SD* = 47.9) and 159 g (*SD* = 15.8), respectively. Mean body mass of 24 juveniles was 94 g (*SD* = 30.4). Mean change in mass from implantation to recapture for adult males, adult females, and juveniles was 1.1% (*SD* = 11.9), -1.6% (*SD* = 9.0), 17.3% (*SD* = 18.8), respectively (Table 3.1). Mass of one juvenile increased from 44 to 61 g in 36 days; likely reflective of a normal rate of growth for a juvenile of that age.

No pocket gopher that was recaptured, including individuals that were recaptured ≤325 days after having a radiotransmitter implanted, showed any sign of restrained movement, infection, or abnormal scarring from the surgery. Pocket gophers were captured and radiotransmitters were implanted in spring when food was abundant and the majority recaptured during drier, hotter months when food was less abundant, which resulted in some loss of mass (Table 3.1). Additional recaptures of females in winter suggested that losses in mass probably were due to pregnancy during the previous spring. Mean change in mass per day in the pocket gophers with radiotransmitters (0.09%; *SD* = 0.33) was similar to other pocket gophers recaptured that did not have implanted radiotransmitters (0.03 %; *SD* = 0.13; SAS, Inc. 1990). A Wilcoxon rank-sum test did not reveal any significant difference between the two groups (*P* = 0.83; SAS, Inc. 1990).

Successful surgeries on juveniles, some as small as 41 g, showed potential applicability for use with other species. This is the first time subcutaneous radiotransmitters have been used during long-term studies of *G. bursarius*. Once radiotransmitters are placed subcutaneously, scientists can collect biological data on pocket gophers via radiotelemetry without intrusion into their closed burrow system (e.g., digging open the burrow to place a trap). Gathering data with subcutaneous radiotransmitters also might elucidate some biological questions currently unanswered, such as patterns and rates of dispersal (Busch et al., 2000).

I had comparable results (retention of radiotransmitters without infection) as those reported with subcutaneous implantations on other species of pocket gophers (Bandoli, 1987; Cameron et al., 1988). Subcutaneous implantation of radiotransmitters is a reliable procedure that can be successfully done under field conditions at the site of capture. The procedure described herein is the least intrusive and most appropriate for use in research with small mammals that are either fossorial or their morphology is not conducive to attachment of radiocollars. When completed in the field, this procedure minimizes time required for surgery and limits stress on the individual; thus, ensuring minimal alterations of behavior and physique. Furthermore, it is not a technical surgery and can be successfully done by field technicians without previous surgical training.

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TABLE 3.1-- Initial mass and percent change of 22 Ozark pocket gophers (*Geomys bursarius ozarkensis*) at the time of implantation of radiotransmitter and at the time of recapture, Izard County, Arkansas.

Sex	**Mass at Implantation (g)**	**Mass at recapture (g)**	**Mass change %**	**Days between captures**
Male	157	200	27.4	54
Male	165	178	7.8	47
Male	237	243	2.5	34
Male	220	212	-3.6	42
Male	257	245	-4.7	38
Male	257	244	-5.1	270
Male	274	253	-7.7	50
Male	248	228	-8.1	20
Female	149	179	20.1	57
Female	140	144	2.9	48
Female	146	150	2.7	53
Female	139	139	0	28
Female	174	168	-3.4	21
Female	161	155	-3.7	107
Female	173	160	-7.5	292
Female	155	143	-7.7	93
Female	168	155	-7.8	305
Female	170	151	-11.2	325
Juvenile	44	61	41.5	36
Juvenile	124	145	16.9	53
Juvenile	93	107	15.1	24
Juvenile	113	108	-4.4	50

CHAPTER IV

MOVEMENT AND BURROW USE OF THE OZARK POCKET GOPHER (*GEOMYS BURSARIUS OZARKENSIS*)

Abstract

Subterranean rodents, such as Ozark pocket gophers (*Geomys bursarius ozarkensis*), pose difficulty in collecting data on movements due to their fossorial lifestyle. Thus, I employed radio telemetry and mark-recapture techniques to collect data from which I calculated minimum convex polygons for individuals to determine movement patterns and home range sizes of Ozark pocket gophers. Adult females had an average home range of 178.3 m^2 (SD 108.2 m^2, range 67.9 – 384.3 m^2; n = 11) and 406.8 m^2 (SD 206.7 m^2; range 163.2 – 823.2 m^2; n = 10) in 2007 and 2008, respectively. Adult female home ranges were significantly larger in 2008 than 2007 (t-value = -3.13; P = 0.0078). Adult males had an average home range of 321.9 m^2 (SD 140.3 m^2; range 162.7 – 546.5 m^2; n = 7) and 261.7 m^2 (SD 187.6 m^2; range 23.7 – 513.7 m^2; n = 7) in 2007 and 2008, respectively with no difference between years (t-value = 0.68; P = 0.51). Juvenile/subadult females had an average home range of 225.2 m^2 (SD 151.8 m^2; range 47.9 – 439.8 m^2; n = 12) and juvenile/subadult males had an average home range of 246.2 m^2 (SD 70.9 m^2; range 34.3 – 533.7 m^2; n = 7) for the seasons combined. Home range size could be predicted by using body mass as the variable in both adult females (r = 0.268; df= 1, 18; F=8.33; P = 0.009; Fig. 4.10) and

juvenile/subadult females (r = 0.524; df=1, 11; F=12.54; P = 0.006; Fig. 4.12). I indirectly observed one adult male that dispersed above ground during a snowfall, documenting that above ground dispersal occurs in this subspecies.

Introduction

Home range can be defined as the area that an organism uses throughout the year to obtain resources required to survive and reproduce (Burt 1943). The size of an organism's home range is related to its body mass and food requirements. Basically, as species increase in mass, the size of their home range will increase in response to meet higher demands of food and water resources (Kelt and Van Vuren 1999). Yet, some environmental factors result in a disproportionate home range size as compared to the individual's body mass. For example, a subterranean activity pattern exhibited by several mammals, including pocket gophers, reduces the size of the home range due to energetic constraints from behaviors such as digging (Kelt and Van Vuren 1999).

Other movements, specifically dispersal and nest site relocation, also contribute to the ability of pocket gophers to establish and maintain their home ranges. Subterranean burrows aid to buffer environmental dangers, such as weather extremes and above ground predators. Due to the energetic demands of burrowing, home ranges of pocket gophers should only be as large as required to efficiently obtain food resources while allowing for interaction with neighboring pocket gophers during mating seasons.

Home range estimates have been calculated by excavation of burrows and subsequent measurement of total surface area covered (Reichman et al. 1982, Cameron et al. 1988, Romañach et al. 2005), multiple live trap locations (Howard and Childs 1959, Wilks 1963), and radio telemetry (Artmann 1967, Zinnel 1992, Witmer et al. 1996). The excavation of burrows is very labor and time intensive and results in the removal of the gopher. Home range estimates can alternately be obtained from multiple live trap capture locations, which is also labor intensive and can be destructive to the burrow. Radio telemetry allows scientists to collect vast amounts of location data with minimal contact with pocket gophers and without extensive damage to the burrow system under study (only one live trap capture event is required). Additionally, radio transmitters are becoming increasing smaller with longer life spans further increasing their alternativeness in studies of subterranean animal movements.

I conducted radio telemetry on Ozark pocket gophers (*Geomys bursarius ozarkensis*) during 2007 and 2008 to elucidate home range size and dispersal distances. My goal was to estimate home range size for individuals for each of the following categories; adult male, adult female, and juvenile/subadult. Kershen (2004) estimated this subspecies to have very high densities (≥50 individuals/ha). Therefore, I studied the home range size and dispersal distances in order to determine if they are comparable with other gopher species' home range estimates and dispersal distances. These parameters may provide insight as to how the high densities are affecting intraspecific competition and social behavior.

In addition, drift fences were employed to document above ground dispersal. Some studies have had success by using drift fences in conjunction with pitfall and funnel traps to capture pocket gophers (Imler 1945; Howard and Childs 1959; Daly and Patton 1990). In areas with high densities of gophers, above ground dispersal would minimize contact among aggressive territorial adults, however above ground movements likely increase surface predation rates.

Methods

Home Range

Pocket gophers were live trapped using both Baker and Williams (1972) and Connior and Risch (*in press* a; Chapter II) live traps. I recorded mass (recorded to the nearest gram with a Pesola® 300g spring scale [Pesola AG, Baar, Switzerland]), length, sex, and reproductive condition of captured individuals and implanted a passive integrated transponder (PIT tag; Fokidis et al. 2006). Selected individuals were implanted with a subcutaneous radio transmitter after which implanted gophers were released at their capture site within an hour. Captured pocket gophers were anesthetized with Isoflurane (Webster Veterinary Supply, Inc., Sterling, MA) and then the radiotransmitter was implanted subcutaneously between the scapula and then the incision was glued closed (Chapter III; Cameron et al. 1988) Transmittered gophers were tracked either daily or every other day. Radio telemetry was conducted from March 3 to July 24 in 2007 and from December 15, 2007 to April 8, 2008. Pocket gophers were tracked using a TRX 1000s receiver (Wildlife Materials, Inc, Carbondale, IL) and locations were recorded in UTM to the nearest sub-meter using a Global positioning satellite (GPS; GeoTrimble Explorer).

Majority of the tracking periods were either in the morning or afternoon and lasted ca. one hour. Only one location for each individual was recorded per tracking period. During 2007, adults were tracked 3 times/week and juveniles were tracked 5 times/week. During 2008, I tracked all individuals ≥5 times/week. I focused my radio telemetry on longer durations of home range use rather than shorter durations with multiple locations per day (Connior and Risch *in press* b). This technique should elucidate realistic home range use rather than daily activity centers.

Individual positions were recorded and uploaded into ArcGIS 9.2 (ESRI; Redlands, California). I projected XY data as NAD 1983 Zone 15N and displayed them as a spatial layer. Home ranges were calculated using Minimum Convex Polygon (MCP) using Hawth's tools (Beyer 2004). I selected MCPs so that area estimates could be compared to other studies. I included home ranges that contained ≥20 radio telemetry points in statistical analyses. I identified areas that contained multiple relocation events (≥10 locations) as nest sites. In all cases, areas that were identified as nests sites via radio telemetry were confirmed to be so.

I conducted linear regression on body mass versus home range size on adult males, adult females, juvenile males, and juvenile females (Minitab Inc. 2007). Additionally, I conducted t-tests on adult female home range size between the 2007 and 2008 season, adult male home range size between the 2007 and 2008 season, and adult male versus adult female home range size for the seasons combined (SAS Institute Inc. 1990). Extreme observations were excluded from statistical analyses but are reported individually in the results.

Dispersal

Gophers were deemed as a disperser if the individual left its initial home range and did not return for the remaining telemetry study. Additional knowledge about the dispersing location was used to aid in this determination, such as distance travelled and status of new location (newly constructed burrow or vacant old burrow).

In addition to collecting movement data via radio telemetry, I placed two drift fences per site at two sites during March to August 2007 to determine if this technique would be effective at capturing Ozark pocket gophers. Drift fences (Fig. 4.1) were 60 cm high and were 33 m long with bucket pitfall traps at each end (Fig. 4.2) and additional bucket pitfall traps on either side of the drift fence spaced every ca. 8 m (a total of 8 buckets per fence). All bucket pitfall traps were 18.9 liters. In addition to the pitfall buckets, I placed a funnel trap 12 m from the end of the drift fence on either side along the fence. The funnel traps (90 x 30 x 30 cm) had double entrances and were made of wire mesh hardware cloth.

Results

Home Range

I tracked 70 implanted pocket gophers during 2007 (*n*= 35; 3 March- 24 July 2007) and 2008 (*n*= 35; 15 December 2007-8 April 2008). Of these, there were 26, 20, 14, and 10 adult females, adult males, subadult/juvenile females, subadult/juvenile males, respectively. I obtained $\bar{X}$ = 41 ± 22.8, $\bar{X}$ = 41 ± 24.3, $\bar{X}$ = 52 ± 27.2, and $\bar{X}$ = 38 ± 27.5 relocations for adult females, adult males, subadult/juvenile females, and subadult/juvenile males, respectively. In general, relocations did not vary with sex or age (ANOVA; DF=1, 3; F=0.37; P=0.774).

Appendix A has GPS locations for each site. Site 1 had 13 home ranges (Fig. 4.3), Site 2 had 6 home ranges (Fig. 4.4), Site 3 had 9 home ranges (Fig. 4.5), and Site 5 had 7 home ranges (Fig. 4.6) in 2007. The Site 3 had 15 home ranges (Fig. 4.7) and Site 4 had 20 home ranges (Fig. 4.8) in 2008. Figure 4.9 shows the spatial relationship of tracked gophers at Site 3 during both 2007 and 2008 seasons. I statistically analyzed the home ranges of 57 individuals (≥20 locations; Tables 4.1, 4.2).

Repeated telemetry relocations indicated suspected nest sites. Seven of these areas were excavated and confirmed to be nest sites. Nests were spherical in shape and comprised of grass material (Figs. 4.10; 4.11). Nest locations averaged 47 ± 12 cm below the soil surface (range 30-50 cm; Table 4.3). Means of nests for the seven excavated were as follows: height 21 ± 4 cm (range 15-25cm), width 22 ± 4 cm (range 13-27), and length 23 ± 5 cm (range 18-30cm; Table 4.3).

Statistical Analyses

Adult females had an average home range of 178.3 m^2 (SD 108.2 m^2, range 67.9 – 384.3 m^2; n = 11) and 406.8 m^2 (SD 206.7 m^2; range 163.2 – 823.2 m^2; n = 10) in 2007 and 2008, respectively. Adult female home ranges were significantly larger in 2008 than 2007 (t-value = -3.13; P = 0.0078). The largest home range for an adult female (144 g) was 940.7 m^2 (Table 4.1). Adult males had an average home range of 321.9 m^2 (SD 140.3 m^2; range 162.7 – 546.5 m^2; n = 7) and 261.7 m^2 (SD 187.6 m^2; range 23.7 – 513.7 m^2; n = 7) in 2007 and 2008, respectively and did not differ between (t-value = 0.68; P = 0.51). Two adult males, 165 and 239 g, had home ranges of 2732.2 and 1814.9 m^2, respectively (Table 4.1, 4.2). Considering both years, adult females had an average home range size of 287.1 m^2 (SD 196.8 m^2; range 67.9 – 823.2 m^2; n = 21) and adult males had an average of 291.8 m^2 (SD 162.2 $m^{2;}$ range 23.7 – 546.5 m^2; n = 14) with no significant difference between sexes (T test; P = 0.94). Juvenile/subadult females had an average home range of 225.2 m^2 (SD 151.8 m^2; range 47.9 – 439.8 m^2; n = 12) and juvenile/subadult males had an average home range of 246.2 m^2 (SD 70.9 m^2; range 34.3 – 533.7 m^2; n = 7) for the combined years.

Home range size could be predicted by using body mass for both adult females (r = 0.268; df=1, 18; F= 8.33; P = 0.009; Fig. 4.12) and juvenile/subadult females (r = 0.524; df=1, 11; F= 12.54; P = 0.006; Fig. 4.13). However, home range size was not associated with body mass for either adult males (r = 0; df=1, 12; F=0.52; P = 0.486; Fig 4.14) or juvenile/subadult males (r = 0.299; df=1, 6; F=3.56; P = 0.118; Fig. 4.15). Although not significant, a trend is apparent between body mass and home range size in juvenile/subadult males (Fig. 4.15).

Dispersal

I did not catch any pocket gophers in the drift fence traps throughout the complete trapping season. However, I indirectly observed one adult male that dispersed above ground during a snowfall. It emerged from its burrow and travelled above ground and then entered into another pocket gophers burrow (Figs. 4.16, 4.17, 4.18). The gopher travelled 165 m above ground while dispersing (Fig. 4.19).

Discussion

Home Range

My adult female and adult male home range averages over two years of 287.1 m^2 (SD 196.8 m^2; range 67.9 – 823.2 m^2; n = 21) and 291.8 m^2 (SD 162.2 $m^{2;}$ range 23.7 – 546.5 m^2; n = 14), respectively, are larger than previous estimates for *G. bursarius*. This may be attributed to the long duration that I tracked individuals. Artmann (1967) only tracked gophers for either a 24 or 48 hr duration at a time. Zinnel (1992) had comparable tracking durations, but had a smaller sample size, which may have affected the average estimates. Both Bandoli (1987) and Witmer et al. (1996) tracked gophers for a duration of ca. 10 weeks. I tracked the majority of the individuals for ≥10 weeks with many ≥3 months.

My juvenile/subadult female and juvenile/subadult male home range estimates were comparable to each other with an average of 225.2 m^2 (SD 151.8 m^2; range 47.9 – 439.8 m^2; n = 12) and 246.2 m^2 (SD 70.9 m^2; range 34.3 – 533.7 m^2; n = 7) for the combined years, respectively. These estimates are similar to adults suggesting that resource requirements and mating opportunities among neighboring pocket gophers are obtained within these home range sizes. Paucity of immature gopher home range estimates in the literature confines comparison within and among species.

Adult female home ranges were larger in the 2008 field season as compared to 2007, but the adult male home ranges were not different. This can be attributed to the season in which the gophers were tracked. Pocket gophers were tracked during spring and summer in 2007 and the winter and spring in 2008. Females give birth and raise their young in late winter and early spring (Pitts and Choate 1997; Pitts et al. 2005), which the increased demand of resource requirements coupled with reduced food resources available in the winter would result in larger home ranges (McNab 1963). However, males defend their territories year round from invading pocket gophers. Adult males defend their home range, which is basically their territory, throughout the year with short durations of territory relaxation during the breeding season. Thus, sizes of home ranges of adult males should not change throughout the year once an adult has established its territory due to this defensive behavior.

Although juvenile/subadult males did not have a significantly larger home range than juvenile/subadult females, the average was slightly larger. This was expected since subadult males have to establish a large enough territory that will enable them to make future contact with reproductive females. On the other hand, females only have to establish a home range large enough to acquire food resources to survive. Zinnel and Tester (1994) found that 50% of adult females relocated, leaving female offspring in possession of an existing burrow, whereas juvenile males dispersed. Female offspring that remain in an established burrow would not have to forge out a new burrow as opposed to males, resulting in a smaller home range of subadult females than subadult males.

Adult female home range size was inversely proportional to its body mass, whereas juvenile/subadult females' home range was directly proportional to its mass. This suggests additional resources are required as younger females grow until they either maintain an optimum home range area where additional body mass does not require additional territory or larger females control better resources. Either one of these would lead to larger adult females not requiring proportionally larger home ranges. On the other hand, juvenile/subadult males showed a general trend that as the young's mass increased so do their home range. Yet, adult males' masses did not predict home range at all. This may suggest that males can only reliably defend a certain amount of territory regardless of body mass.

Table 4.4 summarizes home ranges for Geomyidae in North America. These data for the home ranges were collected by either excavation, live trapping, or radio telemetry but were all calculated by Minimum convex polygon. These home range estimates vary greatly, but for the most part increase in size by method from excavation (smallest) to live trapping to radio telemetry (largest).

The method used to calculate home ranges will affect the size. Home ranges collected over short intervals will probably be smaller than home ranges calculated over longer durations. The method by which the location data points are collected also will affect the size. For instance, excavation of burrow and subsequent calculation of surface area covered will estimate the individual's home range at that specific time. Andersen (1987) found that the volume of tunnels backfilled during new excavation varies. This causes dynamic daily burrow lengths and areas, which may create biases in home range calculations. Multiple live trapping can predict home range size but will only calculate the area that is actually trapped. Specifically, if the pocket gopher is not trapped at the perimeter of its home range then the home range will be underestimated. Radio telemetry can produce accurate home ranges if numerous data points are collected. One problem with telemetry is that gophers can move away from an area as the investigator approaches resulting in underestimated home ranges. Therefore, if more points are collected fleeing behavior may ensue and produce more accurate estimates.

My results of nests dimensions of 21 by 22 by 23 cm with an average depth below soil surface of 47 cm were comparable with nest dimensions in Kansas. Underground nests (n=4) in Kansas were an average of 50.2 cm below ground and two had diameters of 17.8 and 15.2 cm, while the other two had dimensions of 10.6 by 15.2

cm and 17.8 by 8.9 by 16.5 cm (Scheffer 1940; Smith 1948; Downhower and Hall 1966). The depth below soil surface may suggest adequate protection from yearly external temperatures.

Dispersal

Ozark pocket gophers may confine themselves to their burrows more than other species of pocket gophers, as evidenced by my failure to capture individuals above ground using drift fences. In contrast to my results, Imler (1945) had success with capturing *Geomys lutescens* in Nebraska with drift fences, and moreover, most studies that were effective with drift fences captured *Thomomys*, specifically *T. bottae* (Howard and Childs, 1959; Daly and Patton, 1990) and *T. talpoides* (Verts and Carraway, 1998). Yet, I did confirm one adult male dispersing above ground. Therefore, surface activity of Ozark pocket gophers may not include foraging behaviors and may be limited to dispersal events. Adams (1966) used drift fences to determine that the majority of *G. bursarius* disperse during late summer and early fall. Thus, an alternative explanation for the lack of captures of dispersing individuals is my trapping period concluded in the summer, possibly before the young were old enough to disperse. Vaughan (1962) reported that young *Geomys* dispersed above ground frequently. Other pocket gophers, such as *G. attwateri* (Williams and Cameron 1984) and *T. bottae* (Howard and Childs 1959; Daly and Patton 1990), disperse above ground as well. Above ground dispersal in pocket gophers may be an adaptation to minimize energy expenditure during the dispersal event. Large amounts of energy are required to construct subterranean tunnels, especially when considering the distance accrued during dispersal, whereas relatively little energy is used during surface movements (Vleck 1979).

The individual adult male that dispersed moved into a juvenile females' burrow for ca. 4 days before moving to an adult females' burrow and displacing her for the remaining duration of the study (Fig. 15). Upon subsequent capture after the dispersal on 15 February 2008, the male weighed 178 g and was scrotal, suggesting that the gopher was not only dispersing but also may have been seeking mating opportunities during dispersal.

Ozark pocket gopher activity, exclusive of dispersal, is predominately restricted to subterranean movements similar to other *Geomys* sp. (English 1932; Panich 2006). Home range estimates of 287.1, 291.8, 225.2, and 246.2 m^2 for adult females, adult males, juvenile/subadult females, and juvenile/subadult females, respectively is similar to other studies of pocket gophers (Table 4.4). I tracked Ozark pocket gophers to nest locations the majority of the time confirming that these are high use areas. Ozark pocket gophers can disperse above ground like other *Geomys* sp. (Adams 1966; Vaughan 1962; Williams and Cameron 1984); however, it seems to be uncommon during the spring and summer. These home range and dispersal results are new data for the Ozark pocket gopher and should help conservationists make managerial decisions involving spatial dynamics and intraspecific behaviors.

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Table 4.1: Characteristics of 28 radiotracked Ozark pocket gophers in Izard County, Arkansas in 2007. M = adult male, M/J = subadult male, F = adult female, F/J = subadult female.

Tag	Site	Sex	Mass (g)	Area (m^2)	Perimeter (m)	Number of Relocations
076 092 864	Site 5	F	158	230	67	27
076 121 632	Site 5	F	185	133	46	28
076 112 025	Site 1	F	173	384	102	27
076 084 038	Site 1	F	168	158	70	40
076 119 637	Site 3	F	144	940	142	41
076 111 319	Site 3	F	160	125	44	42
076 030 591	Site 3	F	172	154	50	56
076 081 377	Site 2	F	161	79	40	24
076 105 543	Site 2	F	162	171	52	34
076 258 339	Site 2	F	188	88	40	34
076 032 374	Site 2	F	155	67	33	39
076 035 123	Site 5	F/J	62	156	53	32
076 017 846	Site 5	F/J	72	85	37	32
076 061 381	Site 1	F/J	113	368	97	25
076 042 573	Site 1	F/J	44	105	50	36
076 258 355	Site 1	F/J	59	101	40	37
076 100 520	Site 3	F/J	65	48	27	47
076 048 013	Site 5	M	179	547	101	40
076 101 066	Site 5	M	138	219	65	48
076 032 544	Site 5	M	258	436	86	65
076 031 530	Site 1	M	257	210	60	29
076 083 527	Site 1	M	146	286	74	40
076 099 291	Site 1	M	239	1815	186	40
076 056 774	Site 3	M	152	393	89	35
076 017 034	Site 3	M	203	163	57	62
076 020 116	Site 1	M/J	70	373	103	33
076 079 100	Site 1	M/J	91	34	34	34
076 114 816	Site 3	M/J	41	68	35	50

Table 4.2: Characteristics of 29 radiotracked Ozark pocket gophers in Izard County, Arkansas in 2008. M = adult male, M/J = subadult male, F = adult female, F/J = subadult female.

Tag	**Site**	**Sex**	**Mass (g)**	**Area (m^2)**	**Perimeter (m)**	**Number of Relocations**
076 081 602	Site 4	F	152	163	53	33
076 059 863	Site 4	F	140	823	131	43
076 075 057	Site 4	F	149	557	96	51
076 048 078	Site 4	F	182	298	77	56
076 068 339	Site 4	F	142	428	88	57
076 073 541	Site 4	F	143	635	108	67
076 017 562	Site 3	F	150	209	56	65
076 038 066	Site 3	F	142	301	75	73
076 034 264	Site 3	F	140	358	75	88
076 021 085	Site 3	F	185	296	72	90
076 047 873	Site 4	F/J	89	88	46	21
076 027 785	Site 4	F/J	114	147	48	83
076 060 018	Site 4	F/J	120	395	80	85
076 117 521	Site 4	F/J	123	292	67	85
076 108 782	Site 4	F/J	124	440	91	87
076 077 352	Site 3	F/J	129	184	53	64
076 112 350	Site 3	F/J	129	383	77	81
076 034 123	Site 4	M	157	106	42	45
076 123 538	Site 4	M	165	2732	211	79
076 047 801	Site 4	M	144	347	75	86
076 015 383	Site 4	M	194	477	102	86
076 031 806	Site 3	M	166	175	62	20
076 026 818	Site 3	M	260	24	20	21
076 258 377	Site 3	M	220	189	66	28
076 067 014	Site 3	M	260	514	106	45
076 014 880	Site 4	M/J	98	203	65	28
076 022 334	Site 4	M/J	93	127	44	60
076 071 050	Site 3	M/J	134	385	92	65
076 098 770	Site 3	M/J	134	534	100	87

Table 4.3: Nest Characteristics of seven select Ozark pocket gophers in Izard County, Arkansas. M = adult male, M/J = subadult male, F = adult female, F/J = subadult female.

Date	**Tag**	**Sex**	**Mass of gopher (g)**	**Depth below soil (cm)**	**Height (cm)**	**Width (cm)**	**Length (cm)**
2/3/2008	076 026 818	M	260	50	23	20	25
2/3/2008	076 100 611	M	248	46	23	23	25
1/27/2008	076 014 880	M/J	98	41	25	22	28
1/27/2008	076 059 863	F	140	46	23	27	30
3/27/2008	076 092 066	F	191	46	15	23	18
3/23/2008	076 027 785	F/J	114	30	18	13	18
3/23/2008	076 048 078	F	182	70	20	25	20
Means			176	47	21	22	23
SD			63	12	4	4	5

Table 4.4: Home range estimates for Geomyidae in North America based on varying methods.

	Location	No. burrows	average mass (g)	Area (SD) in m^2	method
Geomys attwateri					
male[a]	Texas	5	141	188.1 (84.9	excavation
female[a]	Texas	5	136.9	217.2 (127.3)	excavation
male[b]	Texas	7	N/A	560 (66.2)	live trapping
female[b]	Texas	6	N/A	173.3 (34.1)	live trapping
Geomys bursarius					
genders pooled[c]	Kansas	38	N/A	34.5 (10.2)	excavation
genders pooled[c]	Minnesota	20	172.5, 193.9[k]	95.3 (28.6)	excavation
genders pooled[d]	Minnesota	16	N/A	66.3 (23.2)	radio telemetry
male[e]	Minnesota	N/A[j]	N/A	150	radio telemetry
female[e]	Minnesota	N/A[j]	N/A	206.7	radio telemetry
Thomomys bottae					
genders pooled[f]	Arizona	17	121.3	34.6 (30.5)	excavation
genders pooled[f]	Arizona	27	121.3	35.5 (34.8)	excavation
male[g]	California	N/A	N/A	300	live trapping
female[g]	California	N/A	N/A	144.4	live trapping
male[h]	New Mexico	7	N/A	474.4 (148.2)	radio telemetry
female[h]	New Mexico	7	N/A	286.4 (59.4)	radio telemetry
Thomomys mazama					
male[i]	Washington	4	N/A	108 (37.9)	radio telemetry
female[i]	Washington	4	N/A	97 (57.1)	radio telemetry

[a]Cameron et al. 1988

[b]Wilks 1963

[c]Romanach et al. 2005

[d]Artmann 1967

[e]Zinnel 1992

[f]Reichman et al. 1982

[g]Howard and Childs 1959

[h]Bandoli 1987

[i]Witmer et al. 1996

[j]17 total burrows but individual genders not reported

[k]Wasley 1995; female, male, respectively

Figure 4.1: Installed drift fence and bucket pitfall traps to capture dispersing Ozark pocket gophers in Izard County, Arkansas.

Figure 4.2: Pitfall bucket trap installed at the end of drift fence to capture pocket gophers in Izard County, Arkansas.

Figure 4.3: Home ranges of 13 Ozark pocket gophers at Site 1 in Izard County, Arkansas in 2007. Some home ranges may overlap. M = adult male, M/J = subadult male, F = adult female, F/J = subadult female.

Figure 4.4: Home ranges of 6 Ozark pocket gophers at Site 2 in Izard County, Arkansas in 2007. Some home ranges may overlap. M = adult male, M/J = subadult male, F = adult female, F/J = subadult female.

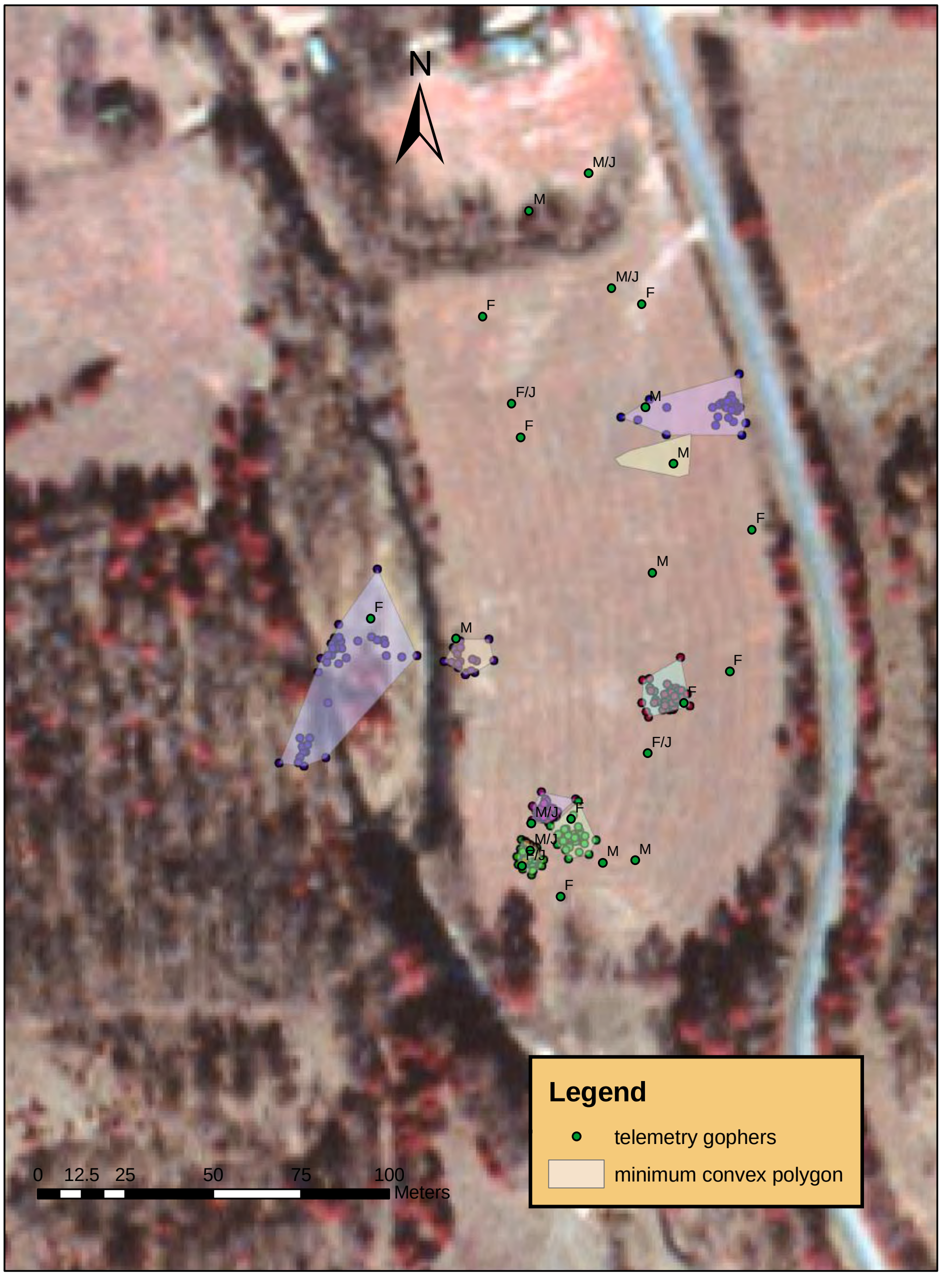

Figure 4.5: Home ranges of 9 Ozark pocket gophers at Site 3 in Izard County, Arkansas in 2007. Some home ranges may overlap. M = adult male, M/J = subadult male, F = adult female, F/J = subadult female.

Figure 4.6: Home ranges of 7 Ozark pocket gophers at Site 5 in Izard County, Arkansas in 2007. Some home ranges may overlap. M = adult male, M/J = subadult male, F = adult female, F/J = subadult female.

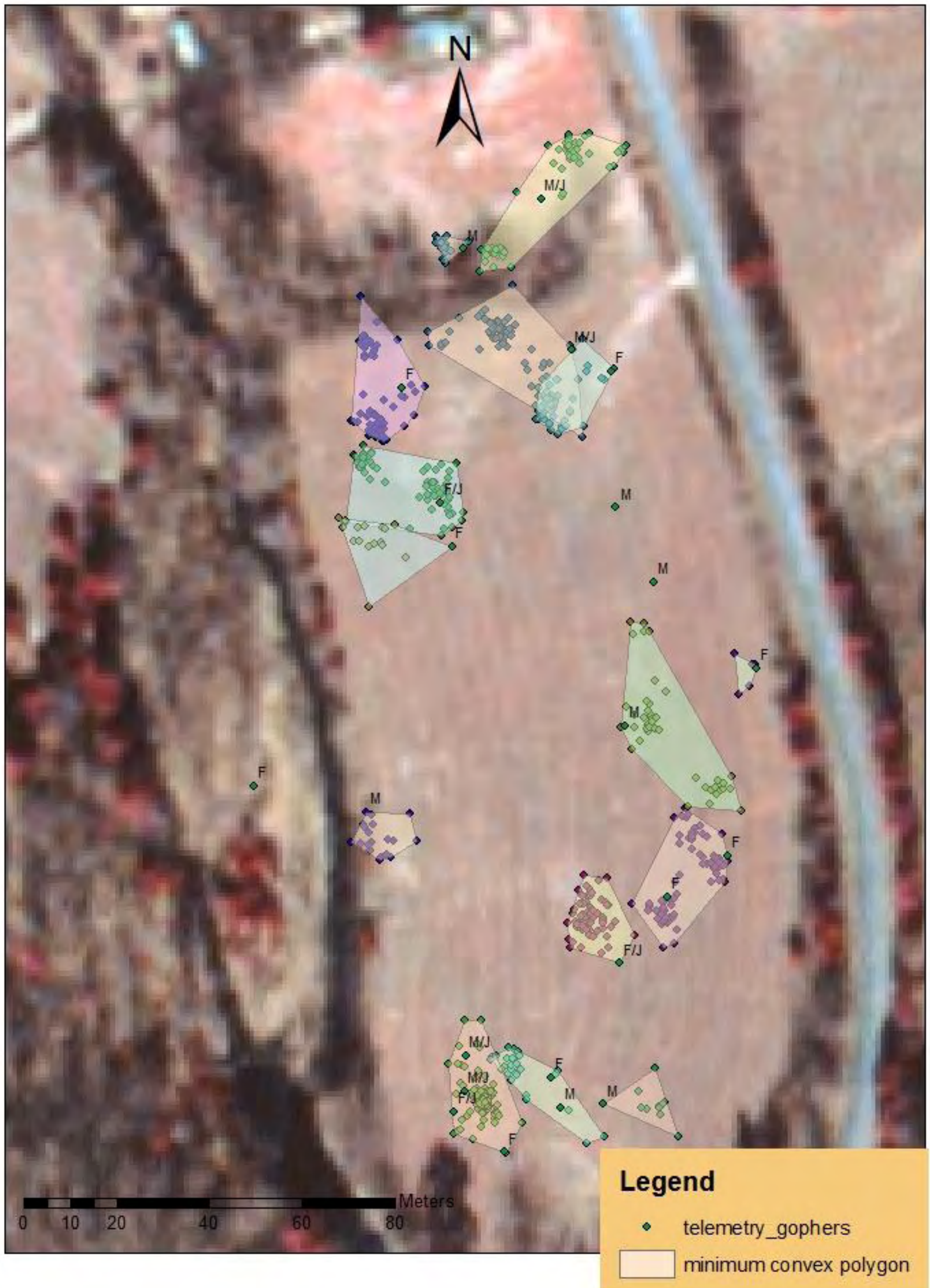

Figure 4.7: Home ranges of 15 Ozark pocket gophers at Site 3 in Izard County, Arkansas in 2008. Some home ranges may overlap. M = adult male, M/J = subadult male, F = adult female, F/J = subadult female.

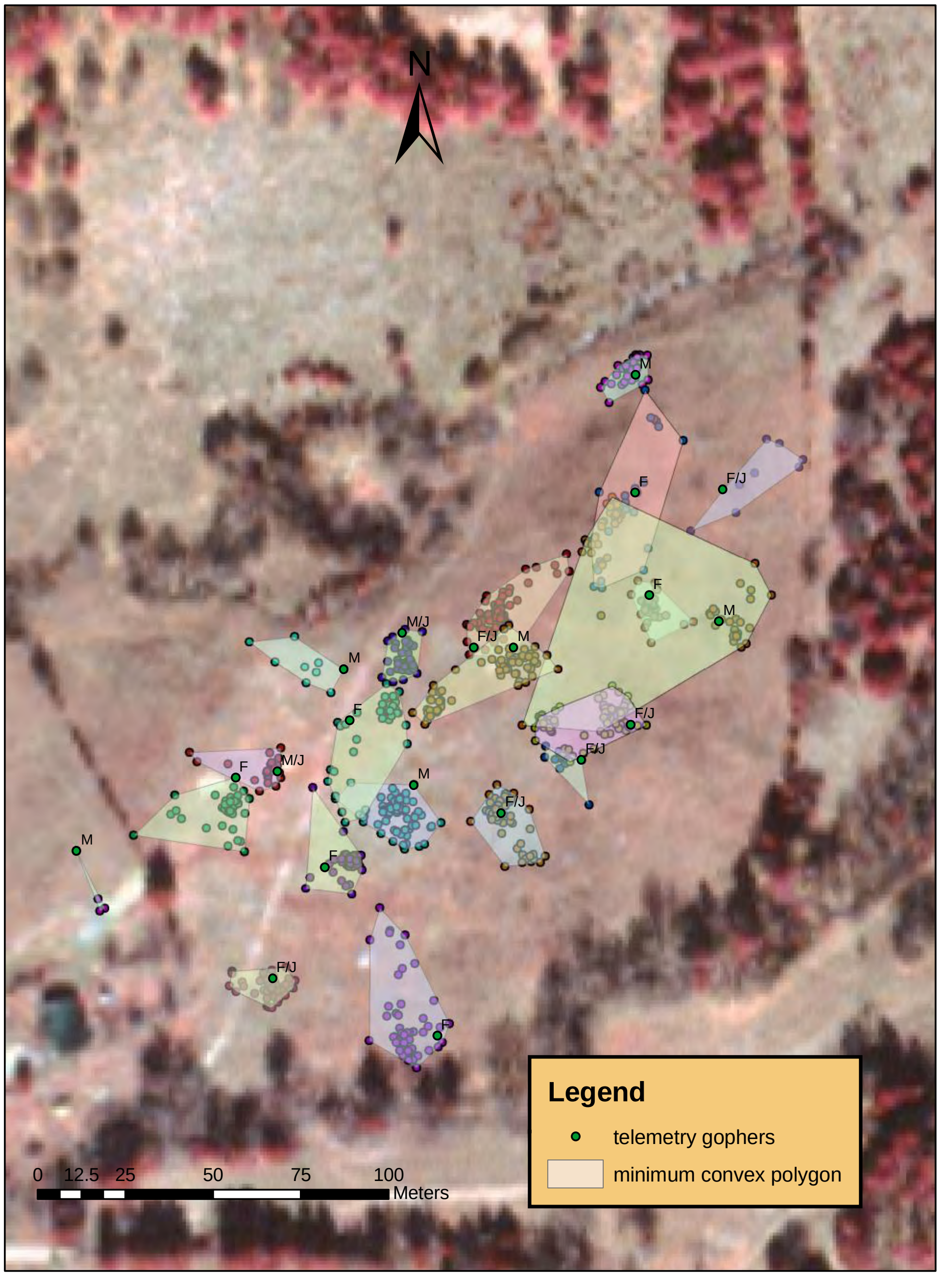

Figure 4.8: Home ranges of 20 Ozark pocket gophers at Site 4 in Izard County, Arkansas in 2008. Some home ranges may overlap. M = adult male, M/J = subadult male, F = adult female, F/J = subadult female.

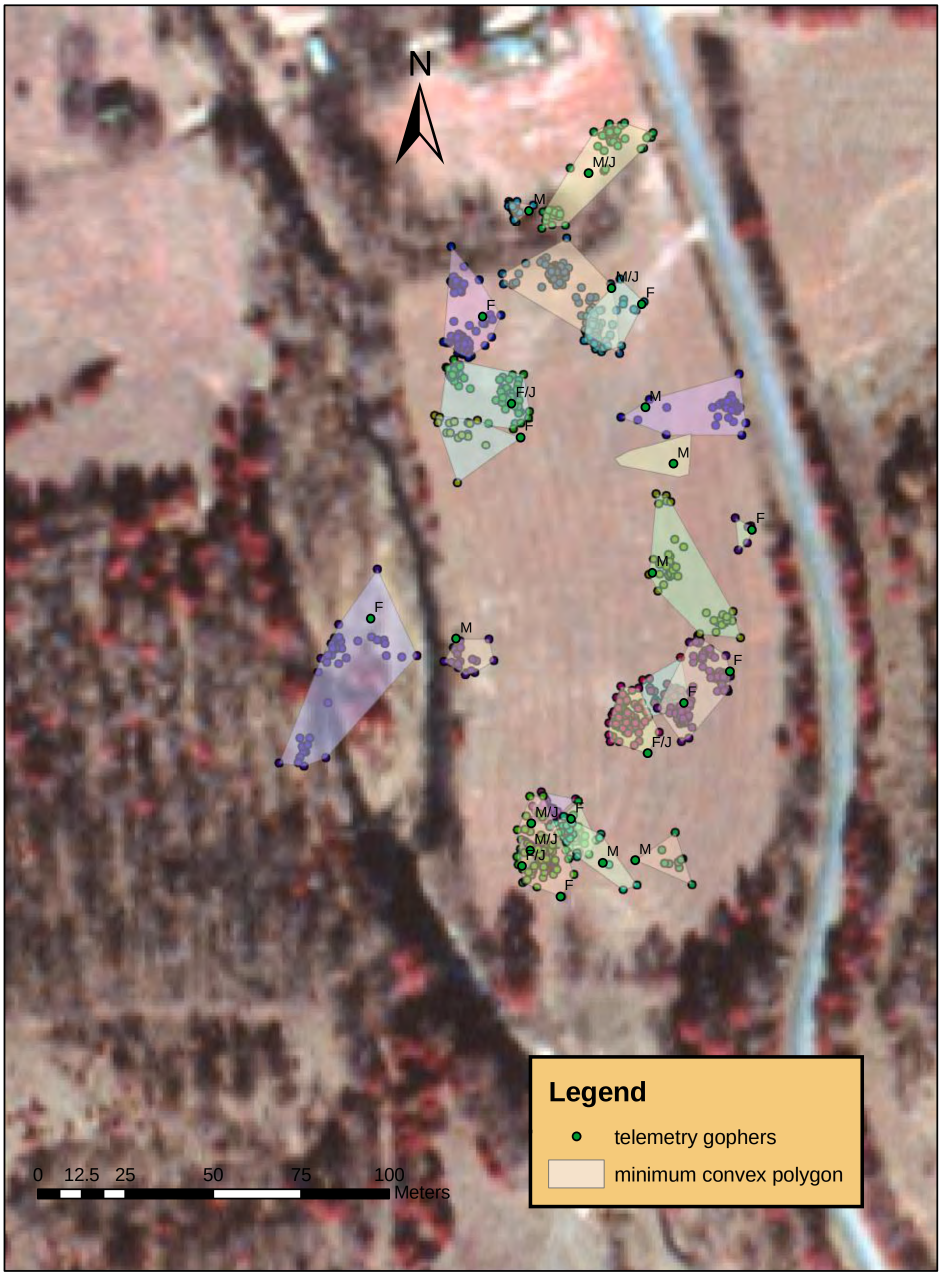

Figure 4.9: Home ranges of 24 Ozark pocket gophers at Site 3 in Izard County, Arkansas in 2007 and 2008. Some home ranges may overlap. M = adult male, M/J = subadult male, F = adult female, F/J = subadult female.

Figure 4.10: Adult male Ozark pocket gopher nest located ~50 cm below ground in Izard County, Arkansas in 2008.

Figure 4.11: Juvenile male Ozark pocket gopher nest located below large rock in Izard County, Arkansas in 2008.

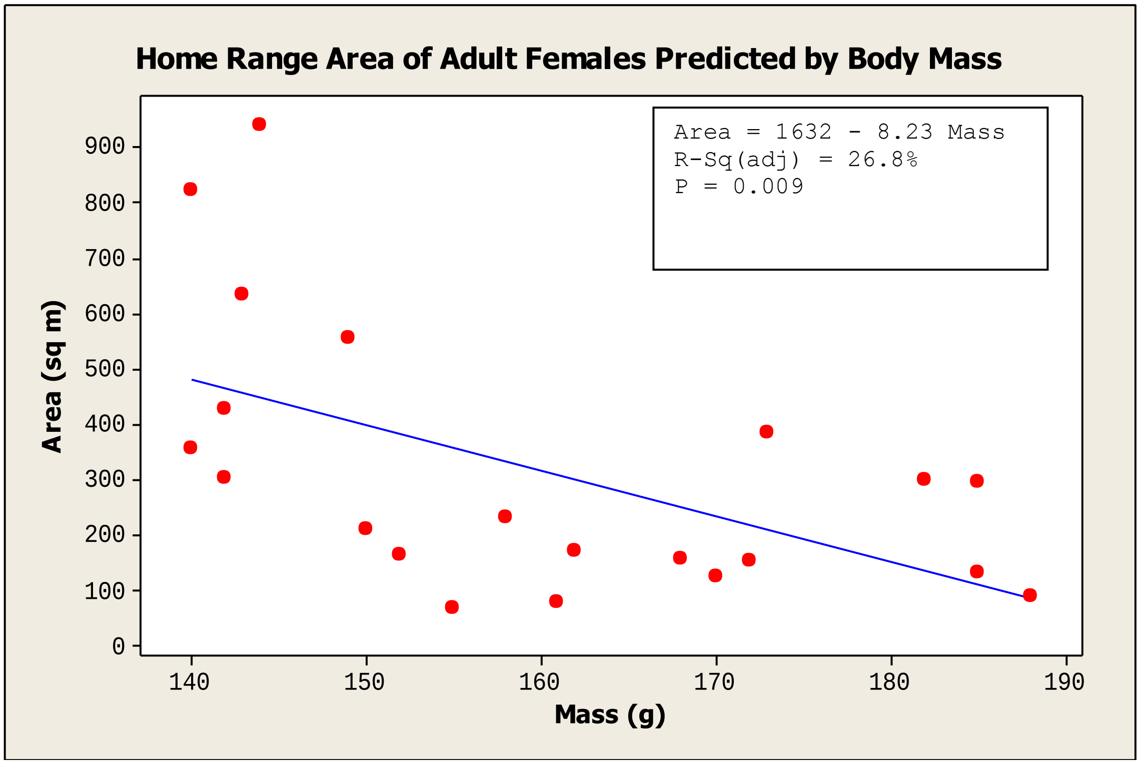

Figure 4.12: Linear Regression of 19 Adult female Ozark pocket gopher home ranges (m^2) predicted by mass (g) in Izard County, Arkansas in 2007 and 2008.

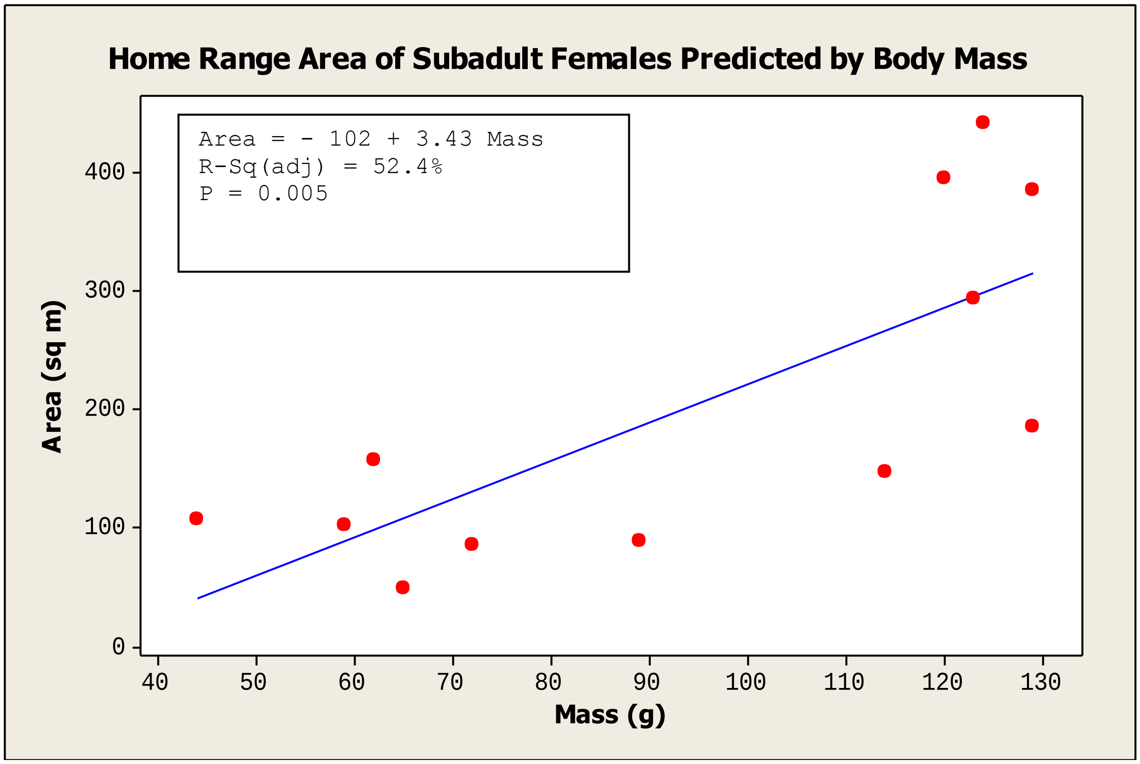

Figure 4.13: Linear Regression of 12 subadult female Ozark pocket gopher home ranges (m^2) predicted by mass (g) in Izard County, Arkansas in 2007 and 2008.

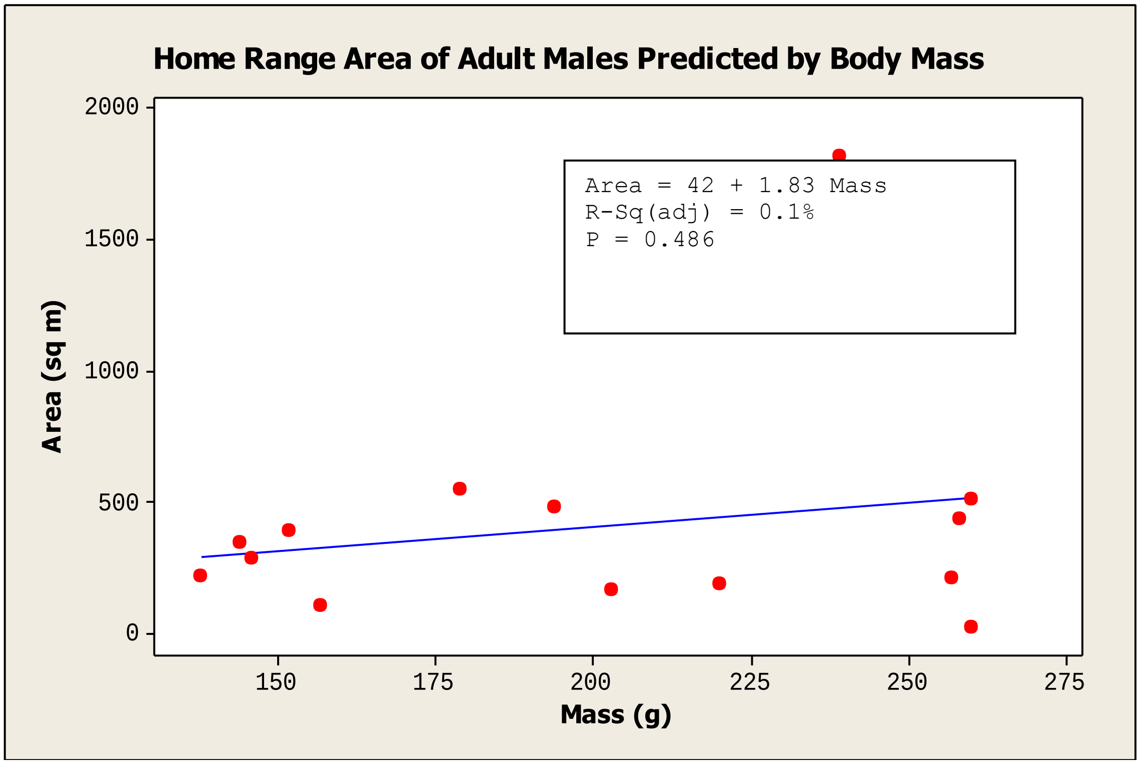

Figure 4.14: Linear Regression of 13 Adult male Ozark pocket gopher home ranges (m^2) predicted by mass (g) in Izard County, Arkansas in 2007 and 2008.

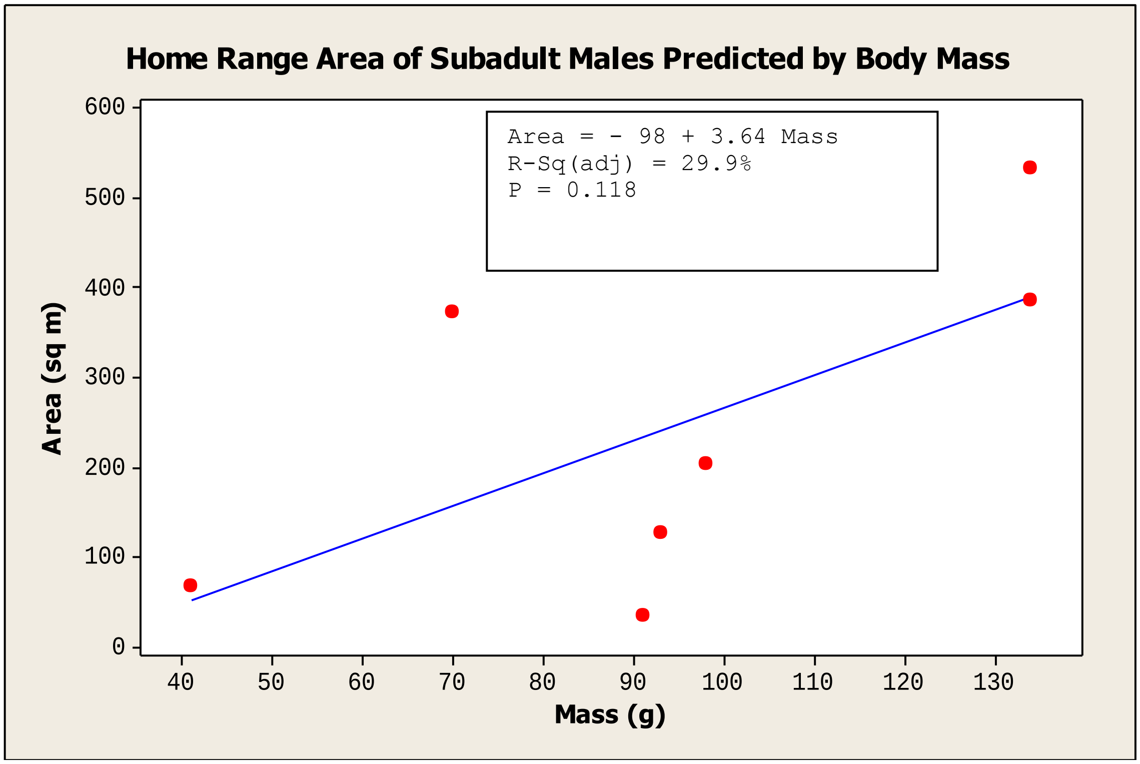

Figure 4.15: Linear Regression of 7 juvenile male Ozark pocket gopher home ranges (m^2) predicted by mass (g) in Izard County, Arkansas in 2007 and 2008.

Figure 4.16: Location where adult male Ozark pocket gopher entered into an existing burrow in Izard County, Arkansas 2008.

Figure 4.17: Snow tracks of an Ozark pocket gopher in Izard County, Arkansas in 2008.

Figure 4.18: Ozark pocket gopher tracks indicating above ground dispersal in Izard County, Arkansas in 2008.

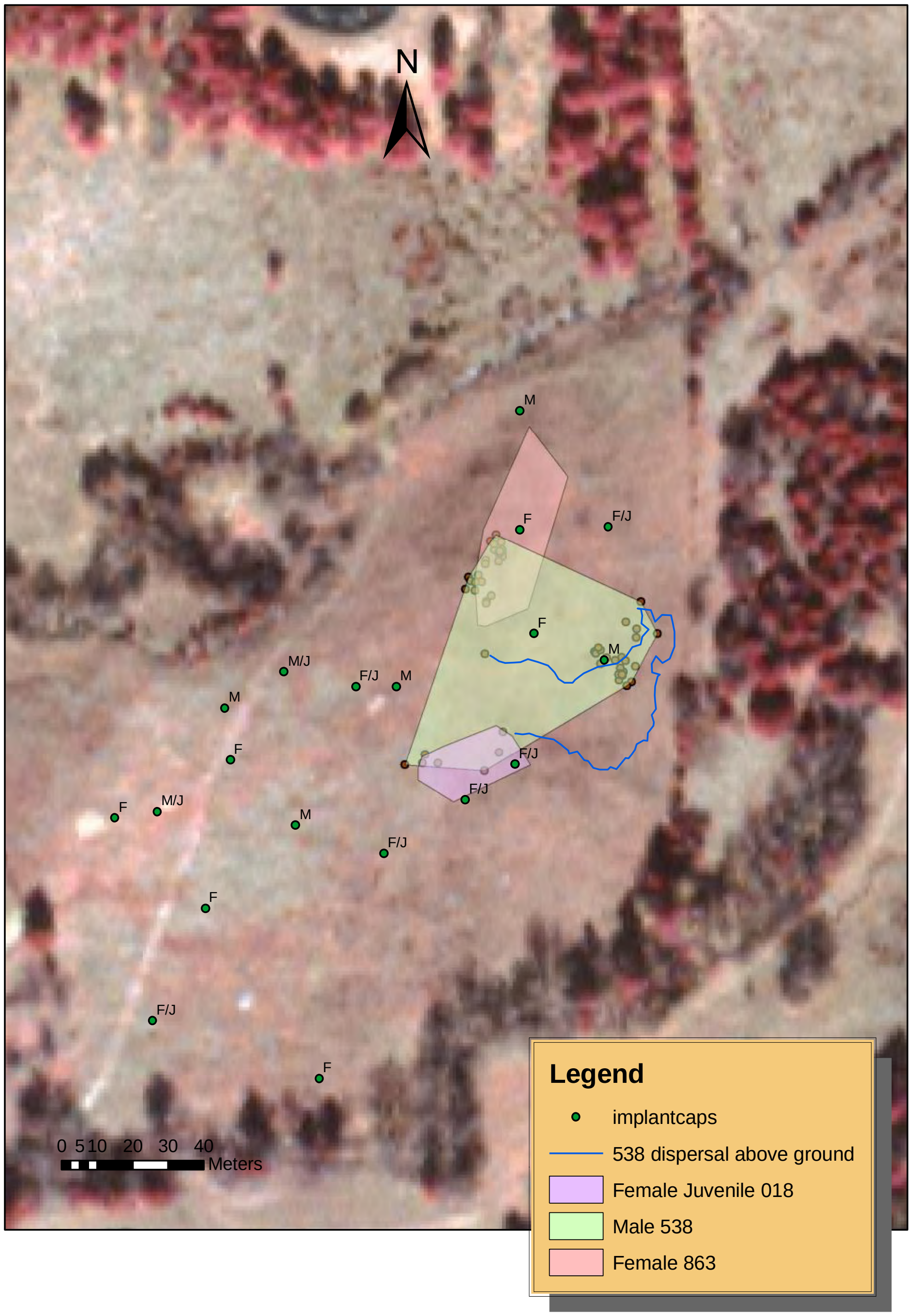

Figure 4.19: Adult male Ozark pocket gopher above ground dispersal path on February 1, 2008 in Izard County, Arkansas. M = adult male, M/J = subadult male, F = adult female, F/J = subadult female.

CHAPTER V

SURVIVAL OF THE OZARK POCKET GOPHER

Abstract

I conducted a radio telemetry and mark-recapture study on Ozark pocket gophers to elucidate survival rates and predators. Kaplan-Meier survival curves were estimated for the radioed individuals. Survival rates were significantly lower in both the winter and spring than in the summer (P-value < 0.0001). During the 2007 season, only two individuals out of 35 died during the telemetry study. The two individuals died within the first 40 days and the remainder of the individuals survived for the duration of the study. During the 2008 season, nine individuals died out of 35. The deaths occurred during the first 95 days and the remainder survived for the duration of the study. Forty four out of 152 individuals were recaptured at least once during the study. One of the mortalities was confirmed after locating a snake after it had consumed the transmittered juvenile male and at least two individuals, possibly three died as a result of a flood in March of 2008.

Introduction

Survival rates of rodents will directly affect the population demographics including dispersal, reproduction, population size and growth, and competition. Rodents are typically short-lived mammals. One group of rodents, the pocket gophers (Geomyidae), generally has greater longevity than other small rodents. Fossorial habits of the pocket gophers partially contribute to this longevity difference. Pocket gophers are solitary and remain in closed underground burrow systems (Chase et al. 1982). These characteristics increase survival rates by reducing the spread of diseases by limited intraspecific interactions and reducing predation.

Survival rates of pocket gophers have not been thoroughly studied. Pocket gophers are difficult to study because they remain underground making direct observations difficult. Intensive trapping is required to conduct mark-recapture or radio telemetry on pocket gophers. However, some studies (Howard and Childs 1959, Wilks 1963) have calculated the longevity for some species of pocket gophers. In a study conducted on Botta's pocket gopher (*Thomomys bottae*), Howard and Childs (1959) determined that the majority only lived for one to two years, but a few lived as long as four years. Although Wilks (1963) only studied survival for one year, he suggested that Attwater's pocket gopher (*Geomys attwateri*) may be capable of living considerably longer than two years. Adams (1966) estimated that the turnover-rate of *Geomys bursarius* in Minnesota was 4.5 years. However, limited data exists on mark-recapature studies that estimate survival rates in the plains pocket gophers (*Geomys bursarius*).

Previous radio telemetry on plains pocket gophers did not elucidate any estimates for survival rates, only home range estimates and behavior (Artmann 1967, Zinnel 1992, Benedix 1994). Thus, I employed both mark-recapture and radio telemetry on a subspecies of the plains pocket gopher, the Ozark pocket gopher (*Geomys bursarius ozarkensis*), to elucidate survival rates and predators. Previous studies were able to document predation using radio telemetry (Bandoli 1987, Witmer et al. 1996). The Ozark pocket gopher is a disjunct subspecies occurring only in Izard

County, Arkansas. This disjunct subspecies, due to its restricted range and population size (Kershen 2004), is an excellent study organism to determine if the same environmental restraints act on its survival as compared to other pocket gopher species. Furthermore, knowledge of survival rates and predation is also important for conservation of this subspecies too.

Methods

Live Trapping and Marking

I conducted mark-recapture and radio telemetry studies at 5 field locations (see Appendix A for GPS locations). Each field site was ~2-4 ha and was bordered by roads, creeks, woodland, or a combination. Pocket gophers were live trapped and individually marked with a passive integrated transponder (PIT tag) using the technique described in Fokidis et al. (2006). Both Baker and Williams (1972) and Connior and Risch (*in press* a) live traps were used. Live trapping was conducted from January-June 2007 and from December 2007-March 2008. Mass of individuals was noted (recorded to the nearest gram with a Pesola® 300g spring scale [Pesola AG, Baar, Switzerland]) along with gender by examining external genitalia. Reproductive condition was also noted as either reproductively active or inactive. I used multiple external characteristics to reduce error in sexing individuals (Witmer et al. 1996). Captured individuals were classified as juvenile, sub-adult, or adult based on pelage, sexual characteristics, and mass. Sub-adults have a grayer pelage and longer, softer hair than adults and can be identified by these characteristics (Schwartz and Schwartz 1981) whereas juveniles weighed <100 g. When marked pocket gophers were recaptured, the date and location was recorded along with mass and reproductive condition.

Radio Telemetry

Some of the live trapped individuals were selected to be implanted with a radio transmitter to evaluate survival rates of pocket gophers along with any predation events. Selected individuals were implanted with a subcutaneous radio transmitter after which implanted gophers were released at their capture site within an hour. Captured pocket gophers were anesthetized with Isoflurane (Webster Veterinary Supply, Inc., Sterling, MA) and then the radiotransmitter was implanted subcutaneously between the scapula and then the incision was glued closed (Chapter III, Cameron et al.1988). A total of 70 individuals were successfully implanted with radio transmitters (Connior and Risch *in press* b). I estimated survival rates for 19 adult males and 27 adult females along with 24 juveniles. Adults were tracked either daily or every other day and juveniles were tracked daily. At least some individuals were tracked during the months of December, January, February, March, April, May, June, and July. I did not collect any survival data on pocket gophers in August, September, October, or November.

Locations were recorded until one of the three following events occurred: transmitter failure, mortality, or unable to relocate. Survival estimates were calculated for individuals up to the point that the transmitter failed. Known predations were recorded and identified to species when possible or higher taxon groups. When mortality was not due to predation, I determined cause of death if possible by noting external condition and environmental circumstances. If I was unable to relocate a radioed individual, then survival rates were calculated for the individual up to the last known point that the pocket gopher was alive (usually the day before I was unable to relocate a transmitter). This probably underestimates survival because possibly some of the pocket gophers we were unable to relocate had been predated.

Kaplan-Meier survival curves were estimated for the radioed individuals using PROC LIFETEST in SAS 9.1 (Allison 1995). Estimates of survival were produced for the 2007 field season, 2008 field season, and 2007 and 2008 field seasons combined. Additionally, Wilcoxon test was conducted for Chi-square analysis on the combined field seasons to determine if there were differences in survival between winter, spring, and summer. Survival data collected in December, January, and February were categorized as winter data; March, April, and May were categorized as spring data; and data collected in June and July were categorized as summer. Survival rates were too high to determine any significant differences in survival between genders or age classes (see results). Thus, only differences in seasons are given. I also estimated survival rates on the combined field seasons by deeming the individuals that were unable to be relocated as dead to determine a range in survival rates between known mortality and possible mortality.

Results

Mark-Recapture

Forty four out of 152 marked individuals were recaptured at least once during the study (Appendix A). Several individuals were recaptured approximately one year after the initial capture (Figure 5.1). However, none of the juveniles that had radio transmitters implanted in the first year were recaptured the following year.

Radio Telemetry

I only confirmed 11 out of 70 individuals that died during the radio telemetry study (Table 5.1). Only one predator, a prairie kingsnake (*Lampropeltis calligaster calligaster*), could be positively identified to species. I confirmed this when the snake was located after it had consumed the transmittered juvenile male (Connior et al. *in pressa*). I could not identify the predators of the other six individuals. However, mammalian teeth marks were discovered in one of the recovered transmitters. Upon excavation, one adult female gopher was found dead in its nest. The cause of death was unknown but it is unlikely that it was due to the implantation of the radio transmitter since the incision had completely healed. At least two individuals and possibly three died as a result of a flood in March of 2008. One individual drowned, one was crushed by a backhoe that had sunk in the ground due to saturated soil directly above the gopher's nest, and only a transmitter was recovered from the third individual. The third individual possibly had drowned and was subsequently preyed upon. Rains that often exceeded six inches in a 24-hr period during the week of March 17, 2008 led to flood events that had recurrence intervals of 25 to 100 years (Petersen 2008). Figures 5.2 and 5.3 show water levels of the nearby North Sylamore Creek at Fifty Six, Arkansas and White River at Allison, Arkansas.

During the 2007 season, only two individuals out of 35 died during the telemetry study. The two individuals died within the first 40 days and the remainder of the individuals survived for the duration of the study (Figure 5.4). During the 2008 season, nine individuals died out of 35 during the telemetry study. The deaths occurred during the first 95 days and the remainder survived for the duration of the study (Figure 5.5).

When known survival rates for the combined seasons (Figure 5.6) are compared to survival rates where all individuals that were not relocated were assumed dead (Fig. 5.7), survival rates range from 84 % to 66% for up to 164 days. Season was the only variable that significantly affected survival throughout the study. Survival rates were significantly lower in both the winter and spring than in the summer (P-value < 0.001). Overall, survival rates estimated with radio telemetry data were high.

Discussion

The mark-recapture data produced relatively low survival rates. Two main reasons contributed to this. First, I did not conduct intensive mark-recapture because I focused my data collection on the radio telemetry. Second, all the field locations were on active cattle and hay pastures on private property. Thus, I limited intensive live trapping to reduce economic losses to landowners as a result of reduction of ground cover (i.e., grass or hay) due to digging holes for trap placement. Mean monthly survival rates based on the mark-recapture were not calculated due to the prior reasons. Subsequent trapping in 2008 resulted in numerous new individuals occupying areas inhabited by other individuals the previous year. This suggests that pocket gophers have a fairly high turnover rate. All individuals that were recaptured ~one year later were all adults at time of first capture. Thus, Ozark pocket gophers can live at least 2 years or more. Several of the large adult males were grizzled around the face and head which might indicate that they were > 2 years old and reaching senility (Wilks 1963). The oldest male and female *Thomomys bottae* that Howard and Childs (1959) recorded was 3 years and 4 years 9 months, respectively.

The high survival rates of juveniles during the 2007 tracking period and the paucity of juvenile recaptures the following year presents an enigma. I specifically live trapped the area where I had tracked the juveniles the year before and surrounding areas to document juvenile survival. However, I was not able to recapture a single juvenile. I did not monitor the population during the late summer through fall. Therefore, either two things occurred: the juveniles did not survive through the fall or they dispersed far enough away and left my study area. Additional tracking during late summer and fall might elucidate the reasons why juveniles did not show up in the population the following year.

Two main mortality factors and survival rates were indicated by radio telemetry. The highest cause of mortality was predation and the second factor was a flood event. Seven of the 11 mortalities were the direct result of predation and another two, possibly three, were the result of either a direct or indirect effect of flooding.

Although no avian predations were observed during my study, the range of numerous bird predators occurs in the study area, such as barn owls (*Tyto alba*), great horned owls (*Bubo virginianus*), broad-winged hawks (*Buteo platypterus*), and red-tailed hawks (*Buteo jamaicensis*), that could potentially prey on pocket gophers (James and Neal 1986). *Geomys bursarius* has been recorded in the prey of owls (Cahn and Kemp 1930, Goyer et al. 1981, Gubanyi et al. 1992), hawks (Cartron et al. 2004), and even bald eagles (*Haliaeetus leucocephalus*; Boal et al. 2006). Potential mammalian predators that occur in the area are red foxes (*Vulpes vulpes*), gray foxes (*Urocyon cineroargentius*), long-tailed weasels (*Mustela frenata*), coyotes (*Canis latrans*), and dogs (*Canis familiaris*) and cats (*Felis catus*; Sealander and Heidt 1990). *Geomys* *bursarius* have been recorded in the diet of weasels (Polderboer et al. 1941), red and gray foxes (Hatfield 1939, Scott 1955), and coyotes (Best et al. 1981). Even though I did not witness cats and dogs preying on pocket gophers, numerous landowners reported that they had witnessed both of these actively hunting gophers. Domestic cats have been recorded preying on *Thomomys bottae* in California (Howard and Childs 1959). I witnessed several large cats at the study site the same time that several of the unknown predations occurred. I suspect that some of the predations were the direct result of these domestic cats. Potential snake predators besides the prairie kingsnake that occur in the area are eastern coachwhips (*Masticophis flagellum*), eastern racers (*Coluber constrictor*) and speckled kingsnakes (*Lampropeltis getula*; Connior et al. *in press* b).

An unexpected contributing factor to mortality during the study was a flood event that ultimately led to the deaths of three radioed gophers. All three of these deaths occurred in the same field as a result of the entire field being inundated during the rainfall. As soil becomes saturated, subterranean burrows can become flooded even in the absence of standing water on the soil surface. The extent to which this flood impacted the overall population is unknown; however, in this particular field 3 out of 8 radioed gophers died. Many other locations where the Ozark pocket gophers exist were also inundated by the rainfall. Pocket gophers often occur near streams and rivers due to the sand deposition that is conducive to tunneling. Yet, documentation of pocket gophers drowning due to flooding has not been recorded previously in the literature.

Geomys breviceps were restricted from permanently inhabiting areas that received frequent flooding in Texas (Davis et al. 1938). Hansen and Beck (1968) suggested that water has a direct effect on the distribution of *Thomomys talpoides* in areas where water accumulates sufficiently. Ingles (1949) found that during the spring thaw *T. monticola* could not remain in the saturated soil and had to move their burrows to drier areas. Furthermore, Grinnell (1914) explained the absence of pocket gophers in the Lower Colorado Valley by the yearly flooding which would drown out the gopher population. Although several studies have indicated that flooding and soil moisture affect the distributions of pocket gophers, Williams (1976) conducted intensive investigation and did not find any evidence where pocket gophers had drowned or wandered outside of their burrows during flash floods. Pocket gophers would be expected to drown during these quick flooding events because they would not have ample time to extend their burrows into drier soil. The pocket gopher that was crushed by the backhoe had made a temporary nest ~7.5 cm below the ground surface during this flood event likely exposing it to the backhoe. Three other temporary nests made by other individuals were also discovered. Pocket gophers may construct these temporary nests to buffer against mortality induced by flooding events and the saturation of soil by water during wet periods.

The higher mortality in the winter and the spring as opposed to the summer can be explained by their activity. Pocket gophers are active throughout the year but with peak activity in the spring. Gophers are very active in the spring during the reproductive season when they are focused on mating (Chase et al. 1982). The increased activity during the spring due to the breeding season makes them susceptible to predators since they are not confined to their deep underground nests. They are also active in the winter although not as much as in the spring (Miller 1948). Even though they are not as active in the winter as the spring, their susceptibility to predation is greater because the majority of small mammals hibernate or remain inactive unlike pocket gophers. On the other hand, pocket gopher mortality is very low in the summer due to their limited activity and other prey items available to potential predators.

The mark-recapture and radio telemetry data seem to contradict each other. The mark-recapture suggests high mortality while the telemetry suggests low mortality. Indeed, numerous new individuals were captured in 2008 after extensive marking of the populations at the study sites the previous year. Yet, telemetry survival data of individuals indicates that gophers have rather high survival rates. I did not conduct the study during the fall season; thus, a data gap occurs in the survival data. Environmental pressures and events may occur during this period not seen in other seasons, explaining the contradiction between radio telemetry and mark-recapture. Additionally, mark-recapture data may be confounded by the fact that some of these areas have densities ≥50 individuals/ha (Kershen 2004). These densities would make actual individual recaptures difficult using my limited trapping techniques. Thus, high densities in mark-recapture studies would mask actual survival times because survivability would be underestimated due to the population size. Larger sample size and longer study periods then I used would be required to elucidate Ozark pocket gopher survival using mark-recapture.

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Table 5.1**:** Fate of 11 radiotransmittered Ozark pocket gophers in Izard County, Arkansas in 2007 and 2008. M = male, F = female, A = adult, J = subadult.

Tag	**Sex**	**Age**	**Mass (g)**	**Duration Tracked**	**Fate**
076 023 294	M	A	198	40	Unknown Predator
076 067 014	M	A	260	53	Unknown Predator
076 102 032	M	A	257	10	Unknown Predator
076 042 053	M	J	84	11	Prairie Kingsnake
076 071 050	M	J	134	94	Crushed by Backhoe
076 017 562	F	A	150	85	Drowned in Flood
076 038 066	F	A	142	95	Possibly Drowned
076 092 109	F	A	163	25	Unknown Predator
076 058 028	F	A	150	7	Unknown Predator
076 048 078	F	A	182	66	Died in Nest
076 047 873	F	J	89	25	Unknown Predator

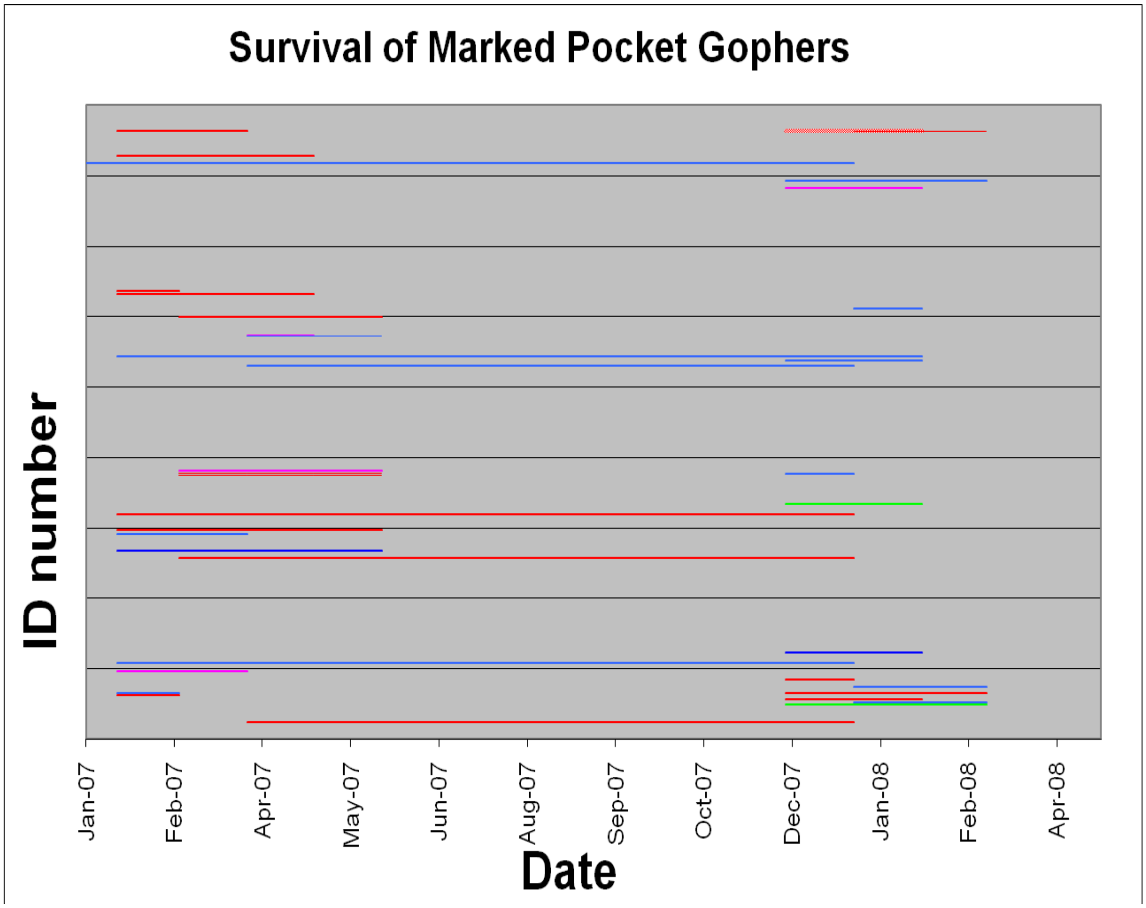

Figure 5.1: Duration of 44 marked Ozark pocket gophers in the population in Izard County, Arkansas in 2007 and 2008.

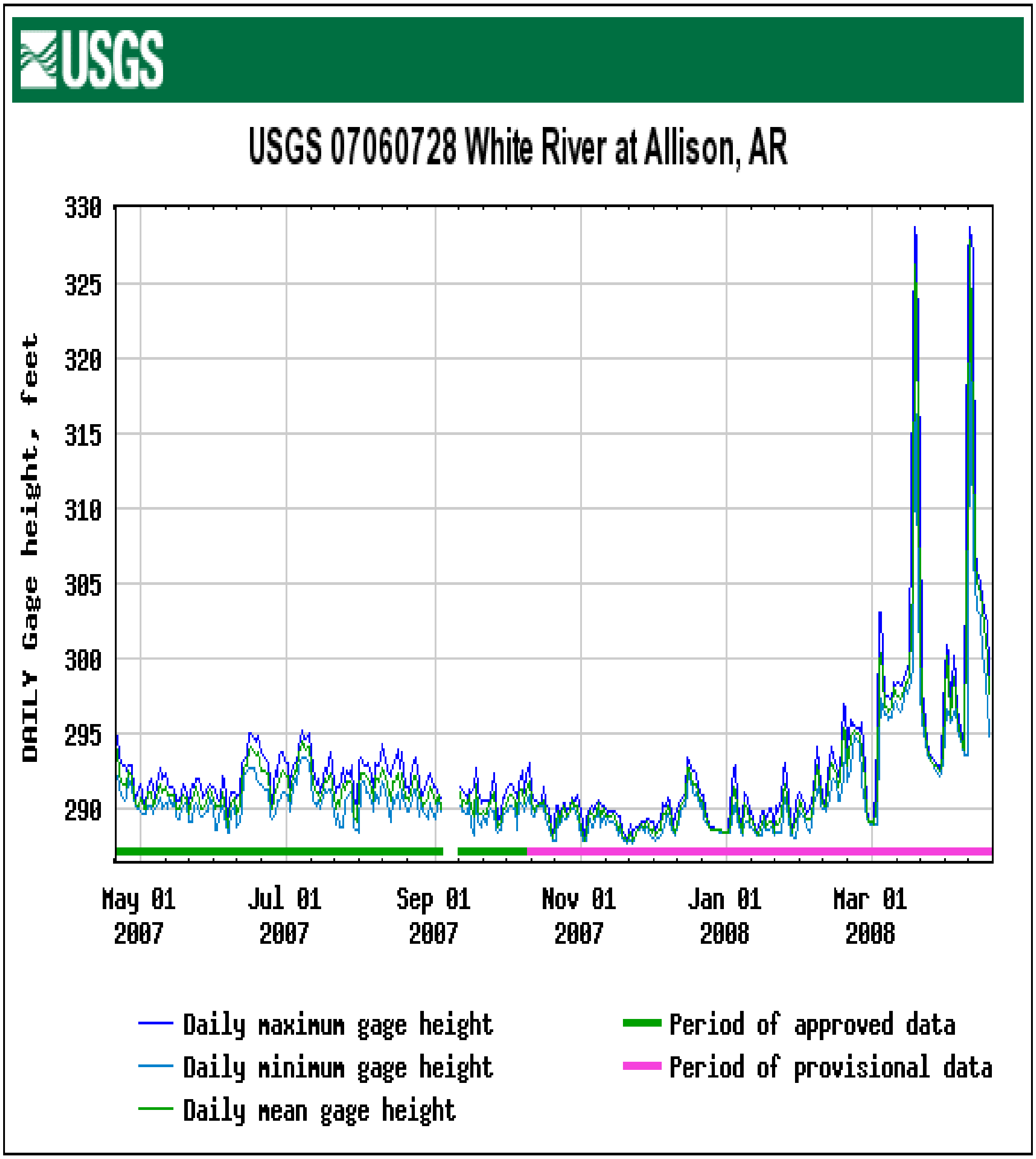

Figure 5.2: United States Geological Survey (USGS) water gauge closest to study area showing the flooding events of the White River at Allison, Arkansas in March of 2008.

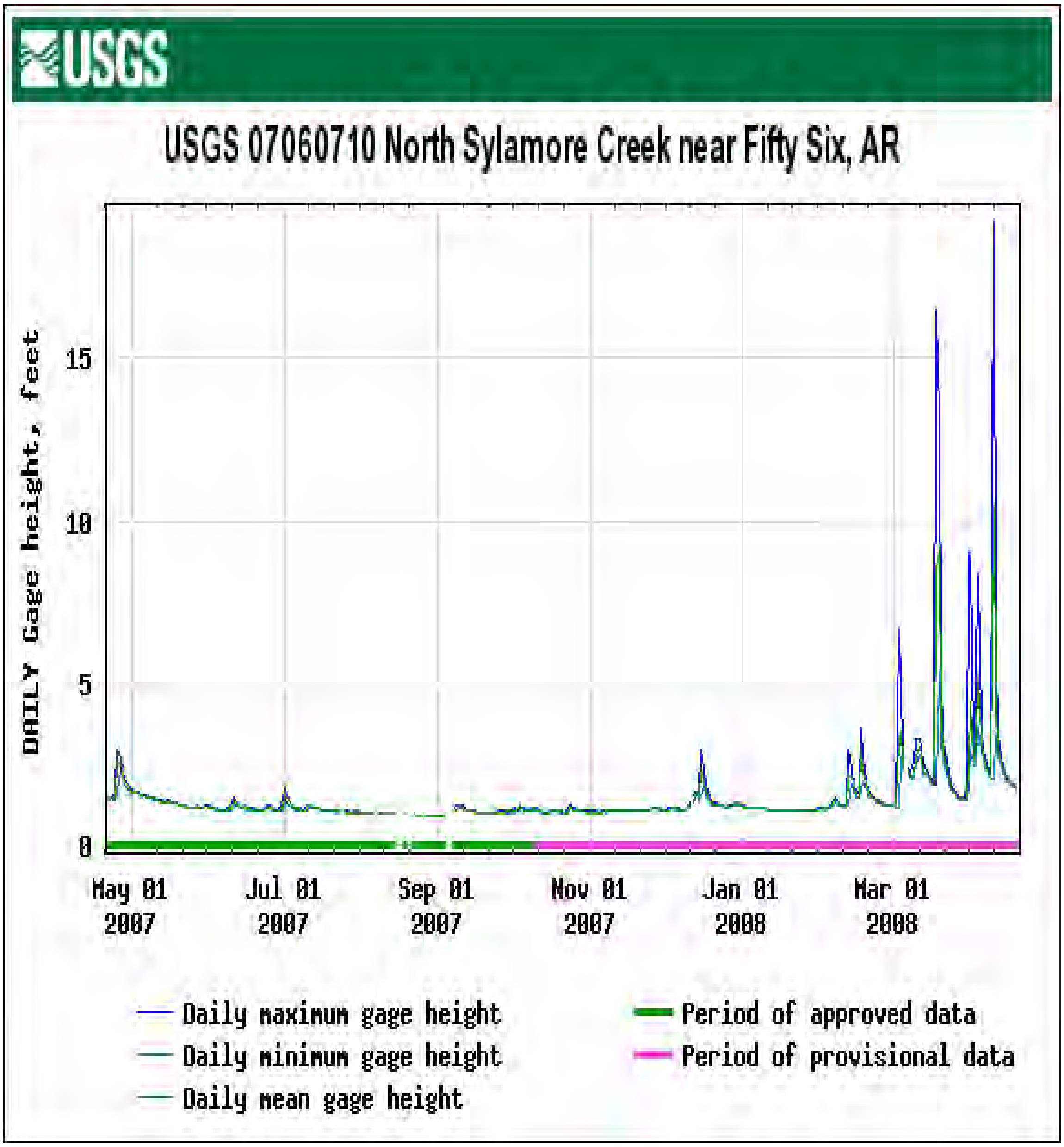

Figure 5.3: United States Geological Survey (USGS) water gauge showing the flooding events of Nearby North Sylamore Creek at Fifty Six, Arkansas in March of 2008.

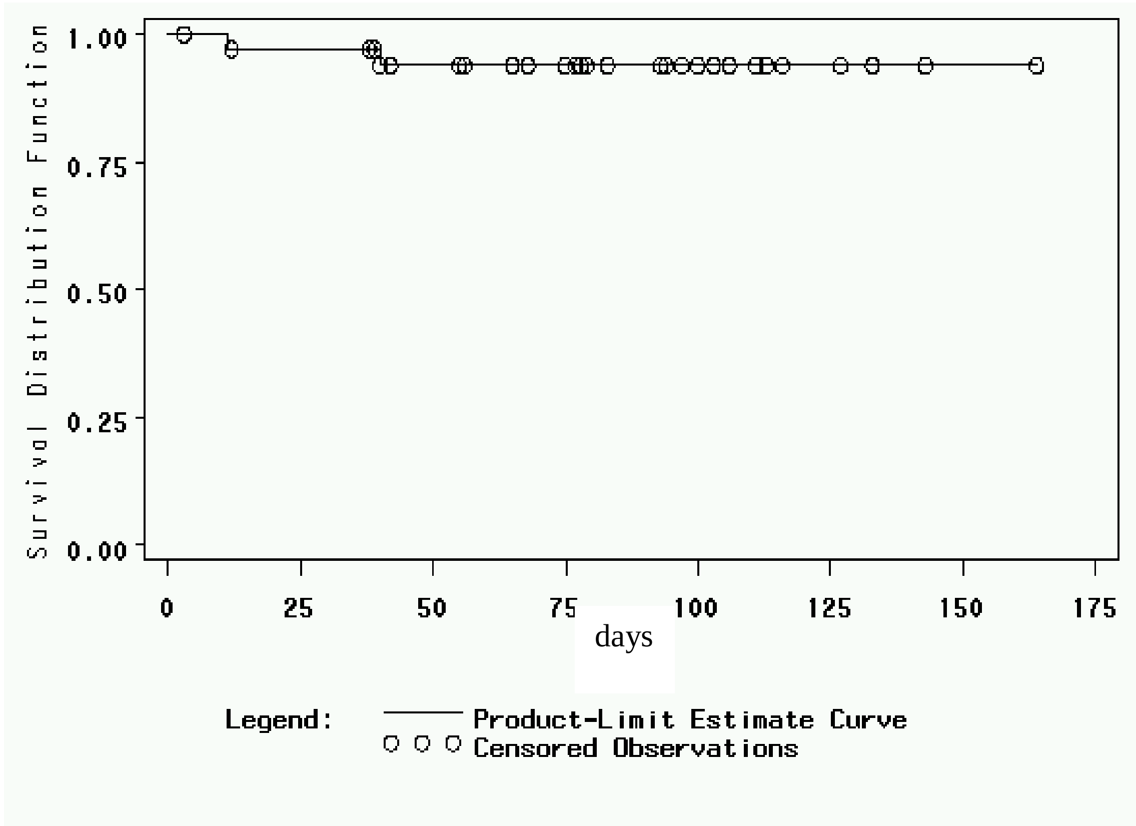

Figure 5.4: Survival Curves for 35 radiotransmittered Ozark pocket gophers in Izard County, Arkansas in 2007.

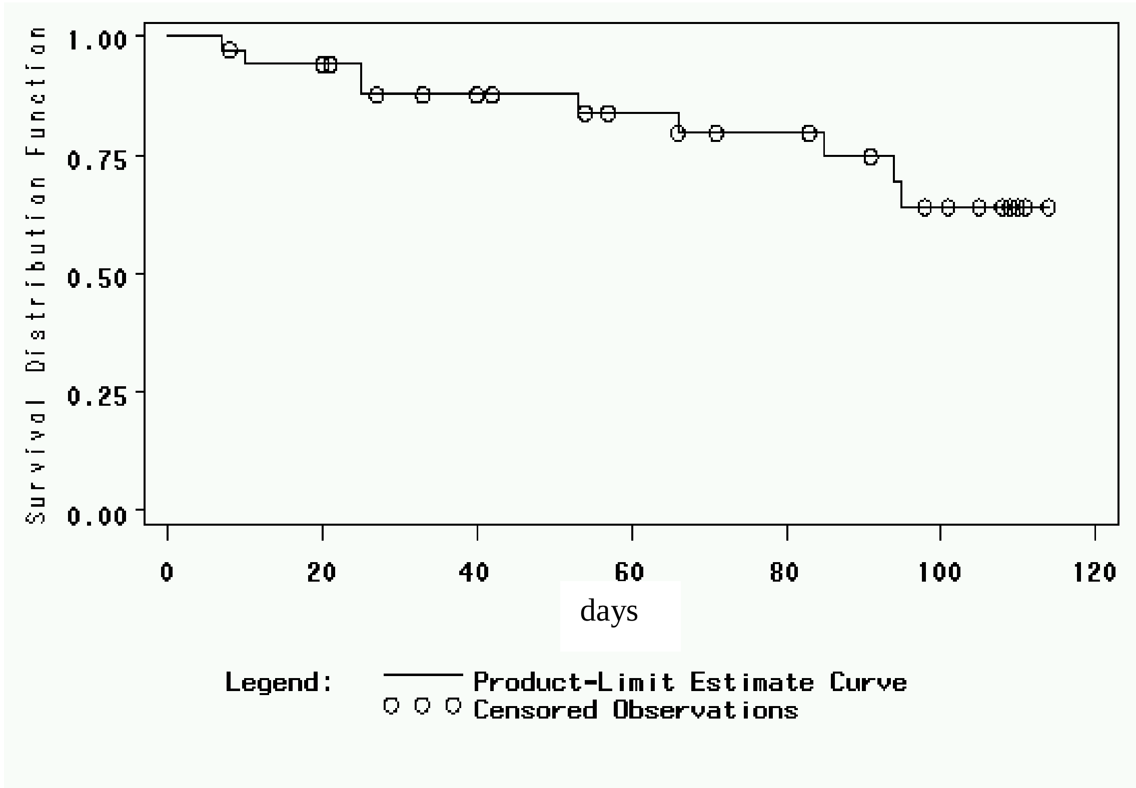

Figure 5.5: Survival Curves for 35 radiotransmittered Ozark pocket gophers in Izard County, Arkansas in 2008.

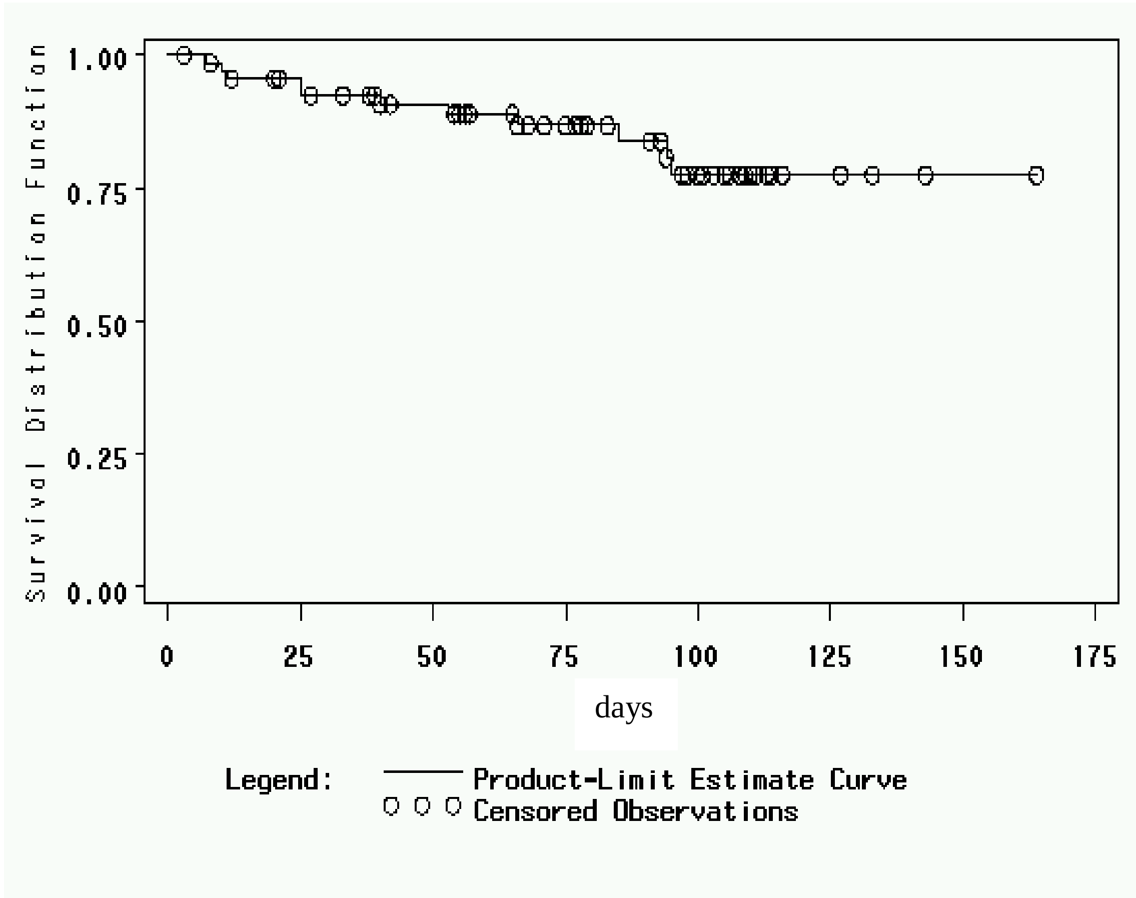

Figure 5.6: Combined 2007 and 2008 survival curves for 70 radiotransmittered Ozark pocket gophers in Izard County, Arkansas.

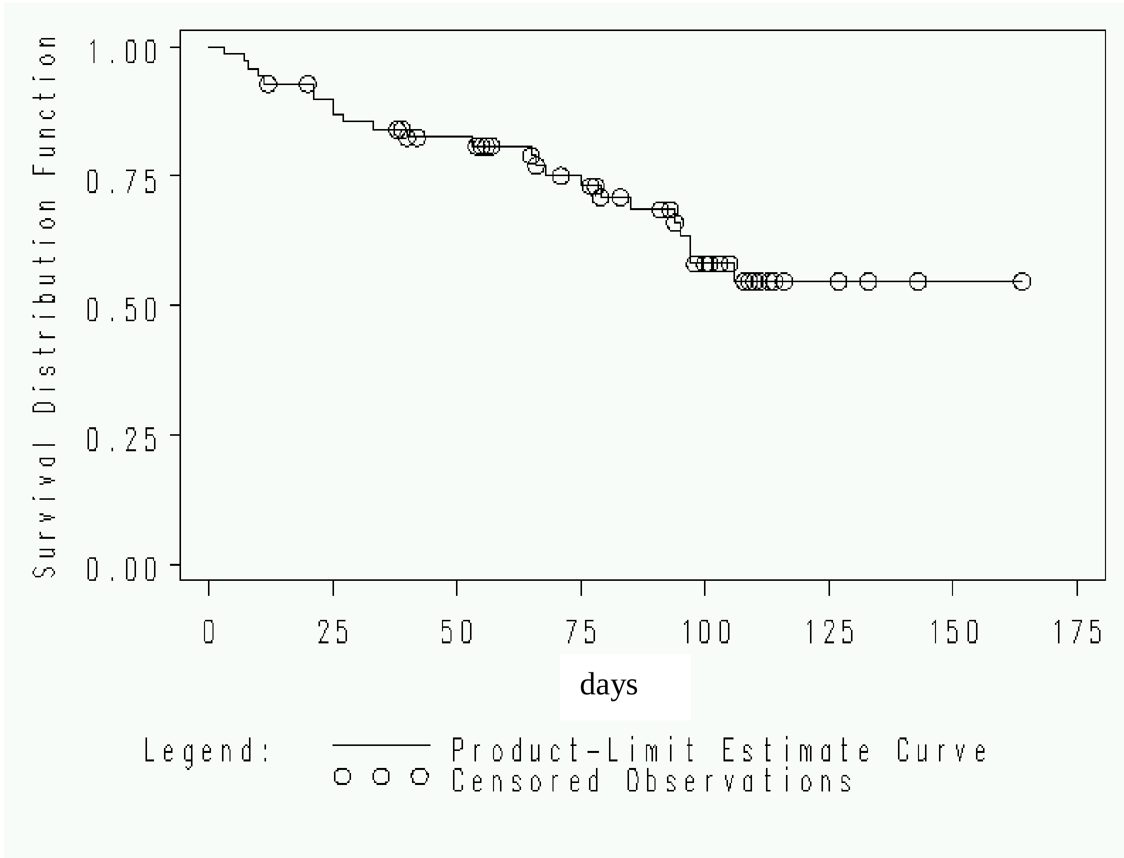

Figure 5.7: Combined 2007 and 2008 survival curves for 70 radiotransmittered Ozark pocket gophers where unknown fates were considered mortality in Izard County, Arkansas.

CHAPTER VI

AMPHIBIAN, REPTILE, AND SMALL MAMMAL ASSOCIATES OF OZARK POCKET GOPHER HABITAT IN IZARD COUNTY, ARKANSAS

*accepted in a modified version in the Journal of the Arkansas Academy of Science

Abstract

I conducted a study of the amphibian, reptile, and small mammal community assemblage of Ozark pocket gopher (*Geomys bursarius ozarkensis*) habitat in north-central Arkansas. I used two methods to capture individuals: hand capture and drift fences. During the study, I captured and marked a total of 9 frog, 4 salamander, 5 lizard, 3 turtle, 16 snake, and 8 small mammal species exclusive of pocket gophers. I found one hatchling three-toed box turtle (*Terrapene carolina triunguis*) and one rough earth snake (*Virginia striatula*) inside a pocket gopher burrow and mound, respectively. Additionally, I witnessed both eastern racers (*Coluber constrictor*) and eastern coachwhips (*Masticophis flagellum*) retreat into pocket gopher burrows, as well as Hurter's spadefoots (*Scaphiopus holbrookii hurterii*) burrow into pocket gopher mounds when released. My results highlight the importance of mammalian burrows, specifically pocket gophers, to other vertebrate associates in grassland ecosystems. Both conservationists and managers need to determine the pocket gopher's impact on ecosystem health and viability, specifically in natural grasslands, before conservation and/or management strategies are employed.

Introduction

Pocket gophers are fossorial rodents that mound dirt above ground while burrowing, which can alter the temporal microhabitat significantly. Prior to the 1990s, all pocket gophers in Arkansas were classified as Baird's pocket gopher (*Geomys breviceps*; Sealander and Heidt 1990). However, a second species, the Ozark pocket gopher (*G. bursarius ozarkensis),* was described through further DNA testing and additional ectoparasite examination (Elrod et al. 1996, 2000). The Ozark pocket gopher is endemic to Izard County, Arkansas (Elrod et al. 2000, Kershen 2004), and is currently a "species of greatest conservation need" in the Arkansas Wildlife Action Plan (Anderson 2006). Thus, the Ozark pocket gophers' impact on the ecology of their habitat community should be determined before making future management/ conservation decisions. Previous studies have shown that pocket gopher habitats are high in species richness and provide abundant cover for associates (Howard and Childs 1959, Vaughan 1961, Wilks 1963).

As part of a larger study, I conducted an inventory of Ozark pocket gopher associates (i.e., amphibians, reptiles, and small mammals) found both on the surface and in the burrows. My primary objective was to document the amphibians, reptiles, and small mammals that use pocket gopher habitat.

Methods and Materials

The study area consisted of 2 study sites (Site 1, Site 2) located on private property in Izard County, Arkansas (see Appendix A for GPS locations). Both study sites were ~ 4 ha open, grassy cattle pastures bordered by small creeks, roads, and woodland.

I collected specimens along drift fences and by hand. Drift fences were placed at the periphery of the pastures, as I used drift fences to assess possible pocket gopher dispersal. I ran two drift fences per site at two sites for a total of 101 trap nights per site during 3 March to 2 July 2007 to capture species that co-exist with pocket gophers. The drift fences measured 33 m in length and had an 18.9 l bucket pitfall trap at each end with an additional 18.9 l bucket on either side of the drift fence every ca. 8 m (8 buckets per fence). I also placed a funnel trap 12 m from the end of the drift fence on either side. The funnel traps (90 x 30 x 30 cm) were made of 0.62-cm wire mesh hardware cloth and had double entrances.

I placed two additional drift fences at Site 2 from 2 January to 4 April 2008. These drift fences were similar to those described above, except, they lacked funnel traps. The funnel traps were not installed due to cold temperatures that would cause mortality to captured individuals.

I captured additional vertebrate species by hand at both sites by searching by sight and excavation of burrows during pocket gopher trap placement. Hand capture collection technique was opportunistic where no specific transects or efforts were employed. Typically, hand captures were limited to reptiles due to their ectothermy and basking behavior.

I identified all captured individuals to species or subspecies. I marked small mammals with ear tags using the same procedures as Fokidis et al. (2006) and the herpetofauna, exclusive of turtles, by either toe-clipping or scale-clipping (Nietfeld et al. 1996). I marked turtles by notching carapace scutes (Cagle 1939). I implanted passive integrated transponder (PIT) tags into snakes that were large enough to mark. I deposited voucher specimens of all amphibians and reptiles captured in drift fences and most of the hand captures in the Arkansas State University Museum of Zoology Herpetology Collection (ASUMZ; see Table 6.1). I deposited all small mammal specimens collected (i.e., trap mortality) in the Arkansas State University Museum of Zoology Mammalogy Collection (ASUMZ).

Results

Vertebrate Captures in Habitat

I captured 13 amphibian, 25 reptile, and 8 small mammal species or subspecies in Ozark pocket gopher habitat during field seasons in 2007 and 2008. Two subspecies of *Coluber constrictor* were captured, *C c. priapus* and *C. c. flaviventris*. Drift fences accounted for the majority of the species/subspecies collected in 2007 (Table 6.2). One additional species, tiger salamander (*Ambystoma tigrinum*), was captured in the drift fences in 2008 (n = 2 females; 6 February). Of the 18 families represented, 8 were amphibians (3 urodela; 5 anuran), 7 were reptiles (2 testudines; 5 squamates), and 3 were small mammals (2 insectivores; 1 rodent; Table 6.1).

An additional 11 amphibian and reptile species were captured by hand. Box turtles and large snakes made up the majority of hand captures. I captured eastern racers (*Coluber constrictor*) and three-toed box turtles (*Terrapene carolina triunguis*) frequently (n = 14, 16, respectively). Eastern coachwhips (*Masticophis flagellum flagellum*) and prairie kingsnakes (*Lampropeltis calligaster calligaster*) were fairly common based on visual observations.

During this study, I documented five new county records. Four of those records were herpetofauna: eastern yellowbelly racer, *Coluber constrictor flaviventris* (Connior et al. 2007a); great plains rat snake, *Elaphe guttata emoryi* (Connior et al. 2007b); hurter's spadefoot, *Scaphiopus holbrookii hurterii* (Connior et al. 2007c); three-toed box turtle, *Terrapene carolina triunguis* (Connior et al. 2007d). Captures of Southern short-tailed shrew, *Blarina carolinensis*, also represented a new county record (see below).

Blarina carolinensis

Izard Co.--Found in a cattle pasture on private property; off Co. Rd. 3, 4 km E of St. Hwy 9. UTM 15N 0597627E, 3987505N. 4 individuals. 20 March 2007 (1 individual; ASUMZ 28413); 25 April 2007 (1 individual; ASUMZ 28414); 26 April 2007 (2 individuals; ASUMZ 28415, ASUMZ 28416).

Vertebrate Observations in Burrows and Mounds

I captured a juvenile three-toed box turtle inside a pocket gopher burrow while setting a live trap. Additionally, I captured a rough earth snake (*Virginia striatula*) in a pocket gopher mound. I also witnessed both eastern racers and eastern coachwhips retreat into pocket gopher burrows and common map turtles (*Graptemys geographica*) digging nests in the soft dirt of pocket gopher mounds. After release of captured Hurter's spadefoots, they would commonly retreat by digging into pocket gopher mounds.

Discussion

Pocket gophers are ecosystem engineers, which not only provide habitat for other vertebrates but also impact the distribution of soil and nutrients (Reichman and Seabloom 2002, Reichman 2007). Other subterranean rodents, such as prairie dogs, have great impacts on the ecosystem and vertebrate fauna that elevate them to keystone species (Kotliar et al. 1999, 2006). Keystone species are species whose effect on the ecosystem is exceptionally larger than expected relative to its abundance (Power et al. 1996). Gopher tortoises (*Gopherus polyphemus*) have numerous vertebrate associates in their burrows as well (Lips 1991, Witz et al. 1991). Madison (1997) found that spotted salamanders (*Ambystoma maculatum*) almost exclusively used small mammal (*Blarina; Peromyscus; Microtus*) burrows for terrestrial refuge. Small mammal and gopher tortoise burrows provide refuge for numerous vertebrates throughout North America. Ozark pocket gophers provide similar refuge as the aforementioned species.

I documented 46 species or subspecies of herpetofauna and small mammals in pocket gopher habitat although only 5 species were actually captured or observed in gopher mounds or burrows. However, I suggest that the majority of species that were captured at both sites in drift fences probably utilized pocket gopher burrows in some way. Furthermore, certain species have been captured in pocket gopher burrows or habitat in multiple studies. Vaughan (1961) recorded 22 species of vertebrates using pocket gopher burrows in Colorado; Funderburg and Lee (1968) recorded 20 herpetofauna species inhabiting pocket gopher mounds in Florida. Both studies suggested that some of the species were true burrowers and relied on this habitat for survival.

I recorded substantially lower number of drift fence captures in 2008 vs. 2007 at Site 2. Drift fences were open from January through early April in 2008 of which the majority of the time was cold. Surface activity of both herpetofauna and small mammals was minimal. I probably would have recorded similar results if the drift fences remained open into the summer, since surface activity was increasing at the end of this study.

Site 1 had an overflow reservoir adjacent to a creek that remained flooded for the majority of the year. This habitat feature explains the abundance of amphibians, especially juvenile dwarf American toads and American bullfrogs captured at this site compared to Site 2 (Table 6.2). Pickerel frogs (*Rana palustris*) were captured more frequently at Site 2; yet, both sites have clear, cool streams, which is preferred habitat (Trauth et al. 2004). Hurter's spadefoots (*Scaphiopus holbrookii hurterii*) were also captured frequently at both sites. Both *Scaphiopus* sp. and pocket gophers prefer sandy or friable soils and are expected to share the same geographic distribution (Wasserman 1958). Hurter's spadefoots are a "species of greatest conservation need" in Arkansas (Anderson 2006). The common occurrence of spadefoots in pocket gopher habitat may reflect their utilization of mounds and burrows of pocket gophers. In Texas, the only record of a *Scaphiopus holbrookii* (eastern spadefoot) in the Welder Wildlife Refuge was collected inside a pocket gopher burrow (Wilks 1963).

Tiger salamanders are also a "species of greatest conservation need" and are apparently absent from most of Arkansas except the northern one-third of the state (Trauth et al. 2004, Anderson 2006). They have been found in pocket gopher burrows in Arizona (Calef 1954), California (Howard and Childs 1959), and Colorado (Vaughan

1961). A similar species, California tiger salamander (*Ambystoma californiense*), have also been reported from pocket gopher burrows (Pittman 2005). Due to their fossorial behavior, areas with sandy or friable soils offer optimal habitat for this species (Petranka 1998). Thus, pocket gopher habitat may provide habitat that tiger salamanders can occupy easily due to the abundant loose, sandy soil. Vaughan (1961) stated that the occurrence of tiger salamanders in Colorado is determined by the presence of burrows. I suspect that the females we captured were moving to breeding sites since reproductively active females have been previously recorded during this time of the year (Trauth et al. 1990).

Although the three-toed box turtle is a new county record, they have been documented in surrounding counties (Trauth et al. 2004). Box turtles have been known to hibernate or seek refuge in mammal burrows (Vaughan 1961, Degenhardt et al. 1996, Nieuwolt 1996). Additionally, the mounds may supply box turtles along with other reptiles a place to bask.

Large snakes are commonly found in pocket gopher habitat probably due to the abundance of prey, including pocket gophers. The most common large snake we encountered was the black racer; several of which were observed both entering and exiting pocket gopher burrows. Although most racers probably do not prey on pocket gophers, larger individuals potentially could. Similar sized prey to the pocket gopher, such as weasels, rabbits, and large rodents, has been reported in the diet of racers (Fitch 1963). Another large snake species that was fairly common at the study sites was the eastern coachwhip. These snakes on occasion would retreat into pocket gopher burrows when alarmed. Johnson et al. (2007) documented eastern coachwhips using small mammal burrows as refugia; therefore, they may use pocket gopher burrows when available. Other large snakes have been recorded occupying pocket gopher burrows, such as *Pituophis* sp. (Vaughan 1961, Ealy et al. 2004, Himes et al. 2006, Rudolph et al. 2007). Eastern coachwhips are large enough that they could potentially prey on pocket gophers. Prairie kingsnakes occupy the same habitat as pocket gophers and their most common prey items are small mammals (Fitch 1999). Connior et al. (*in press*) presented the first record of the prairie kingsnake preying on the Ozark pocket gopher. The ecological relationship between large snakes, such as coachwhips and kingsnakes, and Ozark pocket gophers is not known. However, pocket gophers may act as a prey item and provide them with refugia in their burrows. Further investigation of this relationship needs to be determined.

Conclusions

The role that Ozark pocket gophers play in the ecosystem of Izard County cannot be determined at this time. Although I did not have a reference site for comparison (i.e., habitat with pocket gophers vs. habitat lacking pocket gophers), this preliminary study suggested that burrow associates utilize pocket gopher burrows and mounds. The number and extent to which associate species rely on the pocket gophers needs to be determined through both experimental and long term studies. If the Ozark pocket gophers' effect on the ecosystem is disproportionately large relative to its abundance, then it may in fact be a keystone species (Power et al. 1996).

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Table 6.1. Complete list of all amphibian, reptile, and small mammal species captured by hand and drift fences in Ozark pocket gopher habitat in Izard County, Arkansas.

Scientific Name	Common Name
Class Amphibia	Amphibians
Ambystoma tigrinum tigrinum	Eastern Tiger Salamander[1]
Ambystoma opacum	Marbled Salamander
Eurycea lucifuga	Cave Salamander
Notophthalmus viridescens louisianensis	Central Newt
Bufo americanus charlesmithi	Dwarf American Toad
Bufo fowleri	Fowler's Toad
Acris crepitans blanchardi	Blanchard's Cricket Frog
Pseudacris crucifer crucifer	Northern Spring Peeper
Gastrophryne carolinensis	Eastern Narrowmouth Toad
Scaphiopus holbrookii hurterii	Hurter's Spadefoot[1]
Rana catesbeiana	American Bullfrog
Rana palustris	Pickerel Frog
Rana sphenocephala	Southern Leopard Frog
Class Reptilia	Reptiles
*Chelydra serpentina serpentina**	Common Snapping Turtle
*Graptemys geographica**	Common Map Turtle
Terrapene carolina triunguis	Three-toed Box Turtle
Sceloporus undulatus hyacinthinus	Northern Fence Lizard
Eumeces anthracinus pluvialis	Southern Coal Skink
Eumeces fasciatus	Five-lined Skink
Scincella lateralis	Ground Skink
Aspidoscelis sexlineata viridis	Prairie Racerunner
Cemophora coccinea copei	Northern Scarlet Snake
Coluber constrictor priapus	Southern Black Racer
Coluber constrictor flaviventris	Eastern Yellowbelly Racer
*Elaphe guttata emoryi**	Great Plains Rat Snake
Heterodon platirhinos	Eastern Hognose Snake
Lampropeltis calligaster calligaster	Prairie Kingsnake
*Lampropeltis getula holbrooki**	Speckled Kingsnake
*Masticophis flagellum flagellum**	Eastern Coachwhip
*Nerodia erythrogaster flavigaster**	Yellowbelly Water Snake
*Nerodia sipedon pleuralis**	Midland Water Snake
*Opheodrys aestivus**	Rough Green Snake
*Storeria dekayi wrightorum**	Midland Brown Snake
Tantilla gracilis	Flathead Snake
*Thamnophis proximus proximus**	Western Ribbon Snake
Thamnophis sirtalis sirtalis	Eastern Garter Snake
Virginia striatula	Rough Earth Snake
*Agkistrodon contortrix contortrix**	Southern Copperhead
Class Mammalia	Mammals
Blarina carolinensis	Southern Short-tailed Shrew
Cryptotis parva	Least Shrew
Scalopus aquaticus	Eastern Mole

Microtus pinetorum	Woodland Vole
Mus musculus	House Mouse
Ochrotomys nuttalli	Golden Mouse
Peromyscus maniculatus	Deer Mouse
Reithrodontomys fulvescens	Fulvous Harvest Mouse
**Hand Capture*	
1 Species of Concern	

Table 6.2. Amphibian, reptile, and small mammals captured in drift fences in 2007 and 2008 at two Ozark pocket gopher habitat sites in Izard County, Arkansas.

Scientific Name	Common Name	Site 1 (2007) No. Captured	Site 2 (2007) No. Captured	Site 2 (2008) No. Captured
Amphibians				
Acris crepitans blanchardi	Blanchard's Cricket Frog	1	4	0
Ambystoma opacum	Marbled Salamander	0	2	0
Ambystoma tigrinum tigrinum	Tiger Salamander	0	0	2
Bufo americanus charlesmithi	Dwarf American Toad	65	8	2
Bufo fowleri	Fowler's Toad	1	0	0
Eurycea lucifuga	Cave Salamander	1	0	0
Gastrophryne carolinensis	Eastern Narrowmouth Toad	3	4	0
Notophthalmus viridescens louisianensis	Central Newt	1	1	1
Pseudacris crucifer crucifer	Northern Spring Peeper	0	1	0
Rana catesbeiana	American Bullfrog	18	1	0
Rana palustris	Pickerel Frog	17	43	5
Rana spenocephala	Southern Leopard Frog	10	7	0
Scaphiopus holbrookii hurterii	Hurter's Spadefoot	18	11	1
Reptiles				
Cemophora coccinea copei	Northern Scarlet Snake	3	1	0
Aspidoscelis sexlineata viridis	Prairie Racerunner	30	5	0
Coluber constrictor priapus	Southern Black Racer	1	3	0
Coluber constrictor flaviventris	Eastern Yellowbelly Racer	0	1	0
Eumeces anthracinus pluvialis	Southern Coal Skink	2	3	0
Eumeces fasciatus	Five-lined Skink	3	3	0
Heterodon platirhinos	Eastern Hognose Snake	1	1	0
Lampropeltis calligaster calligaster	Prairie Kingsnake	1	0	0
Sceloporus undulatus hyacinthinus	Northern Fence Lizard	19	16	5
Scincella lateralis	Ground Skink	3	9	2
Tantilla gracilis	Flathead Snake	8	3	0
Terrapene carolina triunguis	Three-toed Box Turtle	3	1	0
Thamnophis sirtalis sirtalis	Eastern Garter Snake	0	1	0
Virginia striatula	Rough Earth Snake	1	0	0
Mammals				
Blarina carolinensis	Southern Short-tailed Shrew	0	4	0
Cryptotis parva	Least Shrew	10	89	8
Microtus pinetorum	Woodland Vole	21	41	9
Mus musculus	House Mouse	0	1	0

Ochrotomys nuttalli	Golden Mouse	0	2	0
Peromyscus maniculatus	Deer Mouse	19	14	0
Reithrodontomys fulvescens	Fulvous Harvest Mouse	14	14	0
Scalopus aquaticus	Eastern Mole	0	1	0

CHAPTER VII
FUTURE OF THE OZARK POCKET GOPHER

General Conclusions

As this study has shown, the Ozark pocket gopher (*Geomys bursarius ozarkensis*) is unique not only from other small mammals but other pocket gophers as well. Pocket gophers have numerous morphological and physiological adaptations for fossorial lifestyles (Merriam 1895; Nevo 1979; Lessa 1989; Stein 2000). Also, Ozark pocket gophers currently reside in habitat not normally associated with pocket gophers. Izard County lies in the Ozark Mountains in north central Arkansas and the majority of the land is either rocky or mountainous and not conducive for burrow construction. Yet, Ozark pocket gopher populations seem to be stable in the fields where they do exist.

Because of pocket gophers' fossorial habitat, certain challenges of data collection pertain to these animals. Spatial dynamics and home range use are just two of the many ecological characteristics that are difficult to study. Pocket gophers rarely come aboveground and have elaborate burrows that can only be seen by destructive and labor intensive excavation and mapping. Previously, either extensive live trapping or excavation was required to examine spatial dynamics and home range use. With the advent of radio telemetry, researchers are able to collect data on pocket gophers' use of the burrows with minimal intrusion to the burrows. By using this method, only one successful live trap per gopher is required to produce vast data on spatial use and social dynamics. As demonstrated in Chapters II and III, new techniques such as live traps and telemetry techniques are still being developed to produce more efficient and reliable data collection methods.

Spatial dynamics and home range use can elucidate which habitat requirements are most important. Pocket gophers have bouts of activity that coincide with temperature fluctuations within burrows and during times that predation risks are minimal (Benedix 1994). As shown in the GIS analysis in Chapter IV as well as in other studies (Bandoli 1987; Zinnel 1992; Benedix 1994), pocket gophers spend the majority of their time in the nest or a central location possibly to reduce predation and energy expenditure. In this study, gophers had a wide range in size that was not necessarily predicted by mass. Only the females' mass could be effective at predicting home range size. I was not able to determine if neighboring gophers had a part in determining size or shape of the home range. I suspect that neighboring gophers play an important role in the home range since these fields had populations sometimes exceeding 50 individuals per hectare (Kershen 2004). McNab (1963) suggested that animals would have a larger home range during cold seasons because of increased energy expenditure and during the breeding season for the females to support their young. Home range was affected by seasonality and my results agreed with McNab (1963); gophers had larger home ranges during the winter and early spring when food resources were scare and the animals were reproductively active.

Dispersal is a crucial factor is determining population size and gene flow within and among populations (Howard 1960; Gaines and McClenaghan 1980). If dispersal events are successful, individuals can maintain gene flow among populations or colonize new areas. Yet, dispersing individuals suffer high mortality rates during these events (Gaines and McClenaghan 1980). Dispersal is especially important in the ecology of the Ozark pocket gopher for two main reasons. First, pocket gophers are restricted in their ability to colonize new areas because of their fossorial lifestyle. Second, the majority of Izard County is not ideal habitat for pocket gophers which results in Ozark pocket gophers being even more restricted in their ability to colonize new areas. These two factors make successful dispersal events even more important than in many animal populations.

As determined in this study as well as others (Howard and Childs 1959, Adams 1966, Daly and Patton 1990), pocket gophers disperse aboveground probably in order to minimize energy required. I suspect that the majority of individuals dispersing occur in the fall since I only detected one individual that had dispersed in the winter, spring or summer. Juveniles would be both mature and large enough in the fall to disperse. Ozark pocket gophers will only rarely burrow into wooded areas even for short distances. This factor makes evident the importance of maintaining existing roadways and power line clearings for the dispersal of Ozark pocket gophers.

Survival of a portion of a population's offspring until age of reproduction is necessary to maintain the population. Dispersing individuals need to survive and reproduce in order to establish new populations at the periphery of current populations or the dispersal event is essentially void. Although pocket gophers remain relatively safe from predators when they are within their burrows, they frequently ran back to their nest from their foraging chambers when approached during my routine radio telemetry tracking. This behavior has been reported also by Artmann (1967). This suggests that animals above ground still pose threats to pocket gophers, such as coyotes and badgers that can dig into their burrows and potentially capture gophers. Although some predators can either enter or dig into the burrows, most predation probably occurs during surface activity such as mounding dirt or dispersing as evidenced by gophers in the diets of owls and hawks (Cahn and Kemp 1930; Goyer et al. 1981; Gubanyi et al. 1992; Cartron et al. 2004). Young individuals as well as individuals involved in surface activity suffer the greatest mortality from predators.

Human induced mortality can have great impacts on populations of wild animals. Species, such as pocket gophers, that are deemed agricultural pests can suffer extreme mortality rates from humans to alleviate economic loss (Scheffer 1910; Witmer and Engeman 2007). Neither Kershen (2004) nor this study (although I did record one that died as a result of a backhoe) elucidated the mortality rate of pocket gophers induced from humans. Landowners still view the Ozark pocket gophers as pests and continue to kill trap. Landowners may actually maintain stable populations within their fields by removing some of the unwanted pests. By removing a portion of the population within a field, landowners reduce the need for dispersal or the threat of diseases or starvation as a result of high density. Overall, the population seems to be stable or increasing and does not seem to be at risk from dangerously low population size. In January 2008, I conducted a road survey along the periphery of the known range of pocket gophers in Izard County and recorded new pocket gopher locations. In fact, Ozark pocket gophers seem to be expanding their range evidenced by my 2008 automobile survey compared to Kershen (2004) distribution (Figure 7.1). With this in mind, monitoring of the population is still needed to insure that a population crash does not occur as witnessed in a population of *Thomomys bottae* by Howard (1962).

Ozark pocket gophers do not seem to be in danger from neither intraspecific nor interspecific competition. On the other hand, some community associates may be in danger if the pocket gopher population crashes or is eliminated from portions of its current range. As shown in Chapter VI and Vaughan (1961), vertebrate species richness is high in pocket gopher habitat. Many of these species rely on the burrows of the pocket gophers. In addition, many insects, especially scarab and histerid beetles, rely on the burrows of pocket gophers (Hubbell and Goff 1939; Skelley and Kovarik 2001; Gordon and Skelley 2007). In fact, several new state records and undescribed species of insects have been collected from Ozark pocket gopher burrows in Izard County (Kovarik et al. *in press*). The status of the extent and importance of burrows to community associates is not known at this time but should to be studied further.

Other subterranean rodents, such as prairie dogs, have great impacts on the ecosystem that elevate them to keystone species (Kotliar et al. 1999; 2006). Keystone species are species whose effect on the ecosystem is disproportionately large relative to its abundance (Power et al. 1996). Pocket gophers are ecosystem engineers that greatly impact the distribution of soil and nutrients (Reichman and Seabloom 2002; Reichman 2007). Pocket gophers like prairie dogs modify the habitat to an extent that affects the survival of many other species making them keystone species (Mills et al. 1993).

Future Studies

This study revealed some of the spatial dynamics and population demographics that control the Ozark pocket gopher. However, future research should focus on securing a more permanent study area where control over experimental design can be achieved. Given, landowners have been more than helpful in granting me as well as others permission to conduct studies on their land. An experimental area controlled by a researcher would allow more design freedom, such as excavation of burrows, removal of vegetation, and extensive trapping. This study did not answer the dispersal patterns and rates fully. Further investigation by a year round, long term (~3 year) mark-recapture and telemetric study would produce addition data on dispersal behavior.

Another aspect worth investigation is the Ozark pocket gophers' impact on soil distribution with regards to mineral and nutrient content. Certain plant species require different soil types and nutrient content and their distribution within the Ozark pocket gophers' habitat has not been addressed. Further studies may reveal that plant species distribution is directly affected by burrowing of pocket gophers. Granted, farmers use fertilizer and machinery to supplement soil content, but pocket gophers may be important within Izard County where fertilizer and/or machinery are not employed.

Ozark pocket gophers' impact on community associates is perhaps the most important area for future study. If the Ozark pocket gopher is in fact a keystone species in Izard County, then by managing their population we can also manage other species as well. Pocket gopher burrows are used by rare species such as tiger salamanders (*Ambystoma tigrinum, A. californiense*; Vaughan 1961; Pittman 2005) and spadefoot toads (*Scaphiopus* sp.; Wilks 1963; Vaughan 1961). Furthermore, a new species of histerid beetle has recently been found in the burrows of the Ozark pocket gopher (Kovarik et al. *in press*). Both these rare and new species that rely on the Ozark pocket gopher help support the importance of the Ozark pocket gopher in the ecosystem of Izard County, Arkansas.

Finally, continued surveying of the adjacent counties of Izard County for new populations of pocket gophers is important. Relict populations may still occur that could be very important in the maintenance of the genetic integrity of the Ozark pocket gopher. If corridors within and adjacent to the current range continue to be maintained for pocket gopher use, then the Ozark pocket gopher should remain with us.

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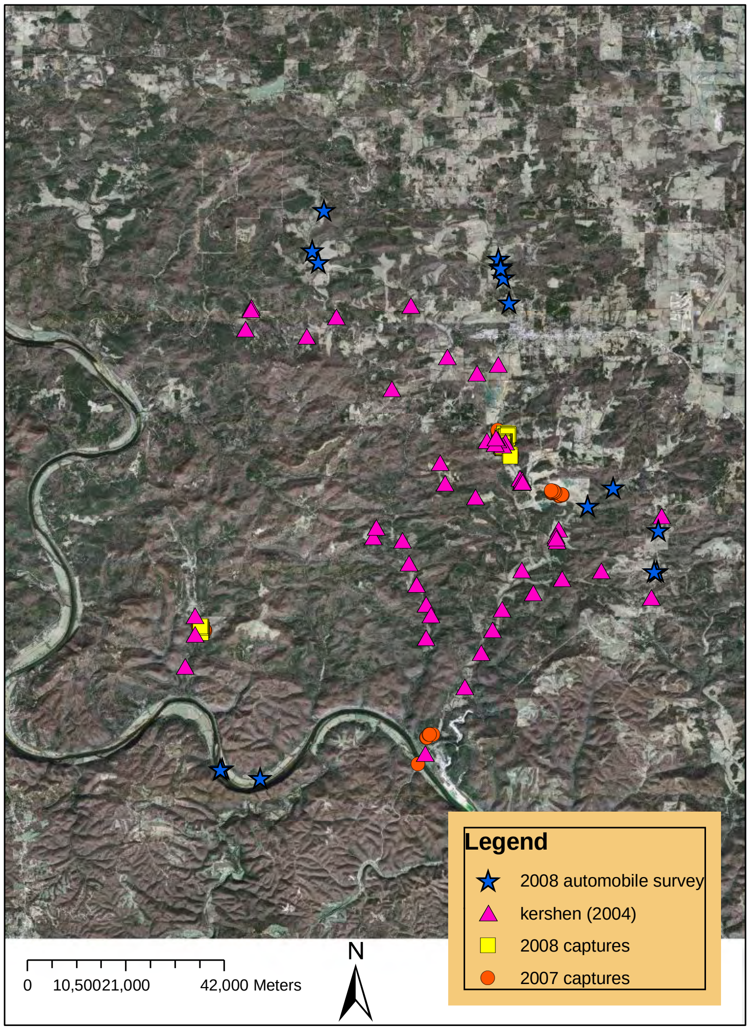

Figure 7.1: Ozark pocket gopher distribution in Stone (one individual confirmed south of the White River in 2007) and Izard County, Arkansas as of 2008.

Appendix A

Locations and biological attributes of 179 captured Ozark pocket gophers in Izard and Stone County, Arkansas in 2007 and 2008. M = adult male, M/J = subadult male, F = adult female, F/J = subadult female, N/A = not available.

Site	Date	Trap Number	Time	Tag	Sex	Mass (g)	Total L in mm	Tail L in mm	Northing	Easting
Site 1	2/5/2007	1B	13:31	076 014 014	F	151	212	45	587183	3980671
Site 1	5/31/2007	3B	13:00	076 021 002	F	155	225	55	587313	3980674
Site 1	1/29/2007	9A	14:40	076 029 540	F	234	250	58	587165	3980703
Site 1	1/4/2008	5A	16:30	076 068 044	F	132	209	50	587167	3980606
Site 1	2/5/2007	5B	16:18	076 074 375	F	164	227	54	587223	3980666
Site 1	3/5/2007	19A	14:44	076 084 038*	F	168	219	45	587187	3980718
Site 1	1/4/2008	2B	15:35	076 084 038*	F	155	217	46	587189	3980724
Site 1	2/5/2007	2B	14:45	076 090 557	F	159	214	47	587131	3980635
Site 1	4/9/2007	9B	16:20	076 112 025*	F	173	223	50	587175	3980760
Site 1	1/26/2008	7B	12:15	076 112 025*	F	160	220	47	587160	3980776
Site 1	3/1/2007	6B	13:44	076 125 258*	F	139	216	55	587145	3980804
Site 1	3/5/2007	7B	13:10	076 125 258*	F	139	n/a	n/a	587131	3980798
Site 1	3/29/2007	5B	15:55	076 125 258*	F	143	n/a	n/a	587140	3980801
Site 1	1/4/2008	10B	16:00	076 125 258*	F	149	229	53	587142	3980802
Site 1	6/14/2007	8B	9:00	collected	F	148	225	51	587271	3980700
Site 1	4/9/2007	8A	16:20	076 042 573*	F/J	44	153	38	587155	3980798
Site 1	5/15/2007	14A	14:30	076 042 573*	F/J	63	173	40	587165	3980793
Site 1	3/1/2007	8B	13:16	076 057 053*	F/J	123	199	44	587197	3980743
Site 1	3/29/2007	9B	13:57	076 061 381*	F/J	113	213	50	587075	3980822
Site 1	5/20/2007	10B	16:30	076 061 381*	F/J	112	n/a	n/a	587077	3980825
Site 1	6/2/2007	2B	15:00	076 061 381*	F/J	113	n/a	n/a	587101	3980815
Site 1	1/29/2007	7B	14:12	076 068 044	F/J	118	189	51	587180	3980621
Site 1	1/26/2008	10A	12:15	076 092 326	F/J	128	226	54	587173	3980811
Site 1	3/1/2007	1B	12:34	076 114 626	F/J	110	201	46	587149	3980797

Site 1	6/12/2007	1B	17:26	076 125 258*	F/J	128	224	55	587137	3980810
Site 1	5/17/2007	14A	13:45	076 258 355*	F/J	59	162	40	587143	3980823
Site 1	3/5/2007	6B	16:34	076 023 294*	M	198	235	52	587132	3980821
Site 1	1/26/2008	9A	13:20	076 023 576	M	225	258	54	587163	3980826
Site 1	1/26/2008	8A	14:30	076 023 788	M	250	268	56	587140	3980824
Site 1	4/9/2007	2B	16:20	076 031 530*	M	257	257	62	587203	3980708
Site 1	5/17/2007	17A	12:30	076 031 530*	M	245	n/a	n/a	587197	3980714
Site 1	1/4/2008	11A	15:00	076 031 530*	M	244	263	58	587199	3980703
Site 1	1/4/2008	2A	14:30	076 050 634	M	157	247	57	587189	3980674
Site 1	3/1/2007	2B	12:31	076 083 527*	M	146	219	50	587188	3980737
Site 1	3/5/2007	1B	13:31	076 083 527*	M	146	n/a	n/a	587171	3980750
Site 1	1/4/2008	3B	14:30	076 085 883	M	208	246	57	587157	3980766
Site 1	2/5/2007	10A	14:10	076 099 291*	M	239	257	62	587155	3980628
Site 1	3/5/2007	9B	15:21	076 099 291*	M	237	n/a	n/a	587160	3980635
Site 1	4/9/2007	8B	16:00	076 099 291*	M	248	n/a	n/a	587151	3980627
Site 1	5/20/2007	8B	18:00	076 103 876	M	187	231	54	587209	3980743
Site 1	6/14/2007	1B	18:00	076 020 116*	M/J	70	192	52	587278	3980712
Site 1	5/31/2007	2B	16:00	076 051 127*	M/J	70	183	45	n/a	n/a
Site 1	6/12/2007	5B	17:00	076 079 100*	M/J	91	203	53	587191	3980717
Site 1	1/4/2008	8B	15:35	076 084 601	M/J	104	201	44	587161	3980720
Site 1	6/1/2007	2B	18:30	076 102 556*	M/J	64	168	42	587145	3980794
Site 2	3/10/2007	8B	16:10	076 014 563	F	194	214	38	597628	3987507
Site 2	3/8/2007	1B	12:46	076 032 374*	F	155	202	43	597632	3987608
Site 2	6/10/2007	8B	8:30	076 032 374*	F	147	202	46	597629	3987607
Site 2	3/10/2007	13A	15:27	076 055 590	F	165	223	50	597655	3987530
Site 2	2/23/2007	8B	17:55	076 075 042	F	152	209	44	597612	3987689
Site 2	3/10/2007	8B	13:23	076 081 377*	F	161	194	21	597662	3987568
Site 2	6/27/2007	1B	12:15	076 081 377*	F	159	193	25	597654	3987566
Site 2	2/25/2007	10A	17:07	076 099 828*	F	148	208	42	597649	3987613
Site 2	3/8/2007	3B	14:50	076 099 828*	F	146	n/a	n/a	597644	3987612
Site 2	5/1/2007	2B	17:30	076 099 828*	F	154	n/a	n/a	597647	3987621

Site 2	2/25/2007	2B	14:05	076 100 120	F	181	219	45	597643	3987608
Site 2	3/8/2007	10B	14:49	076 105 543*	F	162	226	45	597635	3987649
Site 2	2/25/2007	7A	17:52	076 112 029	F	154	207	42	597658	3987535
Site 2	4/16/2007	9B	17:50	076 124 534*	F	162	n/a	n/a	597614	3987720
Site 2	3/10/2007	9B	15:27	076 258 339*	F	188	234	54	597627	3987505
Site 2	6/28/2007	8B	14:00	collected	F	130	231	56	597638	3987560
Site 2	6/28/2007	9B	7:00	collected	F	132	218	46	597689	3987515
Site 2	6/28/2007	1B	14:00	collected	F/J	54	172	46	597644	3987485
Site 2	2/23/2007	1B	15:53	076 016 353	M	170	234	55	597627	3987652
Site 2	6/10/2007	3B	8:00	076 016 353	M	164	240	53	597626	3987657
Site 2	5/1/2007	9B	16:25	076 024 038	M	211	253	58	597624	3987625
Site 2	4/19/2007	19A	15:00	076 079 572	M	227	254	59	597651	3987520
Site 2	6/10/2007	6B	8:00	076 079 572	M	226	n/a	n/a	597646	3987520
Site 2	3/10/2007	6B	13:25	076 086 574	M	259	256	56	597634	3987586
Site 2	2/23/2007	8B	16:00	076 098 092	M	292	271	70	597655	3987654
Site 3	3/26/2008	11B	17:00	076 016 559	F	162	231	46	597798	3987147
Site 3	12/28/2007	9B	13:45	076 017 562*	F	150	224	44	597789	3987266
Site 3	5/1/2007	11B	17:00	076 017 628	F	183	226	50	597813	3987145
Site 3	12/17/2007	9B	14:40	076 021 085*	F	185	248	54	597766	3987098
Site 3	1/17/2008	9B	15:15	076 021 085*	F	187	230	55	597770	3987104
Site 3	9/15/2007	3B	13:30	076 026 348	F	164	232	57	597767	3987087
Site 3	4/12/2007	3B	14:15	076 026 620	F	160	222	43	597731	3987237
Site 3	12/31/2007	11B	16:10	076 026 857	F	148	227	47	597750	3987310
Site 3	1/17/2008	7B	13:30	076 027 797	F	171	251	60	597760	3987135
Site 3	3/3/2007	10B	14:24	076 030 591*	F	172	210	44	597801	3987153
Site 3	12/17/2007	10B	15:50	076 034 264*	F	140	227	47	597814	3987162
Site 3	12/18/2007	1A	15:00	076 038 066*	F	142	221	51	597744	3987263
Site 3	1/18/2008	3B	14:15	076 038 066*	F	167	n/a	n/a	597736	3987261
Site 3	1/27/2008	3B	12:05	076 049 039	F	153	239	51	597795	3987173
Site 3	3/26/2008	7B	13:14	076 056 096	F	143	223	46	597798	3987168
Site 3	2/7/2008	1B	14:15	076 057 864*	F	167	229	49	597792	3987119

Site 3	12/28/2007	4A	15:25	076 058 028*	F	150	235	44	597820	3987202
Site 3	2/7/2007	10A	16:03	076 068 800	F	154	214	48	597810	3987187
Site 3	1/13/2008	9B	13:50	076 080 575	F	182	256	58	597770	3987160
Site 3	9/15/2007	10B	15:50	076 085 593	F	134	229	55	597816	3987206
Site 3	1/17/2008	11B	12:00	076 089 829	F	144	226	48	597817	3987239
Site 3	5/1/2007	14A	18:05	076 092 066	F	181	244	59	597792	3987196
Site 3	1/5/2008	3B	14:00	076 092 066	F	191	246	57	597800	3987192
Site 3	12/27/2007	9B	13:30	076 092 109	F	163	242	53	597755	3987229
Site 3	1/17/2008	7B	14:15	076 104 862*	F	178	223	48	597767	3987125
Site 3	3/26/2008	1B	17:10	076 104 862*	F	163	231	50	597763	3987123
Site 3	2/7/2007	8A	13:31	076 111 319*	F	160	225	51	597776	3987114
Site 3	2/8/2007	8A	13:16	076 111 319*	F	n/a	n/a	n/a	597768	3987112
Site 3	3/8/2007	9B	14:37	076 111 319*	F	170	n/a	n/a	597769	3987120
Site 3	1/27/2008	10A	17:00	076 111 319*	F	151	230	49	597773	3987113
Site 3	4/19/2007	9B	15:15	076 113 085*	F	196	231	49	597774	3987252
Site 3	1/8/2007	?A	15:30	076 115 550	F	197	232	57	597793	3987192
Site 3	2/8/2007	8A	15:22	076 117 310	F	148	218	51	597785	3987085
Site 3	2/8/2007	10A	16:35	076 118 297	F	138	201	40	597735	3987146
Site 3	6/15/2007	2B	9:00	076 118 297	F	130	203	43	597744	3987139
Site 3	2/8/2007	5A	?	076 119 637*	F	144	238	61	597712	3987177
Site 3	3/3/2007	10A	14:25	076 119 637*	F	144	n/a	n/a	597714	3987191
Site 3	1/17/2008	6A	11:15	076 077 352*	F/J	129	212	44	597791	3987139
Site 3	5/5/2007	13A	14:30	076 100 520*	F/J	65	165	40	597755	3987107
Site 3	12/27/2007	2A	13:30	076 112 350*	F/J	129	217	46	597752	3987238
Site 3	2/6/2007	2B	12:12	076 015 109	M	168	229	41	597808	3987217
Site 3	2/8/2007	7B	16:00	076 015 109	M	154	n/a	n/a	597807	3987213
Site 3	12/31/2007	2A	12:35	076 015 109	M	165	232	45	597811	3987199
Site 3	1/5/2008	11A	15:00	076 015 109	M	n/a	n/a	n/a	597808	3987199
Site 3	3/3/2007	2B	13:39	076 017 034*	M	203	249	63	597798	3987221
Site 3	3/26/2008	19A	17:42	076 017 379	M	200	253	57	597789	3987138
Site 3	1/9/2007	?A	16:05	076 026 818*	M	265	238	65	597766	3987307

Site 3	2/6/2007	8A	12:36	076 026 818*	M	240	n/a	n/a	597736	3987309
Site 3	1/5/2008	2B	15:00	076 026 818*	M	260	266	61	597757	3987293
Site 3	2/6/2007	5B	16:11	076 027 101	M	147	211	51	597775	3987197
Site 3	12/18/2007	11A	11:00	076 031 806*	M	166	231	42	597720	3987162
Site 3	12/31/2007	6A	13:40	076 035 028	M	n/a	226	49	597730	3987296
Site 3	1/13/2008	6A	13:15	076 035 075*	M	252	248	55	597747	3987159
Site 3	3/26/2008	2A	13:22	076 035 075*	M	226	249	55	597755	3987147
Site 3	1/27/2008	9A	12:05	076 043 102	M	207	254	61	597817	3987183
Site 3	3/3/2007	17A	12:53	076 056 774*	M	152	213	51	597790	3987237
Site 3	12/18/2007	2A	15:15	076 067 014*	M	260	246	48	597792	3987190
Site 3	2/8/2007	9A	15:51	076 072 268	M	224	246	52	597762	3987265
Site 3	4/19/2007	17A	13:15	076 072 268	M	206	n/a	n/a	597762	3987265
Site 3	6/13/2007	11B	19:00	076 072 268	M	212	244	53	597761	3987269
Site 3	1/18/2008	7B	16:45	076 079 547	M	220	266	58	597779	3987216
Site 3	5/1/2007	8B	13:45	076 094 521	M	218	261	64	597790	3987137
Site 3	1/18/2008	5A	14:15	076 100 611*	M	248	264	57	597787	3987108
Site 3	2/7/2008	kill trap	15:40	076 100 611*	M	228	n/a	n/a	597795	3987107
Site 3	12/31/2007	4A	12:35	076 125 792	M	145	230	53	597791	3987309
Site 3	3/26/2008	9A	14:43	076 125 792	M	131	222	54	597766	3987290
Site 3	1/18/2008	9A	14:15	076 257 053	M	225	265	66	597787	3987090
Site 3	3/26/2008	9B	17:00	076 257 053	M	226	270	66	597801	3987110
Site 3	12/18/2007	9B	13:05	076 258 377*	M	220	245	55	597778	3987108
Site 3	1/29/2008	11B	12:20	076 258 377*	M	212	252	54	597769	3987119
Site 3	3/26/2008	9A	17:15	076 281 622	M	240	263	62	597795	3987266
Site 3	5/5/2007	12A	14:30	076 042 053*	M/J	84	186	44	597757	3987111
Site 3	12/31/2007	9B	15:00	076 071 050*	M/J	134	213	38	597769	3987305
Site 3	1/1/2008	5A	12:30	076 071 050*	M/J	134	n/a	n/a	597774	3987304
Site 3	12/18/2007	9B	16:00	076 098 770*	M/J	134	224	54	597780	3987271
Site 3	5/8/2007	hand	12:45	076 114 816*	M/J	41	150	38	597758	3987119
Site 4	1/9/2008	9B	15:32	076 025 279	F	134	219	52	597840	3987603
Site 4	1/13/2008	3B	13:30	076 032 107	F	138	219	45	597885	3987519

Site 4	12/19/2007	3B	15:00	076 048 078*	F	182	223	47	597890	3987461
Site 4	2/10/2008	2B	13:40	076 058 329	F	153	230	49	597969	3987526
Site 4	12/30/2007	10B	11:50	076 059 863*	F	140	217	49	597978	3987567
Site 4	2/16/2008	2B	14:00	076 059 863*	F	144	228	49	597981	3987596
Site 4	12/23/2007	11B	12:20	076 068 339*	F	142	229	45	597864	3987486
Site 4	12/23/2007	1A	15:08	076 073 541*	F	143	213	32	597922	3987413
Site 4	1/13/2008	1B	15:50	076 074 104	F	155	228	51	597912	3987517
Site 4	12/20/2007	9B	10:10	076 075 057*	F	149	232	47	597897	3987503
Site 4	2/15/2008	8B	16:45	076 075 057*	F	179	237	49	597913	3987496
Site 4	12/30/2007	A	16:30	076 077 835	F	144	221	54	597775	3987478
Site 4	12/31/2007	10B	16:20	076 077 835	F	n/a	n/a	n/a	597781	3987494
Site 4	12/20/2007	5A	10:50	076 081 602*	F	152	229	47	597882	3987538
Site 4	1/13/2008	8A	14:50	076 104 080	F	164	232	53	597819	3987463
Site 4	12/23/2007	9B	15:10	076 027 785*	F/J	114	210	36	597875	3987429
Site 4	12/23/2007	6A	13:12	076 047 873*	F/J	89	198	44	597963	3987491
Site 4	12/20/2007	4A	12:45	076 060 018*	F/J	120	215	40	597977	3987501
Site 4	2/15/2008	2B	13:45	076 100 320*	F/J	125	201	38	598006	3987562
Site 4	2/24/2008	7B	15:15	076 100 320*	F/J	127	192	38	598003	3987568
Site 4	12/19/2007	11A	15:05	076 108 782*	F/J	124	225	50	597932	3987523
Site 4	2/10/2008	1B	16:03	076 108 782*	F/J	145	n/a	n/a	597947	3987546
Site 4	2/15/2008	9B	14:00	076 108 782*	F/J	n/a	n/a	n/a	597959	3987545
Site 4	12/20/2007	11A	12:40	076 117 521*	F/J	123	220	47	597940	3987476
Site 4	12/19/2007	1B	13:08	076 015 383*	M	194	253	54	597943	3987523
Site 4	2/10/2008	2B	13:00	076 027 828	M	260	258	53	597872	3987487
Site 4	12/23/2007	10B	11:15	076 034 123*	M	157	228	48	597978	3987601
Site 4	2/15/2008	2B	16:45	076 034 123*	M	200	238	49	597981	3987606
Site 4	12/19/2007	2B	13:05	076 047 801*	M	144	224	47	597915	3987484
Site 4	12/31/2007	2B	16:20	076 066 328	M	242	270	64	597786	3987514
Site 4	2/10/2008	11A	13:05	076 092 373	M	185	240	48	597962	3987456
Site 4	12/30/2007	4A	14:10	076 095 789	M	237	264	61	597819	3987465
Site 4	12/19/2007	5A	13:40	076 102 032*	M	257	273	59	597895	3987517

Site 4	12/30/2007	9B	14:15	076 123 538*	M	165	243	60	598002	3987531
Site 4	2/15/2008	2B	14:30	076 123 538*	M	178	220	54	n/a	n/a
Site 4	2/24/2008	3B	16:30	076 123 538*	M	180	n/a	n/a	597969	3987547
Site 4	12/19/2007	9B	16:10	076 014 880*	M/J	98	194	41	597876	3987488
Site 4	12/20/2007	1A	12:50	076 022 334*	M/J	93	203	42	597912	3987527
Site 4	1/13/2008	9A	13:30	076 022 334*	M/J	111	205	44	597914	3987524
Site 4	2/10/2008	9A	13:35	076 022 334*	M/J	130	203	43	597909	3987526
Site 4	1/9/2008	9B	13:20	076 042 857	M/J	118	207	48	597840	3987621
Site 5	4/2/2007	1B	13:00	076 018 096	F	133	212	45	598096	3986842
Site 5	4/23/2007	1B	12:30	076 018 096	F	133	n/a	n/a	598080	3986833
Site 5	2/11/2007	4B	14:01	076 092 864*	F	158	206	48	598074	3986816
Site 5	4/2/2007	1B	14:00	076 092 864*	F	174	n/a	n/a	598069	3986813
Site 5	4/23/2007	3B	16:10	076 092 864*	F	172	n/a	n/a	598067	3986808
Site 5	2/29/2008	9B	13:25	076 094 316	F	164	232	46	598073	3986857
Site 5	2/10/2007	5B	17:25	076 102 324	F	146	225	47	598052	3986870
Site 5	2/11/2007	9A	16:02	076 114 062	F	162	212	45	598081	3986855
Site 5	3/3/2007	13A	16:15	076 114 062	F	165	n/a	n/a	598086	3986837
Site 5	2/11/2007	7B	15:00	076 121 632*	F	182	216	45	598047	3986792
Site 5	3/3/2007	7B	14:57	076 121 632*	F	188	n/a	n/a	598048	3986798
Site 5	4/30/2007	1B	14:20	076 121 632*	F	185	n/a	n/a	598061	3986786
Site 5	5/5/2007	8B	14:00	076 121 632*	F	n/a	n/a	n/a	598049	3986794
Site 5	6/15/2007	1B	17:30	076 017 846*	F/J	72	176	43	598072	3986872
Site 5	2/10/2007	1B	15:58	076 018 096	F/J	106	194	47	598094	3986845
Site 5	6/16/2007	1B	8:00	076 035 123*	F/J	62	184	45	598093	3986839
Site 5	2/11/2007	11A	16:38	076 045 306	F/J	98	193	42	598083	3986775
Site 5	2/29/2008	8B	15:20	076 078 594	F/J	126	203	43	598035	3986881
Site 5	2/10/2007	9A	14:31	076 015 589	M	280	256	57	598060	3986793
Site 5	2/10/2007	4B	15:31	076 032 544*	M	275	266	60	598083	3986827
Site 5	3/3/2007	7A	12:37	076 032 544*	M	274	n/a	n/a	598088	3986821
Site 5	4/23/2007	B	13:12	076 032 544*	M	258	n/a	n/a	598082	3986848
Site 5	2/29/2008	12B	17:03	076 032 544*	M	243	274	59	598059	3986802

Site 5	3/3/2007	9B	15:43	076 048 013*	M	179	223	44	598074	3986816
Site 5	5/10/2007	17A	14:05	076 094 610	M	147	221	50	598043	3986805
Site 5	2/11/2007	2B	16:02	076 101 066*	M	138	208	54	598079	3986861
Site 5	3/3/2007	9A	15:01	076 101 066*	M	134	n/a	n/a	598077	3986842
Site 5	2/10/2007	3B	17:30	076 108 616	M	183	229	54	598118	3986855
Site 6	1/5/2008	1B	16:30	076 021 382	F	198	241	49	597865	3987339
Site 6	1/12/2008	9A	14:30	076 026 517	F	136	232	58	597854	3987319
Site 6	1/1/2008	8B	14:25	076 040 261	F	142	212	47	597815	3987344
Site 6	1/12/2008	7B	16:45	076 040 261	F	n/a	n/a	n/a	597816	3987340
Site 6	1/27/2008	2B	17:30	076 040 261	F	146	n/a	n/a	597800	3987344
Site 6	1/5/2008	11B	12:30	076 073 075	F	150	225	48	597850	3987333
Site 6	1/12/2008	11B	16:07	076 019 790	M	170	231	46	597841	3987329
Site 7	2/19/2007	2B	14:17	076 019 794	F	156	211	51	599529	3985516
Site 7	3/2/2007	8B	12:44	076 047 599	F	167	232	52	599551	3985550
Site 7	6/30/2007	9B	13:40	076 047 599	F	164	229	56	599551	3985563
Site 7	3/10/2007	1B	11:56	076 052 818	F	146	223	45	599533	3985545
Site 7	3/21/2007	12A	14:21	076 073 593	F	133	207	46	599798	3985434
Site 7	3/2/2007	9B	14:32	076 092 881	F	132	208	45	599599	3985538
Site 7	3/10/2007	4B	12:05	076 092 881	F	134	n/a	n/a	599599	3985542
Site 7	3/2/2007	1B	14:28	076 096 124	F	148	234	50	599553	3985528
Site 7	3/21/2007	9B	13:55	076 112 853	F	154	204	48	599874	3985456
Site 7	3/21/2007	17A	14:27	076 256 054	F	182	219	46	599781	3985405
Site 7	6/30/2007	11B	12:45	collected	F	163	227	54	599583	3985508
Site 7	6/30/2007	6B	10:35	collected	F	182	233	56	599509	3985531
Site 7	3/2/2007	14A	16:26	076 048 862	M	169	218	50	599585	3985574
Site 7	3/2/2007	10A	13:32	076 060 788	M	294	275	65	599629	3985553
Site 7	3/21/2007	10B	14:24	076 082 878	M	249	258	59	599892	3985443
Site 7	3/2/2007	7A	16:47	076 100 300	M	159	223	51	599517	3985564
Site 7	6/30/2007	5B	12:15	collected	M/J	113	215	47	599497	3985594
Site 8	1/27/2007	2B	14:35	076 033 871	F	157	214	45	595190	3977023
Site 8	1/27/2007	4A	13:00	076 044 326	F	148	195	44	595335	3977031

Site 8	1/27/2007	2A	16:37	076 099 778	F/J	124	197	39	595221	3977031
Site 8	1/18/2007	?	16:00	076 036 847	M	210	232	61	595119	3976917
Site 8	1/26/2007	?A	16:00	076 036 847	M	n/a	n/a	n/a	595097	3976915
Site 9	1/19/2007	?A	12:15	076 056 340	M	273	243	54	594802	3976001

*radiotransmittered individuals

Distribution and Habitat Attributes of an Endemic Subspecies of Pocket Gopher

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Abstract

Ozark pocket gophers, Geomys bursarius ozarkensis, are endemic to Izard County, Arkansas with a distribution of approximately 2,321.7 km². Limited data exists on this subspecies; thus, we collected vegetation and soil habitat data within the current range. G. b. ozarkensis were present in 11 named soil types with loamy sand being the most common texture. No statistical significance was found between pocket gopher density and several soil parameters. We documented pocket gophers predominantly occurring in grazed land, hay fields, and lawns. Twenty-one families of vegetation were recorded from samples collected from pocket gopher habitat. Due to the Ozark pocket gophers' restricted range and its predominantly privately owned land locations, conservation strategies are warranted for this endemic subspecies.

Key Words: Ozark pocket gopher; Geomys bursarius ozarkensis; habitat; Arkansas; Geographical Information System

Nomenclature: Kartesz 1994; Wilson and Reeder 2005

Introduction

Geomys bursarius, plains pocket gopher, occurs throughout the Midwest from southern Canada to Texas encompassing a variety of grassy habitats (Elrod et al., 2000). Although the grassy habitats preferred by the plains pocket gopher occur throughout its range, these habitat types occur in a matrix of others including woodlands and agricultural areas. Thus, fragmentation may actually create more habitat for pocket gophers as woodlands are removed and the landcover is transformed from woody to herbaceous plants of varying degree. Another important factor in pocket gopher habitat suitability is soil type. Several studies throughout the range of Geomys including Kansas (Downhower & Hall, 1966), Colorado (Miller, 1964), New Mexico (Best, 1973), and Texas (Kennerly, 1959) have determined that pocket gophers are found in soils with a high sand content, presumably these soils facilitate pocket gopher movement and are conducive to tunnel system construction. Soil particle size, topsoil depth, and food availability are important in the suitability of an area for pocket gophers.

Grassy habitats provide important dietary components for pocket gophers. Several authors (Myers & Vaughn, 1964; Luce, Case & Stubbendieck 1980; Foster & Stubbendieck, 1980) have reported that grasses represent the majority of Geomys diet while forbs contribute a smaller portion. Myers and Vaughn (1964) examined stomach contents in Geomys and concluded that roots comprise the majority of pocket gophers' diet. Yet, Luce, Case and Stubbendieck (1980) reported that roots, stems, and leaves were nearly equal in Geomys' gut contents. The preferred diet of Geomys was reported to be roots of forbs and leaves and stems of grasses. However, late fall and winter bring a shift to higher percentage of roots than aboveground material (Luce, Case & Stubbendieck 1980).

Moderately grazed lands support the highest populations when compared to over-grazed or land otherwise devoid of grazing (Phillips 1936). Pocket gophers generally avoid soils associated with large rocks as well as soils with poor drainage, small particle size, poor gas diffusion, and shallow topsoil (Davis, Ramsey & Arendale, 1938; Davis, 1940; Hansen & Morris, 1968; Kennerly, 1964; Miller, 1964; and McNab, 1966). Areas with shallow topsoil are generally avoided since shallow burrows are prone to cave-ins and temperature fluctuations (Chase, Howard, & Rosenberry, 1982; Kennerly, 1964; McNab, 1966; Turner et al., 1973; Davis, Ramsey, & Arendale, 1938). Davis, Ramsey and Arendale (1938) reported a minimum requirement of approximately 10 cm of topsoil above hard clay for central Texas species of Geomys. The distribution of pocket gophers (genus Geomys) seems to coincide with sandy soils throughout Oklahoma, Arkansas, Texas, and Louisiana (Davis, 1940).

Until the mid 1990's, Geomys breviceps (Baird's pocket gopher) was the only species of pocket gopher thought to exist in Arkansas (Sealander & Heidt, 1990). However, Elrod et al. (1996a) determined by using allozyme analysis and identification of chewing lice that a second species of pocket gopher, the plains pocket gopher, inhabited Arkansas. Furthermore, Elrod et al. (2000) described the disjunct population in Izard County, Arkansas (Fig. 1) as a new subspecies of the plains pocket gopher, Geomys bursarius ozarkensis (Ozark pocket gopher). Kershen (2004) estimated the population of this subspecies at approximately 3,500 individuals, with a range entirely contained within Izard County. This subspecies has been identified as a "Species of Greatest Conservation Need" in the Arkansas Wildlife Action Plan (Anderson, 2006).

Ozark pocket gophers were located in grassy fields and lawns with restricted heavy agriculture activity. This type of activity would cause tractor related burrow system cave-ins, especially if the topsoil depth is less than 10.2 cm or barren fields due to their dependence on vegetation for nourishment (Davis, Ramsey, & Arendale, 1938; Turner et al., 1973).

Several residents of Izard County recounted movement of the pocket gopher along creeks near their home. Small streams provide water for plants consumed by the animal and offer a convenient dispersal corridor while having minimal flood duration as opposed to a major river. Sandy soils are found in close proximity to stream and river drainages in Izard due to the overall steep, rocky terrain (United States Department of Agriculture, 1984). This habitat adjacent to streams and rivers creates excellent soil composition for these fossorial rodents. Furthermore, determination of potential pocket gopher dispersal corridor routes and future habitat may be delineated by identifying the water drainages in areas with steep, rocky topography.

Limited published data exists on the Ozark pocket gopher in the primary literature, with the exception of the initial distribution and historical biogeography of Geomys in Arkansas and surrounding states (Elrod et al., 2000). Thus, the objective of this manuscript is to combine the efforts of 3 studies in an effort to provide a definitive analysis of the species requirements in regards to current conservation needs. The data used in this study were collected between 2002 and 2008 from 3 previous studies (Connior, 2008; Kershen, 2004; Sasse, unpubl. data). By analyzing multi-year data, we were able to complete a synthesis of current habitat requirements and distribution and determine possible dispersal corridors and future range potential for gophers in Izard County. Furthermore, conservation implications are discussed in relation to the limited distribution of Ozark pocket gophers, which is almost exclusively on private land.

Methods

Field Site Description

Field sites were located in the southern portion of Izard County, Arkansas (Fig. 1). Of the 3 Ozark Plateau Provinces, Izard County lies mainly within the Salem Plateau section with a small portion in the Springfield Plateau section. The Salem Plateau has an elevation of 212-303 m above sea level with outcroppings of dolomite and sandstone on gently sloping to rolling uplands and moderate to steep side slopes (United States Department of Agriculture, 1984). The Springfield Plateau has a slightly higher elevation than the Salem Plateau with outcroppings of limestone and sandstone. While there are limited broad upland flats, the majority of the Springfield Plateau is described as steep V-shaped valleys created by streams separated by gently to moderately sloping ridges. The southern and western boundaries of Izard County are delineated by the White River, which has eight major streams feeding the flow (United States Department of Agriculture, 1984). The study area containing potential pocket gopher habitat consisted mainly of cleared stream drainages used for cattle and hay production.

Distribution

Presence of pocket gophers was identified via automobile and helicopter surveys of Izard and surrounding counties. The original distribution for G. b. ozarkensis is published in Elrod et al. (2000) and was determined by examining fields along all roads within a 30 km radius of the assumed epicenter. We conducted additional automobile surveys in 2002, 2007, and 2008. In 2008, we focused additional searching efforts in the area just south of the White River near Guion in Stone County, Arkansas.

Helicopter flights were conducted in Izard, Fulton, Sharp, and Randolph Counties in Arkansas for additional pocket gopher locations. Helicopter flights were completed in a search of above ground sign for new pocket gopher locations during 2002 in Izard County. Helicopter flights were conducted on April 19, 2002 lasting approximately 4 hr and November 24, 2002 lasting approximately 3 hr. Flights were flown in a 1.2 km grid to cover Izard County and overlapped approximately 3.2 km into each surrounding county for a total coverage of approximately 1,737 km^2. During flights, coordinates of Ozark pocket gopher locations were recorded with a global positioning system (GPS) unit. Flights were also conducted along the floodplains of streams and rivers on March 12-14, April 27, and December 21-22, 2005 with a total of 25 hr being flown in a Hughes 300 helicopter to the north and northeast of known range. These flights encompassed all major drainages in Fulton, Sharp, and western Randolph Counties. We recorded locations using a GPS of probable gopher colonies identified during the flights. Later, we ground-truthed the probable gopher colonies identified during aerial surveys to determine if gophers existed in these locations. If confirmed, these sites were recorded with GPS and combined with all known locations into one shapefile for a minimum convex polygon analysis of animal locations using Hawth's tools for ArcGIS.

Habitat Analysis

We used 5 randomly spaced circular plots with a diameter of 88.9 cm to determine percent ground cover of major vegetation species in each of 10 locations containing optimum habitat, identified by large numbers of pocket gopher mounds. We identified each plant type to the lowest possible taxonomic level using dichotomous keys listed in Diggs, Lipscomb, and O'Kennon (1999), Great Plains Floral Association (1986), Hitchcock (1971), Tyrl et al. (1998), U.S. Department of Agriculture (2002) and Waterfall (1969).

We collected soil samples from the same 10 vegetation locations for analyses of soil texture, particle size, percent organic matter and acidity. We used Gee and Bauder (1986) definition of soil texture, which states it is "based on different combinations of sand, silt, and clay separates that make up the particle-size distribution of a soil sample." Soil fertility is indicated by organic matter which is a measure of the amount of organic material, decomposing plant matter, fecal matter, etc., in the soil. Soil acidity is indicated by pH.

We collected and analyzed three random samples of approximately 300 g per each of 10 fields. Soil profiles for all samples were created to a minimum depth of 35.56 cm and samples were collected from the middle of each profile and sealed in a plastic bag (Soil Survey Staff, 1974). Detailed soil analyses methods are described in Kershen (2004). We used visible color change to identify topsoil depth by measuring distance to B horizon on soil profiles in the field. We conducted laboratory analyses by taking the total sample weight after equilibrating samples to room moisture levels, sieving out particles greater than 2 mm then splitting the samples into the correct weights for the various tests. Moisture was removed from approximately 10 g of soil by placing the sample in a 105°C oven overnight. Organic matter and pH were documented using the protocol outlined in Buol, Hole, and McCracken (1989). Soil particle size was determined on approximately 50-60 g of soil by employing the pipette method protocol outlined in Gee and Bauder (1986). We calculated percent clay by taking the original sample weights along with the difference between empty 40 ml beakers and the beakers with dried samples. The cylinders were then rinsed completely using de-ionized water through a 63 μrn sieve, which trapped the sand. Original sample weights and sand weights were used to calculate percent sand of the samples. Silt was calculated as the remainder of the soil not accounted for by clay and sand weights.

We used Minitab 14 (Minitab, Inc., State College, Pennsylvania) to conduct Pearson correlation to elucidate associations of soil particle size classes and multiple regression analyses to determine if density of pocket gophers is related to soil particle size, organic matter, or hydrogen ion concentration. Other studies (Blackburn & Gaston, 1996; Smallwood, Jones, & Schonewald, 1996; Smallwood & Schonewald, 1996; Smallwood & Morrison, 1999) have found high correlations between mammalian density estimates and the size of study area sampled. Thus, we conducted a linear regression between log-transformed density estimates and the corresponding log-transformed study areas reported in Kershen (2004), in order to exclude the variation in density explained by the study area size (Fig. 2). Then, we used the residuals of this analysis as an index of density in subsequent regressions plotted against soil particle size, organic matter, or hydrogen ion concentration.

In addition to soil samples, we used Geographic Information System (GIS) to identify all soil associations that Ozark pocket gophers occupy by relating known pocket gopher occupancy to soils.

We used coordinates in the UTM NAD83 coordinate system of known pocket gopher locations from all automobile and helicopter surveys. We imported the GPS locations into ArcView 9.0 (ESRI, Redlands, CA). For reference, we overlaid the pocket gopher location data on a 2000-2002 county mosaic ftp file and a Natural Resources Conservation Service (NRCS) 2003 SSURGO soil map to investigate soil associations. We identified potential habitat in Izard County by creating a shapefile of all soil associations that contained pocket gophers throughout Izard County. The Clip feature was used to form the entire data set to the Izard County boundary line.

Results

Distribution

As of 2008, the current range of the Ozark pocket gopher remains in the southern portion of Izard County with a total area of 2,321.7 km² calculated using a minimum convex polygon (Fig. 3). Yet, some individuals or relict populations may still occur undetected adjacent to the White River in Stone County. We live trapped an adult male in 2007 in northeastern Stone County. This individual remained at the site throughout the spring and summer of 2007, but in January of 2008 we did not find any evidence (i.e., new mounds) of the individual. In the late 1980's, 2 specimens were collected in Stone County (Elrod et al., 2000). However, these specimens were in central Stone County and were not near the capture location of the individual in 2007. Subsequent surveys of Stone County did not detect any pocket gophers occupying the area (current study; Elrod et al., 1996b). In other areas, we detected 9 possible pocket gopher sites in adjacent Fulton and Sharp Counties during the 2005 aerial surveys, however subsequent ground-truthing in 2007 produced no active pocket gopher evidence.

Habitat requirements and potential

We identified 21 families of vegetation in Ozark pocket gopher fields (Table 1). Poaceae, the grass family, had the highest representation at 30 collections and composed 65.9% of identifiable vegetation. All other identifiable plant species were forbs and combined made up 26%. Euphorbiaceae, the spurge family, and Asteraceae, the sunflower family were collected at the most locations. Euphorbiaceae was collected 12 times and Asteraceae was collected 11 times. Members of family Poaceae were identified to genus 3 times, family 5 times, and species 22 times. Cynodon dactylon, bermuda grass, was the most common species collected at 7 locations, the next most numerous member of this family is Sorghum halapense, Johnson grass, collected at 3 locations. All other species were collected only once. The most common genus was Sporobolus collected 3 times. We identified 2 genera of family Euphorbiaceae. Four species of Croton were identified: C. glandulosis (4 locations), C. monanthogynus (2 locations), C. texensis (1 location) and C. capitatus (1 location) in addition to Chamaesyce nutans (1 location). Three other representatives to the Euphorbiaceae family were identified. Of the Asteraceae family Tetraneuris, bitterweed, was most frequently collected (3 locations). We identified 3 other representatives to family, 5 to genera, and 3 to species, the latter 2 groups represented by a single collection.

We determined in-field topsoil depth, or distance to B horizon, in only one of 33 samples which was determined by a visible lightening of the soil at a depth of 25.4 cm. We could not visually identify any color change in all other samples within the exposed profile of 35.56 cm. Most sampled fields were located at the base of a moderate hill and/or near a waterway. Both of these geographical positions would allow for deposition of soil, thus creating a deeper than expected topsoil (C. R. Ferring, pers. comm.). The pH had a median value of 5.05, (SD=0.97; range 4.03 to 7.12). A broad range was observed from neutral to somewhat acidic. Organic matter averaged 6.72% (SD=3.36; range 0.32 to 16), gravel content averaged 1.87% (SD=3.64; range zero to 18.64%), sand content averaged of 74.5% (SD=13.15; range 41.77 to 97.44%), silt content averaged 20.97% (SD=11.55; range 1.31 to 48.17%), and clay content averaged 4.63% (SD=2.36; range 1.25 to 11.8%). Six soil textures were recorded with laboratory analyses. Soil texture is derived from the percent of sand, clay and silt. Loamy sand composed 40% of samples while sandy loam composed 23%, sand, 17%, gravely sandy loam, 10%, loam, 7%, and silt loam composed 3%.

Density estimates were highly correlated to size of area sampled with a regression equation of: Log Density/HA = 1.19 - 0.943 Log Size (P-value < 0.001; $r^2 = 0.765$; Fig. 2). No significant relationship existed between the residuals of log Density/ HA of pocket gophers (which produces a density index that is controlled for field size) versus soil texture, organic matter, pH, or hydrogen ion concentration.

GIS analysis of all known Ozark pocket gopher occupancy identified 11 soils in which pocket gophers resided with Izard County containing 10 of those soil types (Table 2). The individual gopher captured in Stone County was located in the Wideman loamy fine sand type, which was not found in Izard County. Potential soil habitat occurs to the East, North, and West of current distribution (Fig. 3). Aerial photography reveals much of the potential habitat is presently G. b. ozarkensis' preferred habitat of grassy vegetation.

Discussion

G. b. ozarkensis is restricted to the southern one-third of Izard County. Land-clearing activities have allowed sustained habitation of pocket gophers in Izard County, a terrain dominated by hardwood forests. All sampling locations that contained pocket gophers were grazed land, hay fields or frequently mowed areas. Although aerial surveys detected possible sites in surrounding counties, currently no active populations were found. It is possible that pocket gophers may have been present at the time of the aerial surveys but later dispersed. The individual gopher captured in stone County may have dispersed elsewhere as well. The White River is a significant southern barrier to the Ozark pocket gopher, separating existing gopher colonies in Izard County from potential habitats in Stone County. G. b. ozarkensis has been documented travelling above-ground (Connior 2008), making the Hwy 58 White River bridge a possible conduit for dispersal. This bridge spans the White River near the southernmost active colonies in Izard County. Although we have no direct observation of this dispersal event, the southernmost individual discovered in Stone County in 2007 could have crossed over the White

River via the highway bridge. Another possibility is that the pocket gopher swam the White River, which is a dammed river and has variable stream flow. Pocket gophers are able to cross rivers with variable stream flow and narrower widths during droughts, but not large widths and steady stream flow (Kennerly, 1959; Sudman, Choate, & Zimmerman, 1987; Wilkins, 1985; Wilkins, 1987; Wilkins & Swearingen, 1990). Additional surveys and monitoring in both Izard and Stone counties may determine the status of the White River as a barrier to the Ozark pocket gopher.

Luce, Case, and Stubbendieck (1980) and Myers and Vaughan (1964) concluded that plains pocket gophers live in areas dominated by grasses. Concurrent with their reports, sample fields in this study were dominated by invasive, non-native grass species. With such a wide array of vegetation present in pocket gopher habitat it appears that the Ozark pocket gopher inhabits areas not based on specific plant species, but rather on the proliference of forage. Although bermuda grass, Cynodon dactylon, is by far the most prevalent species, it is quite likely that bermuda grass was planted by landowners to establish a lawn, hay fields or grazed lands and not selected by pocket gophers as optimal forage species. A variety of grasses may be necessary in the pocket gopher diet, evidenced by different species, such as Sporobolus and Digitaria, being the most prevalent in different field locations. Our study area vegetation was dominated by grasses (66%) as was Myers and Vaughn (1964) with 88% grasses. In addition, Luce, Case, and Stubbendieck (1980) reported 44.9% grasses in the stomach contents of Geomys. Thus, grasses appear to outweigh forbs in importance to Geomys, however forbs are prevalent in their diet. Luce, Case, and Stubbendieck (1980) stated that forbs may be most important during the growing season and may be less important in winter months. We collected 26% forbs in our vegetation samples, far less than the amount of grass varieties. Foster and Stubbendieck (1980) found annual grasses, annual forbs, and perennial forbs were more prevalent in areas of pocket gopher activity than in areas devoid of pocket gophers possibly due to pocket gophers creating dirt mounds. Annual grasses and forbs and perennial forbs decline as vegetation reaches climax communities. Thus, pocket gophers maintain fields at an earlier stage of plant succession due to soil mounding and may be an ideal home for organisms that prefer non-climax vegetation type prairies.

Thickened topsoil, which has looser, sandier soil than lower horizons, allows the pocket gophers to have variability in depth of their tunnel system to avoid major temperature fluctuations and frequent cave-ins resulting from shallow burrows. In this study, the soil had a thickened A horizon indicated by the only visible color change at 25.4 cm most likely due to slope position. Yet, pocket gopher activity in the area may have increased the topsoil depth as well (Schwartz & Schwartz, 1981; Jones et al., 1983).

Downhower and Hall (1966) state that G. bursarius prefer soils with a minimum sand content of 40% and a maximum clay and silt content each of 30%. Schmidly (1983) also states G. bursarius prefer high sand and low clay contents. Our findings concur with previous studies with the exception of those relating to silt. High clay and silt content as well as soil moisture may be important variables to pocket gopher occupancy because these factors reduce the aeration of the soil and gas exchange with the external environment (Moulton, Choate & Bissell, 1983). Beck and Hansen (1966) found Geomys of eastern Colorado to be more abundant in sandy loam soils compared to dune sand while Foster and Stubbendieck (1980) report Geomys of northwest Nebraska are restricted to sandy, silty soils. Our findings reveal that Ozark pocket gophers tend to be more prevalent in loamy sand soils. This soil type offers higher silt content supporting more plant life while still being conducive to pocket gopher tunneling. Loamy soils also have a higher water holding capacity than do sandy soils, which would facilitate plant growth and ease of digging. We found 21% of soil samples were sandy loam. Sandy loam is a soil with high sand, low clay and moderate silt contents. This may indicate that some silt may be necessary for vegetation consumed by pocket gophers to survive resulting in additional pocket gopher activity.

The Ozark pocket gopher does not appear to be limited by pH. Davis, Ramsey, and Arendale (1938) also found no correlation between pocket gopher distribution and pH in Texas; G. breviceps occupied soil ranging from 4.5 to 8.0. Pocket gophers and their activities may elevate soil organic matter possibly explaining the expansive range values observed for organic matter.

We did not find any significant relation between pocket gopher density and any measured soil parameter. Homogeneity of sampled fields and wide ranging values for measured soil parameters may have caused the lack of statistical significance. Furthermore, larger soil sample sizes in addition to sampling in non-inhabited fields may lead to statistical significance between density and certain measured soil parameters. Based upon our observations, pocket gophers appear to be less numerous in areas of high gravel content and are more numerous in areas of high sand content possibly due to increased burrowing ease.

Flood plains tend to be more level than lands outside of flood plains (United States Department of Agriculture 1984). This levelness reduces geological erosion which increases soil depth to bedrock as compared to non-flood plain areas. The majority of open, grassy fields in Izard County are located within flood plains due to historical and current farming practices. Open fields along small waterways such as creeks and streams may be preferred over fields along rivers as they have minimal flood inundation. Close proximity to a waterway provides a continuous deposition of sand from the waterway, creating excellent burrowing conditions.

Given that nearly 59% of Izard County is described as moderate to steeply sloping with rocky outcroppings, and/or high levels of surface stoniness and gravel, this additional sand deposition on relatively flat land becomes even more important to pocket gophers. In addition to being flat and of high sand content, the fields within flood plains are also where forest has been cleared to encourage grass production. Healthier herbaceous communities are located within close proximity to waterways as plants utilize the abundance of moisture. Pocket gophers may also utilize this riparian habitat as dispersal corridors from one suitable field of inhabitance to another. Maintaining the current environment of and around streams near known fields of inhabitance may allow and even promote dispersal of the Ozark pocket gopher as they seek more open fields of suitable habitat. Available suitable riparian habitat serving as corridors would decrease overcrowding in fields of known inhabitance creating a stronger, healthier population. Maintaining these dispersal corridors is especially important in the ecology of the Ozark pocket gopher for 2 main reasons. First, pocket gophers are restricted in their ability to colonize new areas because of their fossorial lifestyle. Second, the majority of Izard County is not ideal habitat for pocket gophers which results in Ozark pocket gophers being even more restricted in their ability to colonize new areas.

The current pocket gopher habitats in Izard County are largely privately owned, making direct public management less likely. However, education and outreach can mitigate this problem. Species, such as pocket gophers, that are deemed agricultural pests can suffer extreme mortality rates from humans to alleviate economic loss (Scheffer, 1910; Witmer & Engeman, 2007). Many landowners still view the Ozark pocket gophers as pests and continue to kill trap. Yet, landowners may artificially maintain stable populations within their fields by such removal. By removing a portion of the population within a field, landowners reduce the need for dispersal or the combined threats of disease and starvation as a result of high density. With this in mind, monitoring of the population is recommended to insure that a population crash does not occur as witnessed in a population of Thomomys bottae by Howard (1962). Finally, the small current distribution and the narrow habitat requirements of the Izard County population suggest that additional conservation efforts are warranted for this species.

Acknowledgements

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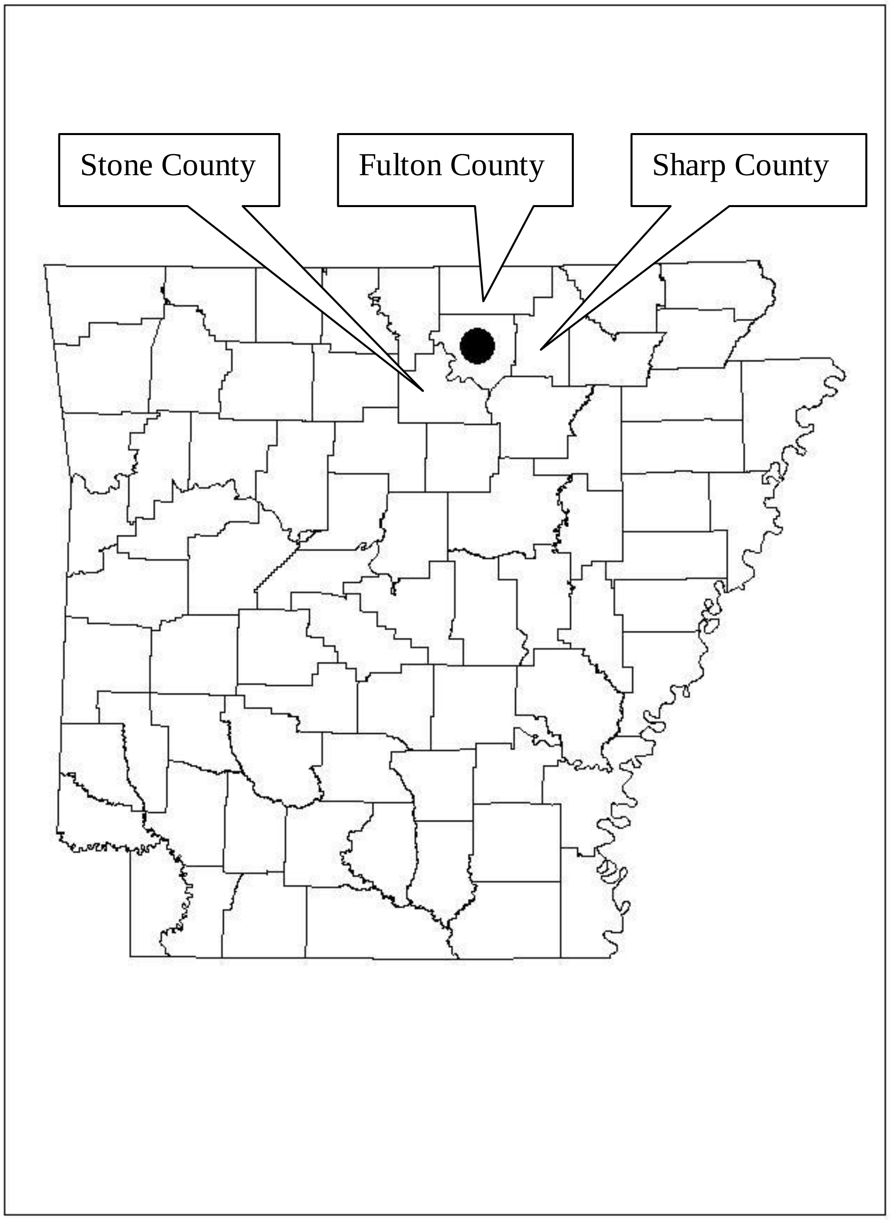
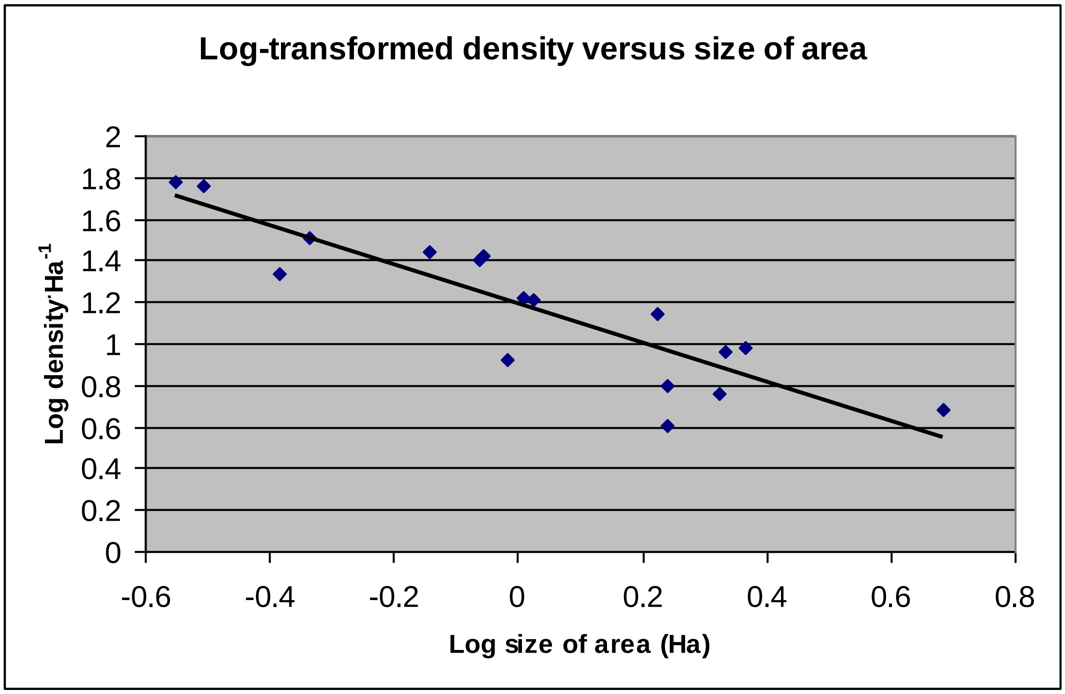
Figure 1: Map showing county occurrence of endemic pocket gopher subspecies Geomys bursarius ozarkensis in Arkansas. Black circle identifies Izard County.

Figure 2: Log-transformed Geomys bursarius ozarkensis density estimates versus size of area sampled from Kershen (2004). The regression equation is Log Density/HA = 1.19 - 0.943 Log Size (P-value < 0.001; $r^2 = 0.765$).

Figure 3: Potential soil habitat for Geomys bursarius ozarkensis within and outside of its known range surveyed in 2008 in Izard County, Arkansas.


Stone County
Fulton County
Sharp County



Log-transformed density versus size of area
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
Log density·Ha-1
Log size of area (Ha)

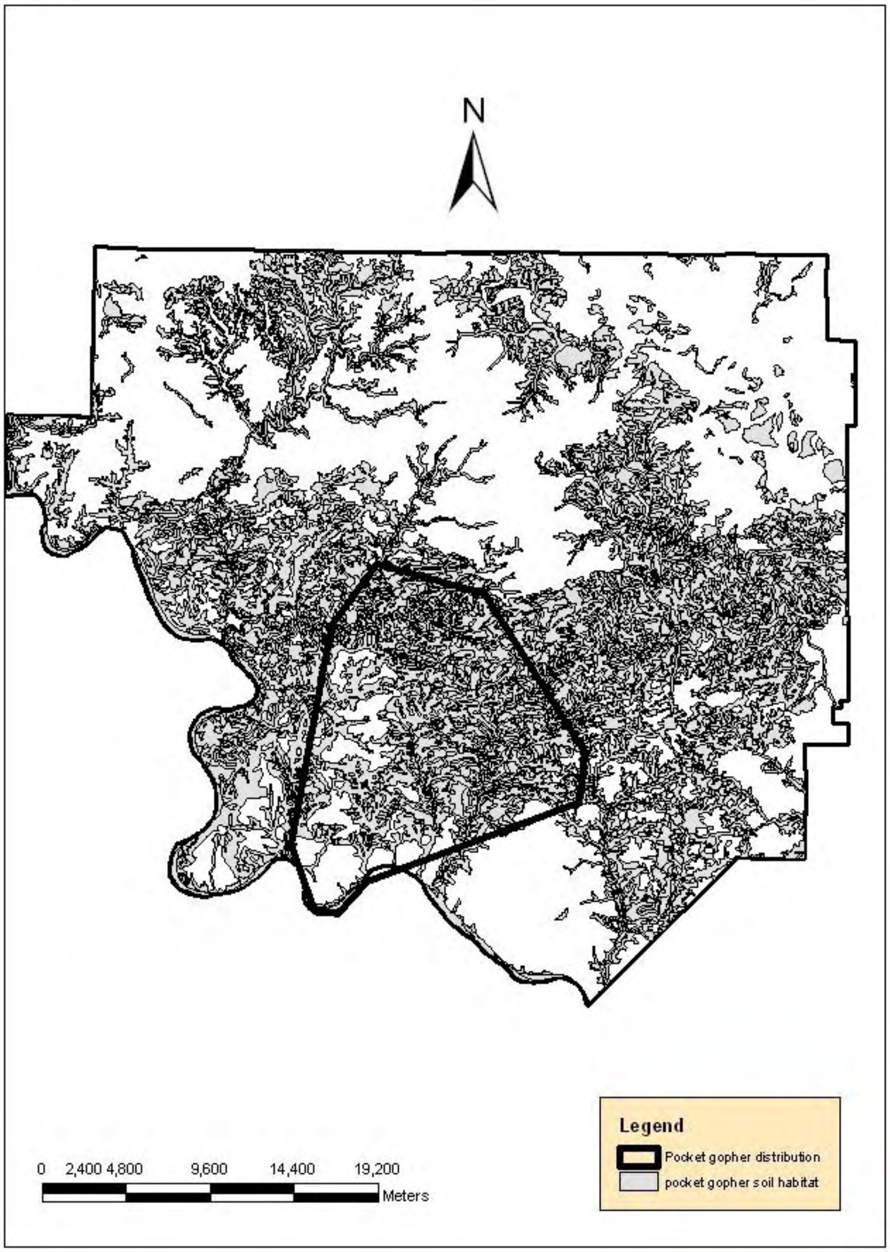

N
Legend
Pocket gopher distribution
pocket gopher soil habitat
0 2,400 4,800 9,600 14,400 19,200
Meters

Table 1: Identification and total percent ground cover of collected vegetation from 10 sites of known Geomys bursarius ozarkensis in Izard County, Arkansas.

Identification	**Percent ground cover**
Family Poaceae	65.91
Cynodon dactylon	41.96
Sorghum halapense	6.20
Sporobolus species	5.30
Panicum species	4.90
Digitaria species	3.20
Setaria glauca	1.10
Tridens flavus	1.00
Sporobolus cryptandrus	0.91
Sporobolus compositus	0.50
Polypogon monspeliensis	0.40
Eragrostis pectinacea	0.20
Cenchrus spinifex	0.10
Paspalum setaceum	0.10
Family Euphorbiacea	7.84
Croton monanthogynus	6.00
Croton texensis	1.10
Croton glandulosus	0.50
Croton capitatus	0.20
Chamaesyce nutans	0.04
Family Fabaceae	3.51
Strophostyles leiosperma	1.35
Trifolium species	1.16
Family Asteraceae	3.40
Tetraneuris species	2.90
Taraxacum species	0.27
Chrysopsis pilosa	0.09
Silphium species	0.06
Gnapthalium species	0.04
Rudbeckia hirta	0.02
Conyza canadensis	0.02
Family Cyperaceae	3.31
Cyperus esculentus	2.20

Cyperus species	1.11
Family Oxalidaceae	1.46
Oxalis stricta	1.04
Oxalis corniculata	0.42
Family Solanaceae	1.29
Solanum carolinense	1.16
Solanum species	0.13
Family Rosaceae	1.23
Family Apiaceae	1.11
Family Caryophyllaceae	1.09
Silene species	1.00
Stellaria calycantha	0.09
Family Amaranthaceae	0.56
Froelichia gracilus	0.56
Family Cactaceae	0.47
Opuntia species	0.47
Family Rubiaceae	0.18
Galium obtusum	0.18
Family Brassicaceae	0.15
Lepidium virginicum	0.15
Family Plantaginaceae	0.15
Family Lythraceae	0.13
Rotala ramosior	0.13
Family Culsiaceae	0.09
Hypericum species	0.09
Family Laminaceae	0.05
Calamintha arkansana	0.05
Family Gentianceae	0.05
Family Commelinaceae	0.02
Commelina erecta	0.02
Family Graminaceae	0.02
Setaria glauca	0.02
Unidentified or bare	11.47

Table 2: Soil types of known Ozark pocket gopher

(Geomys bursarius ozarkensis) locations in Izard County, Arkansas.

Soil Type
Boden gravelly sandy loam, 3 to 8 % slopes
Boden gravelly sandy loam, 8 to 20 % slopes
Estate-Portian-Moko association, rolling
Estate-Portian-Moko association, steep
Peridge silt loam, 3 to 8 % slopes
Portia sandy loam, 3 to 8 % slopes, eroded
Portia sandy loam, 8 to 12 % slopes, eroded
Sturkie silt loam, occassionally flooded
Wideman fine sand, frequently flooded
Wideman fine sandy loam, 0 to 3 % slopes