DENSITY, DISTRIBUTION AND HABITAT REQUIREMENTS FOR THE OZARK POCKET GOPHER (*Geomys bursarius ozarkensis*)

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A new subspecies of the plains pocket gopher (*Geomys bursarius ozarkensis*), located in the Ozark Mountains of north central Arkansas, was recently described by Elrod *et al.* (2000). Current range for *G. b. ozarkensis* was established, habitat preference was assessed by analyzing soil samples, vegetation and distance to stream and potential pocket gopher habitat within the current range was identified.

A census technique was used to estimate a total density of 3,564 pocket gophers. Through automobile and aerial survey 51 known fields of inhabitance were located extending the range slightly. Soil analyses indicated loamy sand as the most common texture with a slightly acidic pH and a broad range of values for other measured soil parameters and 21 families of vegetation were identified. All inhabited fields were located within an average of 107.2m from waterways and over 1,600 hectares of possible suitable habitat was identified.
ACKNOWLEDGMENTS

Appreciation is extended to the members of my committee, Dr. Kenneth Dickson, Dr. Douglas Elrod and Dr. Thomas Beitinger for assistance and support throughout this project. Special gratitude is extended to my parents, Deborah and Douglas Allbach, and to my husband, Daniel Kershen. Their encouragement and support has been invaluable throughout this project and my life. Thanks are also extended to Ronald Kershen, Chad Bradley, Blake Sassee and J.G. Metscher for their field assistance, to Robin Buckallew, Dr. C. Reid Ferring and Johnny Byers for laboratory support and to Bruce Hunter for help with ArcView GIS.

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TABLE OF CONTENTS

Page

ACKNOWLEDGMENTS ........................................................................................................ ii

LIST OF TABLES ................................................................................................................. v

LIST OF FIGURES ................................................................................................................ vi

Chapter

I: INTRODUCTION ................................................................................................................. 1

   Historical Biogeography
   Subspecific Distinction
   Purpose of Study

II: CURRENT RANGE ........................................................................................................... 6

   Introduction
   Study Area
   Methods
   Results
   Discussion

III: DENSITY ESTIMATION .................................................................................................. 18

   Introduction
   Methods
   Results
   Discussion

IV: HABITAT ANALYSIS ....................................................................................................... 27

   Introduction
   Vegetational Analysis
   Methods
   Results
   Soil Analysis
   Methods
Results
Distance to Stream
Methods
Results
Discussion

V: CONSERVATION IMPLICATIONS........................................ 54

Introduction
Conservation Strategies

REFERENCES................................................................. 62
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: Locations of pocket gopher activity reported from fall 2001 newspaper press releases</td>
<td>11</td>
</tr>
<tr>
<td>2: Pilot survey results</td>
<td>23</td>
</tr>
<tr>
<td>3: Collected density data</td>
<td>23</td>
</tr>
<tr>
<td>4: Identification and total percent ground cover of collected vegetation</td>
<td>33</td>
</tr>
<tr>
<td>5: Summary of texture, soil particle size, organic matter, pH and hydrogen ion concentration</td>
<td>40</td>
</tr>
<tr>
<td>6: Known locations of <em>G. b. ozarkensis</em> and distance to stream</td>
<td>47</td>
</tr>
<tr>
<td>Figure</td>
<td>Page</td>
</tr>
<tr>
<td>--------</td>
<td>------</td>
</tr>
<tr>
<td>1: Locations of <em>G. b. ozarkensis</em> identified from aerial survey of Izard County, Arkansas</td>
<td>12</td>
</tr>
<tr>
<td>2: Current range of <em>G. b. ozarkensis</em></td>
<td>13</td>
</tr>
<tr>
<td>3: Potential suitable habitat for <em>G. b. ozarkensis</em></td>
<td>14</td>
</tr>
<tr>
<td>4: Pilot survey grid</td>
<td>20</td>
</tr>
<tr>
<td>5: Fields surveyed for pocket gopher density</td>
<td>21</td>
</tr>
<tr>
<td>6: Location of vegetation sample fields</td>
<td>30</td>
</tr>
</tbody>
</table>
CHAPTER I

INTRODUCTION

Pocket gophers are subterranean rodents of the family Geomyidae that derive their name from a pair of distinctive external fur-lined cheek pouches used to carry food and nesting material. Because of their subterranean lifestyle pocket gophers have evolved: morphological adaptations to burrowing, specific habitat requirements, disjunct distribution, low vagility, aggressive territoriality, genetic effects and reproductive isolation (Davis, 1986). Other unique adaptations of the pocket gopher include a distinguishing mouth structure that keeps large incisors exposed as fur lined lips and front part of the mouth close behind. Having the mouth close behind the incisors allows pocket gophers to keep dirt out of their mouth while excavating and feeding. They also possess small eyes, and thus have limited vision, and small ears with valves that occlude dirt while burrowing (Elrod, 1998). Their skin is fairly loose and covered by short thick fur. Body coloration is medium brown with black hairs, while cheek pockets and mouth hair are light brown to white in color (Schwartz and Schwartz, 1981).

Equipped with a well-developed set of forelimb muscles and strong forefeet, each toe with a prominent claw, these subterranean rodents spend most of their lives burrowing. Kennerly (1964) estimated that each Geomys bursarius
moves approximately 0.95 metric tons of soil per hectare per year. Pocket gophers construct extensive closed tunnel systems in which to reside. With the exceptions of mating and rearing offspring, they live alone and aggressively defend their tunnel system from intruders. Generally, the tunnel system consists of one primary tunnel with several side branches that serve various functions such as food storage, latrine, den and outlets to the surface. Average tunnel diameter is 10 cm (Schwartz and Schwartz, 1981) and can be found 10 to 30 cm below the surface, though the nest tunnel is wider and usually deeper (Chase et al., 1982). Nose, chest, and front feet push excavated dirt to the surface creating a fan shaped mound of dirt 30 to 60 cm in diameter and approximately 15 cm tall (Schwartz and Schwartz, 1981).

Due to specific habitat requirements, distribution patterns among pocket gophers appear patchy. Numerous species and subsequent subspecies have been identified within the family Geomyidae due to isolation created by irregular distribution and possibly by fairly regular generic extinction and origination rates (Cook et al., 2000) resulting in the interruption of consistent gene flow.

Living in small isolated groups can cause several genetic effects such as genetic drift, founder effect and bottleneck effect. Genetic drift occurs when there is rapid change in gene frequency in a population caused purely by chance. Large populations rarely encounter genetic drift due to stabilizing factors with countless breeding individuals. However, small populations are unable to neutralize the effects of a few individuals who quickly pass their genes, leading to
increased rates of evolution. Founder effect occurs when a few organisms establish a new population. When the population becomes large original traits are still prominent and can be traced back to the earliest individuals, or founders, of the population. Finally, bottleneck effect takes place when there is a dramatic decline in population size in a short time period. Severely reducing the number of breeding individuals reduces genetic diversity in the population (O'Neil, 2003). These phenomena could be one reason why the family Geomyidae is so diverse.

**Historical Biogeography**

Prior to the Wisconsin Ice Age, pocket gophers of genus *Geomys* spread from western North America to Florida (Russell, 1968). Currently *Geomys*, the eastern pocket gopher, primarily inhabits the Great Plains of North America from Canada to Texas and into northeastern Mexico however disjunct populations have been observed in the southeastern United States (Lacey *et al*., 2000). Six of the eight Geomyid species are found within the states of Texas, Louisiana, New Mexico, Oklahoma, Arkansas, Missouri, Kansas, Colorado, Nebraska, Wyoming, North and South Dakota, Iowa, Wisconsin, Illinois and Indiana (Elrod *et al*., 2000). The Ozark pocket gopher was suspected to belong to one of two Geomyid species. One of these, *G. bursarius* has a northern boundary in Manitoba, Canada and a southern boundary in central Texas. A second, *G. breviceps* is located from eastern Oklahoma and Texas to Louisiana and Arkansas (Elrod *et al*., 2000). Several genera in the Geomyidae family have isolated or geographically restricted populations. One example, the Mer Rouge
pocket gopher (\textit{Geomys breviceps breviceps}), is located only in Morehouse Parish, Louisiana (Demastes and Hafner, 1991).

Subspecific Distinction

Prior to the findings of Elrod \textit{et al.} (1996), only one species of pocket gopher, \textit{G. breviceps sagittalis} was known to inhabit Arkansas. Sealander (1979) originally stated that all Arkansas pocket gophers were \textit{Geomys bursarius dutcheri}. Later the species was split into two taxa, \textit{G. breviceps} and \textit{G. bursarius}. After the split, Heaney and Timm (1983) asserted that all pocket gophers in Arkansas were \textit{G. b. sagittalis}. Elrod \textit{et al.} (1996) concentrated on a disjunct population in the Ozark Mountains of north central Arkansas. Utilizing allozyme electrophoresis and ectoparasite analysis Elrod \textit{et al.} (1996) determined the isolated population in Izard County, Arkansas is more closely related to its neighbor in Missouri, \textit{G. bursarius missouriensis}, a species inhabiting the north central plains of the United States, than to \textit{G. breviceps}.

The newly identified Ozark population is separated by approximately 65 km from \textit{G. breviceps}, the more ubiquitous of the two species. \textit{G. breviceps} has been identified in 35 Arkansas counties while \textit{G. bursarius} has only been reported from a single county (Elrod \textit{et al.}, 1996). In 2000, Elrod \textit{et al.} compared nucleotide sequences of mitochondrial cytochrome-\textit{b} gene and cranial morphology of the isolated population in the Ozark Mountains to those of \textit{G. breviceps} and \textit{G. bursarius}. Results indicated that the isolated populations in north central Arkansas represent a new subspecies. Taxonomically identified as
*Geomys bursarius ozarkensis* (Elrod et al., 2000), these animals are known to occur only in the southwest one-third of Izard County, Arkansas within the Ozark Mountains.

**Purpose of Study**

Due to their extremely limited range and potential need for conservation consideration, studies to characterize distribution, population density, habitat type and measures that can be taken to protect this geographically restricted taxon are essential and urgent.

Objectives of this study were to:

1.) determine an efficient method of conducting censuses for *G. b. ozarkensis*

2.) establish the distribution of *G. b. ozarkensis*

3.) determine the population density of *G. b. ozarkensis*

4.) determine habitat preferences of *G. b. ozarkensis* by assessing soil parameters and vegetation

5.) use a Geographical Information System (GIS) to spatially document current distribution of *G. b. ozarkensis* and to identify potential habitat

6.) develop conservation strategies for *G. b. ozarkensis* based on extent of distribution and population density
CHAPTER II

CURRENT RANGE

Introduction

*Geomys bursarius ozarkensis* is a relictual disjunct subspecies of pocket gopher in north-central Arkansas. Its closest neighbors are *G. breviceps sagittalis* to the south with a separation of approximately 65 km and *G. bursarius missouriensis* to the north with a separation of approximately 150 km (Elrod et al., 2000). *G. b. ozarkensis* is known only to occur in the southwest one third of Izard County, Arkansas. The expansive White River appears to form a barrier south into Stone County, Arkansas and unsuitable rocky forested habitat might further restrict movement into other portions of Izard County.

Due to limited suitable pocket gopher habitat within Izard County, *G. b. ozarkensis* is found in patchy distribution throughout their restricted range. Pocket gophers are known to prefer loose sandy soils (Davis et al., 1938) in grazed prairie type habitat (Phillips, 1936) and are generally found near streams (Chase et al., 1982; Miller, 1964) where sand content is highest. The Ozark pocket gopher is no exception. Elrod et al. (2000) found that most fields inhabited by *G. b. ozarkensis* were utilized as pasture and hay fields and were
located along six of eight major streams feeding the White River.

Study Area

All research, with the exception of portions of helicopter survey, took place in Izard County, Arkansas. Located in north-central Arkansas, Izard County is approximately 35.4 km north to south and 41.8 km east to west. Total area for the county is roughly 149,447.6 hectares with major bodies of water comprising approximately 906.5 hectares of the total area (United States Department of Agriculture, 1984). Established in October 1825 (Fultz and Fultz, 2003) with Melbourne as the county seat (United States Department of Agriculture, 1984) Izard County had a total population of 13,249 as of 2000 (IEA, 2003). Livestock and poultry production, tourism, retirement income, timber production, small industry and business make up the economy of Izard County. A vast majority of soils on gentle to moderately sloping uplands have been converted into pasture and hay fields. Crop land, generally located in the flood plains of the White River, is minimal. Temperatures throughout the year normally range from mid 20°F to 90°F with an average annual rainfall of 114.3 cm (United States Department of Agriculture, 1984). Of the three Ozark Plateau Provinces, Izard County lies mainly within the Salem Plateau section with a small portion in the Springfield Plateau section. 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 sideslopes (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).

Elrod (1998) established distribution for G. b. ozarkensis by examining fields along all roads within a 30 km radius of the assumed epicenter. All of Izard County and portions of each surrounding county were examined to establish a distribution as the southwest one-third of Izard County, Arkansas. Open areas with herbaceous vegetation and deep, sandy soils associated with pastureland, fields, mowed areas and urban lawns along roads and waterways were reported as common habitat for the Ozark pocket gopher. Using these observations and overlaying known fields of inhabitance with satellite imagery, the amount of suitable vegetation within Izard County for the Ozark pocket gopher was estimated at 56,675 hectares (Elrod, 1998). G. b. ozarkensis was highly fragmented in distribution in an area of the county with the least amount of suitable vegetation.

Elrod et al. (2000) used automobile survey and resident interviews to identify 18 locations of the Ozark pocket gopher. The current study utilized a widespread press release and helicopter observations in addition to automobile surveys to most accurately determine present range for G. b. ozarkensis. Based
on the expansiveness of their range, recommendations will be made for the protection and conservation of these animals.

Methods

As previously described, pocket gopher mounds are above ground evidence of pocket gopher activity. Residents of Izard and surrounding counties were solicited by way of newspaper press releases to report any mound or gopher sightings. Reports of pocket gopher locations were investigated in fall 2001 to determine validity. In addition, presence of pocket gophers was identified via automobile and helicopter surveys of Izard and surrounding counties. All passable roads were driven and two helicopter flights were completed in search of above ground sign for new pocket gopher locations. Helicopter flights were conducted on April 19, 2002 lasting approximately four hours and November 24, 2002 lasting approximately three hours. 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 km². During flights, coordinates of Ozark pocket gopher locations were recorded with a global positioning system (GPS) unit. A digital orthophoto quarter quad (DOQQ) for Izard County, Arkansas was obtained (University of Arkansas, 2002) and added as a theme into ArcView GIS 3.3 (ESRI, 2002), a geographical information system (GIS). Recorded pocket gopher GPS locations were plotted on the image within the GIS to determine subspecies distribution. Using ArcView GIS the DOQQ was visually inspected within the known range of G. b.
ozarkensis to determine habitat characteristics such as distribution, amount of utilized habitat, possible available habitat within current range and distance for each field of inhabitance to the nearest waterway.

Results

Newspaper press releases in the fall of 2000 resulted in more than 20 reports of pocket gopher activity throughout north central Arkansas, all within the White River watershed. Eleven of these reports were investigated visually, each demonstrating the tunnels or mounds of the eastern mole, see table 1, while the remaining reports were discounted by descriptions inconsistent with pocket gopher activity via telephone interview.

Automobile observations of Izard and surrounding counties led to the discovery of three new locations. Thus, locations noted in previous years plus three additional sites were the only locations observed in this study via automobile. Aerial surveys via helicopter revealed 33 previously unknown locations, see figure 1, extending the range to the north and east, see figure 2. These locations were observed in clearings away from roads and usually close to waterways. Melbourne, the county seat, is approximately 15.01 km from the southern most location, 7.94 km from the eastern most location, 4.20 km from the northern most location and 16.79 km from the western most location.

An estimate of approximately 1,626.68 hectares of potential habitat was determined using ArcView GIS, see figure 3. This represents the total amount of cleared uninhabited land within the range of G. b. ozarkensis.
Table 1: Locations of investigated pocket gopher activity reported from fall 2000 newspaper press releases.

<table>
<thead>
<tr>
<th>City</th>
<th>Distance (kilometers) from known range of <em>G. b. ozarkensis</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Batesville</td>
<td>50</td>
</tr>
<tr>
<td>Batesville</td>
<td>50</td>
</tr>
<tr>
<td>Cave City</td>
<td>42</td>
</tr>
<tr>
<td>Cotter</td>
<td>84</td>
</tr>
<tr>
<td>Gamaliel</td>
<td>82</td>
</tr>
<tr>
<td>Lakeview</td>
<td>85</td>
</tr>
<tr>
<td>Mountain Home</td>
<td>71</td>
</tr>
<tr>
<td>Mountain Home</td>
<td>71</td>
</tr>
<tr>
<td>Mountain View</td>
<td>32</td>
</tr>
<tr>
<td>Mountain View</td>
<td>32</td>
</tr>
<tr>
<td>Pineville</td>
<td>13</td>
</tr>
</tbody>
</table>
Figure 1: Locations of *G. b. ozarkensis* identified from aerial survey of Izard County, Arkansas.
Figure 2: Current range for *G. b. ozarkensis*. Triangles (▲) indicate populations that were previously known and sampled in this project. Asterisks (★) indicate populations first seen through aerial survey.
Figure 3: Potential suitable habitat for G. b. ozarkensis.
Discussion

Newspaper press release results were of little value. Although residents were eager to report what they thought was pocket gopher activity, in each instance pocket gopher mounds were mistaken for tunnels and mounds of moles and other animals. However, future press release efforts could be improved by educating residents on the pocket gopher and their above ground signs.

Despite many hours surveying roads of Izard County via automobile only three previously unknown locations were located in this survey increasing the range slightly to the southeast. Several reasons may explain this outcome. Pocket gophers of Izard County, Arkansas may have little suitable habitat within range of migration, efficient dispersal corridors may be few or nonexistent, little dispersal may have occurred between previous studies and the present study, movement among pocket gophers may not be as easily recognized as established populations or other possible causes. Movement was expected along roadways to indicate a migration from one community to another. Lack of roadside mounds may demonstrate that dispersal is not a current driving force among Ozark pocket gopher populations or that these animals choose corridors away from areas of high human activity.

Not surprising, were the additional 33 fields of inhabitance identified from the helicopter surveys. Each previously unknown inhabited field seen from the air was located away from roadways usually behind a large stand of trees and close to small creeks. As mentioned earlier, open areas along small streams
appear to be excellent habitat and corridors for pocket gophers. Land along creeks are expected to have more sand deposited making the tunneling environment ideal and plants would have a continual supply of moisture supporting their feeding requirements. Several locations plotted on the GIS may indicate movement along small waterways as they are positioned one after another along several creeks in Izard County.

One challenge presented by these locations is by what method their success can be monitored. Subsequent helicopter observations may be useful in determining property owners and, with their cooperation, monitoring efforts can begin. These locations may, more reasonably, lend themselves to periodic aerial surveys to check the relative abundance of these organisms. These surveys may best be conducted shortly after haying as mounds would be exposed.

Suitability of estimated available habitat within the known range of the Ozark pocket gopher is not known at this time therefore, 1,626.68 hectares is a generous estimate. Future studies are necessary to determine additional acreage created from additional land clearing and how much of the original estimated acreage plus any additional acreage meets requirements for Geomys bursarius ozarkensis.

Although specimens of G. bursarius were collected across the White River to the south in Stone County over 10 years ago (Elrod 1998) no pocket gopher locations were found in Stone County during this survey or the 1998 survey conducted by Elrod. It is possible that this population may now be extinct. The
White River may form a barrier to southern movement. Another river, the Platte River in Kansas is an effective barrier between two subspecies of *Geomys bursarius* (Sudman *et al*. 1987). A study of the swimming ability of three pocket gopher species reported *G. bursarius* as an average swimmer with a maximum swim time of less than 2.25 minutes (Hickman, 1977), which may allow for crossing small creeks, but not the expansive White River.
CHAPTER III

DENSITY ESTIMATION

Introduction

Several abrupt changes in pocket gopher population sizes have been documented and attributed to a combination of extrinsic and unrecognized intrinsic factors. Extrinsic factors may be change in land use or rainfall and snowmelt creating high water tables. In some cases extreme snowmelt may affect survival of the young (Chase et al., 1982). Turner et al. (1973) reported that loss of young of the year followed by a loss of mature animals prior to the next breeding season may lead to some population declines. Any census technique should provide an accurate, efficient, and cost-effective means of determining pocket gopher densities. Researchers have utilized several census methods to estimate pocket gopher abundance. These efforts have shown that during height of burrow activity fresh mounds can be counted to yield an indirect estimation of population size (Chase et al., 1982). Howard (1961) by transect, Richens (1965) and Reid et al. (1966) by strip transect, and Anthony and Barnes (1983) by circular plot occupancy have all shown the effectiveness of utilizing above ground sign to estimate population density. However, most of these techniques were established for Thomomys species and may not be effective for
**Methods**

Pilot study procedures, modified from Howard (1961), were completed on six test plots for density determination. Four of six fields were completed on *G. breviceps sagittalis* while the remaining two were completed on *G. b. ozarkensis*. Pocket gopher mounds were counted and arrangements recorded on a grid. Using colored flags, this was accomplished by initially setting belt transects at five meter increments. Only fresh mounds within two and a half meters of either side of transect lines were counted, forming a 5 meter belt, and a mound was
only counted if it occurred more than five meters from any previous mound within the same transect. Fresh mounds must not have any vegetation or tracks of any kind through the middle and soil must still appear granular, not compacted. A saturated trapping effort provided the actual density of pocket gophers. As traps were set a notation of their location was made on the documented grid as were location of trapped animals, see figure 4. Using the actual number of trapped pocket gophers in conjunction with the documented mound arrangements and trapped animal locations, appropriate spacing to generate the most accurate density surveyed fields was established.

Figure 4: Pilot survey grid, an example of *G. b. ozarkensis*.

Density determination was accomplished by utilizing the aforementioned transect survey on 17 study plots of known inhabitance by *Geomys bursarius ozarkensis*, see figure 5. Having established transect spacing of 15 meters
Figure 5: Fields surveyed for pocket gopher density.
provided the most accurate estimation of density, flags were spaced 15 meters apart and only every other transect was surveyed, creating a 30 meter belt, thus assuring pocket gopher mounds were not counted twice. These results were extrapolated to conservatively estimate total population density based on the amount of currently utilized habitat.

June 2002 digital orthophoto quarter quad (DOQQ) image data for Izard County, Arkansas and ArcView GIS 3.3 were utilized to visually locate areas of potential pocket gopher habitat within the current range of Geomys bursarius ozarkensis. All open, currently uninhabited fields within the present range of the Ozark pocket gopher were located to determine possible areas of expansion for the Ozark pocket gopher and areas that may be in need of conservation to support future populations. Accomplished by drawing a perimeter around open fields then calculating total area, an estimation of possible suitable habitat was determined as was area of currently inhabited fields.

Results

Pilot surveys resulted in a simple, efficient, low cost, no impact method by which to measure pocket gopher density. Six fields totaling 2.34 hectares were sampled for a total estimated density of 37 animals. Actual density was 29 animals yielding an accuracy of 0.78, see table 2. Fields four and six were completed on G. b. ozarkensis while the others were completed on G. breviceps sagittalis.
Table 2: Pilot survey results.

<table>
<thead>
<tr>
<th>Field</th>
<th>Size (hectares)</th>
<th># Estimated</th>
<th># Active</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.57</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>0.75</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>0.32</td>
<td>6</td>
<td>4</td>
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<td>4</td>
<td>0.25</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>0.20</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>0.25</td>
<td>6</td>
<td>5</td>
</tr>
</tbody>
</table>

Using the 15 meter belt transect method, a pocket gopher population of 346.3 animals ± 78.3 animals in 17 fields totaling 22.91 hectares was estimated for late September 2002. Field size ranged from 0.28 to 4.18 hectares. Number of pocket gophers estimated per field ranged from 4.0 to 60.4 per hectare with an average density of 20.4 animals per hectare, see table 3.

Using the average density of 20.4 pocket gophers per hectare and the area of currently utilized habitat totaling 174.7 hectares, the estimated pocket gopher population for late September 2002 in Izard County, Arkansas is 3,564 ± 597.3 animals. A measure of all open fields within the current range for Geomys bursarius ozarkensis using June 2002 DOQQ image data yielded 1,626.68 hectares of possible suitable habitat for the Ozark pocket gopher.

Discussion

Pilot tests resulted in a reliable, expedient, no impact method to survey pocket gopher populations. Current average density of 20.4 animals is considered a healthy population size among the Ozark pocket gopher in Izard County, Arkansas. Based on previous studies of G. bursarius, Kennerly (1964)
Table 3: Collected density data

<table>
<thead>
<tr>
<th>Field</th>
<th>Estimated # of pocket gophers</th>
<th>Size (hectares)</th>
<th># per hectare</th>
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<td>0.4141</td>
<td>21.7</td>
</tr>
<tr>
<td>14</td>
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<td>0.4596</td>
<td>32.6</td>
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<td>8.3</td>
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<tr>
<td>16</td>
<td>11</td>
<td>1.7423</td>
<td>6.3</td>
</tr>
<tr>
<td>17</td>
<td>20</td>
<td>2.1546</td>
<td>9.2</td>
</tr>
</tbody>
</table>

estimated that on two plots between 3.6 and 5.2 animals per hectare were present in an area of 0.67 hectares while Zinnell (1992) discovered 12.9 Geomys bursarius per hectare. Broussard (1996) found for G. bursarius in McLennan County, Texas 18.7 animals per hectare in hayfield, 16 animals per hectare in riparian sandbar and just 1.3 animals per hectare in a pasture that was, most likely, overgrazed. Demastes and Haffner (1991) estimate for G. breviceps breviceps a mere 0.22 animals per hectare are found in Morehouse Parish, Louisiana. Davis et al. (1938) report an average density of 0.55 G. breviceps per hectare in east Texas with local farmers giving densities of 0.3 and 2.8 animals
per hectare. While limited data are available for density on Geomys species, another closely related genus, Thomomys, has been studied in more depth. Reid et al. (1966) reported a range of 1.2 to 13.8 Thomomys talpoides per hectare with an average density of 6.7 per hectare. Also for T. talpoides, Anthony and Barnes (1983) reported a range of 3.2 to 10.4 animals per hectare over one month periods. On grazed versus ungrazed rangeland, Turner et al. (1973) estimated 9.9 and 22.2 T. talpoides per hectare, respectively. Animals inhabiting fields with sub par conditions may be in the process of relocating to more ideal habitat, utilizing the area as a temporary refuge from competition, may be young animals on the edge of a population that are out competed for resources and forced to move to another location or other unknown reasons.

Izard County seems to support a high number of pocket gophers per hectare. Possibly field conditions in this study far exceed those Kennerly (1964) encountered which would support a much higher density. However, a more likely explanation is that most sampled fields were surrounded by unfavorable pocket gopher habitat therefore G. bursarius ozarkensis may be forced to live in much closer proximity than in areas where more suitable habitat is available. If this is the case, at some point a clear decline in population should be noticed as resources dwindle. In this study it appears as though smaller fields have higher densities than larger fields. Again, this may be because the pocket gophers have little to no refuge from crowding due to a lack of suitable habitat.
In his studies, D. A. Elrod (personal communication) observed that animals caught in the sandiest portions of a field were larger than those caught on the outskirts of a field where habitat becomes less suitable. This may indicate the most ideal habitat of any particular field supports elders of the population and that, upon dispersion, offspring are forced to move away from the most ideal habitat since that territory has already been claimed. A ripple effect may be discovered in which the farther away from optimal habitat one gets the younger the animal.

Population density is dependent upon local climate, soil conditions, altitude, land use, food availability and other habitat factors (Chase et al., 1982). Having completed a thorough census provides baseline population size for Geomys bursarius ozarkensis to which conservation and management strategies and future research studies can be compared. Due to the short-term nature of this research, measured pocket gopher population density provides data for late September 2002 only and does not demonstrate inter-annual population dynamics therefore, further efforts will be necessary to monitor the success of the Ozark pocket gopher.
CHAPTER IV
HABITAT ANALYSIS

Introduction

Pocket gopher preferred habitat has been described as areas having sufficient dispersal corridors of open field with loose, sandy soils having a minimum of approximately 10 cm of topsoil (Davis et al., 1938) with a fair to large particle size and a minimal number of rocks associated with waterways in areas not prone to flooding (Chase et al., 1982; Miller, 1964). Analyzing the previous variables may indicate where populations are likely to be found, where they could be found in the future, and what areas may be in need of conservation as suitable habitat for this subspecies. However, analyzing all the afore mentioned variables is beyond the scope of this research project and is in need of further research utilizing a geographical information system (GIS).

Soil particle size, topsoil depth and food availability are important in the suitability of an area for pocket gophers. Moderately grazed lands have been shown to support the highest populations when compared to over-grazed or land devoid of grazing (Phillips, 1936). Soils with poor drainage, small particle size, poor gas diffusion, and shallow topsoil are generally avoided (Davis et al., 1938; Davis, 1940; Kennerly 1964; Miller, 1964; and McNab, 1966) as are soils associated with large rocks (Hansen and Morris, 1968). Davis et al. (1938)
reported a minimum requirement of approximately 10 cm of topsoil above hard clay for central Texas species of Geomys. Shallow burrows are prone to cave-ins and temperature fluctuations, thus shallow topsoil areas are generally avoided (Chase et al., 1982; Kennerly, 1964; McNab, 1966; Turner et al., 1973; Davis et al., 1938).

Most locations of G. bursarius ozarkensis discovered by Elrod et al. (2000) can be found along six of eight major streams within Izard County, Arkansas flowing into the White River. Several residents of Izard County recounted movement of the pocket gopher along creeks near their home. Small streams might be preferred habitat because they provide water for plants consumed by the animal, offer a convenient passageway while not being as prone to flood as would a major river, and streams deposit sand along the banks creating excellent soil composition for these fossorial rodents.

Vegetational Analyses

Ozark pocket gophers are located in grassy fields or lawns with regular mowing or grazing. However, pocket gophers were not expected to be in fields with heavy agriculture use as the operation of tractors leads to frequent cave-ins of burrow systems in areas where topsoil depth is less than 10.16 cm (Davis et al., 1938) and were absent from barren fields due to their dependence on vegetation for nourishment (Turner et al., 1973).

Several authors (Myers and Vaughn, 1964; Dale et al., 1980; Foster and Stubbendieck, 1980) have reported that grasses represent the majority of a
plains pocket gopher diet while forbs make up a smaller portion. Myers and Vaughn (1964) examined stomach contents of plains pocket gophers and concluded that roots comprise 69% of a pocket gopher’s diet while stems and leaves make up 31%. Dale et al. (1980) reported that roots, stems and leaves were nearly equal in percentage in the gut contents of the plains pocket gopher. They indicated 38.7% of identifiable gut content was shoots and leaves while 30.9% was root material, although they did note these percentages change with season and plant type consumed. Roots of forbs and leaves and stems of grasses were reported to be the preferred diet of the plains pocket gopher. Late fall and winter however bring a shift to higher percentage of roots than aboveground material (Dale et al. 1980).

Methods

Five randomly spaced circular plots with a diameter of 88.9 cm were utilized to determine percent ground cover of major vegetational species in each of 10 fields, see figure 6, containing a large number of pocket gopher mounds. Plants were visually identified as being distinct from one another, descriptions of each plant were written and percent ground cover of each plant type was recorded for each of five plots in 10 sample fields. Total percent ground cover was determined by combining the percent ground cover of each plant type from all plots surveyed and dividing by the total possible percentage. An example of each plant type was collected from each field,
Figure 6: Location of vegetation and soil sample fields.
pressed and returned to the laboratory for identification to the lowest possible
taxonomic level. Along with recorded descriptions at time of collection all
available and pertinent plant parts were used to follow dichotomous keys listed in
Diggs et al. (1999), Great Plains Floral Association (1986), Hitchcock (1971), Tyrl

Results

Poaceae, the grass family, composed 65.9% of identifiable vegetation and had
the highest representation at 30 collections. All other plants are forbs and
combined make up 26% of identifiable plants. Euphorbiaceae, the spurge family,
was collected 12 times and Asteraceae, the sunflower family, 11 times.

Members of family Poaceae were identified to species 22 times, to genus
three times and family only five times. *Cynodon dactylon*, bermuda grass, was
the most common species at seven collections, the next most numerous member
of this family is *Sorghum halapense*, Johnson grass, collected three times. All
other species were represented only once. *Sporobolus* was the most common
genus, collected three times.

Only two genera of family Euphorbiaceae were identified. *Croton* was
identified to species four times with *C. glandulosis* being the most common at
four collections, *C. monanthogynus* at two, *C. texensis* and *capitatus* and
*Euphorbia nutans* at one each. Three other representatives could only be
identified to family.
Asteraceae was dominated by the genus *Tetraneuris*, bitterweed, collected three times. Five other genera were identified, three to species, each represented by a single collection. Three other representatives could only be identified to family.

Samples of 21 families were identified, see table 4. Due to their herbivorous lifestyle the possibility of a direct link between plant species present and pocket gopher population density may need to be explored in future studies.

Soil Analyses

A subterranean lifestyle requires the need for soft, friable, or easily worked, soil that has excellent drainage and air movement. Preferred soils for pocket gophers generally have a light texture and are very porous with poor water-holding capacity (Chase *et al.*, 1982). In one study, *Geomys* excavating tunnel systems through scratching and digging were found to inhabit only sandy friable soils (Lessa and Thaeler, 1989). Davis *et al.* (1938) found *G. breviceps* in east Texas to reside primarily in fine sandy loam soil, only rarely in silt loam and absent completely from sandy loam soil. Soil composition affects the kind and amount of vegetation present and soil porosity, which in turn affects drainage and gas diffusion. Pocket gophers have difficulty living in areas of high rockiness. Given their small size they are not able to move large pieces of rock with ease, if large pieces of rock are common to a field the suitability of that field declines.
Table 4: Identification and total percent ground cover of collected vegetation.

<table>
<thead>
<tr>
<th>Identification</th>
<th>Percent Ground cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Family Poaceae:</td>
<td>65.91</td>
</tr>
<tr>
<td><em>Cynodon dactylon</em></td>
<td>41.96</td>
</tr>
<tr>
<td><em>Sorghum halapense</em></td>
<td>6.20</td>
</tr>
<tr>
<td><em>Sporobolus</em> species</td>
<td>5.30</td>
</tr>
<tr>
<td><em>Panicum</em> species</td>
<td>4.90</td>
</tr>
<tr>
<td><em>Digitaria</em> species</td>
<td>3.20</td>
</tr>
<tr>
<td><em>Setaria glauca</em></td>
<td>1.10</td>
</tr>
<tr>
<td><em>Tridens flavus</em></td>
<td>1.00</td>
</tr>
<tr>
<td><em>Sporobolus cryptandrus</em></td>
<td>0.91</td>
</tr>
<tr>
<td><em>Sporobolus asper</em></td>
<td>0.50</td>
</tr>
<tr>
<td><em>Polypogon monspeliensus</em></td>
<td>0.40</td>
</tr>
<tr>
<td><em>Eragrostis pectinacea</em></td>
<td>0.20</td>
</tr>
<tr>
<td><em>Cenchrus spinifex</em></td>
<td>0.10</td>
</tr>
<tr>
<td><em>Paspalum setaceum</em></td>
<td>0.10</td>
</tr>
<tr>
<td>Family Euphorbiaceae</td>
<td>7.84</td>
</tr>
<tr>
<td><em>Croton monanthogynus</em></td>
<td>6.00</td>
</tr>
<tr>
<td><em>Croton texensis</em></td>
<td>1.10</td>
</tr>
<tr>
<td><em>Croton glandulosus</em></td>
<td>0.50</td>
</tr>
<tr>
<td><em>Croton capitatus</em></td>
<td>0.20</td>
</tr>
</tbody>
</table>
*Euphorbia 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

*Gnaphalium* species 0.04

*Rudbeckia hirta* 0.02

*Conyza canadensis* 0.02

Family Cyperaceae 3.31

*Cyperus Esculents* 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\n\nFamily Caryophyllaceae\n\nSilene species\n\nStellaria calycantha\n\nFamily Amaranthaceae\n\nFroelichia gracilus\n\nFamily Cactaceae\n\nOpuntia species\n\nFamily Rubiaceae\n\nGalium obtusum\n\nFamily Brassicaceae\n\nLepidium virginicum\n\nFamily Plantaginaceae\n\nFamily Lythraceae\n\nRotala ramosior\n\nFamily Culcsiaceae\n\nHypericum species\n\nFamily Laminaceae\n\nCalamintha arkensana\n\nFamily Gentianaceae\n\nFamily Commelinaceae\n\nCommelina erecta
Family Graminaceae 0.02

Setaria glauca 0.02

Unidentified or bare 11.47

Populations of the Ozark pocket gopher identified by Elrod et. al (2000) inhabit four of seven soil series identified in Izard County, Arkansas on the General Soils Map compiled in 1981 located in the soil survey for the county (United States Department of Agriculture, 1984). Arkana-Moko to the northwest, Brockwell-Portia-Boden covering the north-central region, Estate-Portia-Moko to the southeast and Noark-Arkana-Moko stretching across the extreme south and into the northwest. All are described as “deep, well-drained, cherty, stony and loamy soils that formed on uplands in the residuum or colluvium of sandstone, limestone, siltstone and dolomite” (United States Department of Agriculture, 1984). Chert is a dense sedimentary rock consisting primarily of quartz, sometimes containing silica, occurring mainly in limestone or dolomite (Bates and Jackson, 1984). Loam is a soil that has soil particle sizes of seven to 27% clay, 28 to 50% silt and less than 52% sand. Residuum is a loose weathered mineral material that formed from disintegrating rock. Colluvium is soil or rock fragments moved to the base of steep slopes (United States Department of Agriculture, 1984).
Methods

Soil texture, particle size, percent organic matter and pH were measured in this study. Gee and Bauder (1986) describe soil texture as being, “based on different combinations of sand, silt, and clay separates that make up the particle-size distribution of a soil sample.” Organic matter is a measure of the amount of organic material, decomposing plant matter, fecal matter, etc., in the soil and is an indication of soil fertility. Soil acidity is indicated by pH which measures the amount of hydrogen ions.

A soil profile was created for all samples to a minimum depth of 35.56 cm and a sample was collected from the middle of the profile and sealed in a plastic bag (Soil Survey Staff, 1974). Three random samples of approximately 300 grams per each of 10 fields (figure 6) were collected and transported to the laboratory for analyses. Topsoil depth was determined by measuring distance to B horizon on soil profiles in the field. Presence of a visible color change was used to determine a change in horizon, or soil layers. Laboratory analyses commenced by taking the total sample weight after equilibrating samples to room moisture levels, sieving out particles greater than two millimeters then splitting the samples into the correct weights for the various tests. Moisture was removed from approximately 10 grams of soil by placing the sample in a 105°C oven overnight. The same samples were then placed in a muffle furnace at 600°C for 45 minutes to determine furnace weight (Buol et al., 1989). Organic matter accounted for the difference in oven dried and furnace weights. By creating a
slurry of equal parts soil and de-ionized water, pH values were collected on
approximately 10 grams of soil. A calibrated pH probe was submerged into the
slurry until a stable reading was obtained (Buol et al., 1989). Soil particle size
was determined on approximately 50-60 grams of soil by employing the pipette
method (Gee and Bauder, 1986). Samples were placed in 500 ml beakers; 10 ml
of calgon solution was added to each sample then de-ionized water was added
for a total volume of approximately 100 ml. Mixtures were stirred and allowed to
sit overnight. Beakers were then completely rinsed into a metal malt cup with de-
ionized water. An electric mixer was placed into the cup and the mixture was
stirred rapidly for approximately 10 seconds. The mixture was rinsed completely,
using de-ionized water, into one-liter graduated cylinders and de-ionized water
was added to a volume of one liter. Cylinders were then placed into a 24°C
water bath and mixtures were suspended by agitation with a plunger for
approximately 30 seconds then allowed to sit for four and a half hours. A pipette
was lowered 6.2 cm into the cylinders to obtain samples of 25 ml which were
placed into 40 ml beakers. These beakers were placed in a 105°C oven
overnight to remove all moisture. Original sample weights along with the
difference between empty 40 ml beakers and the beakers with dried samples
were used to calculate percent clay of the samples. The cylinders were then
rinsed completely using de-ionized water through a 63 µm sieve. Sand trapped
in the sieve was rinsed into the original 500 ml beakers. Samples were allowed
to settle completely, excess water was aspirated and the samples were dried
completely at 105°C. 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.

Employing Statistical Analysis System (SAS) 8.2 [2001], Pearson correlation and stepwise multiple regression analyses were utilized in an effort to determine if the number of pocket gophers present is related to soil particle size, organic matter or hydrogen ion concentration.

Results

In-field topsoil depth, or distance to B horizon, could only be determined on one of 33 samples. This was determined by a visible lightening of the soil at a depth of 25.4 cm. All other samples had no visible color change within the exposed profile of 35.56 cm. Most fields were located at the base of a moderate hill and/or near a waterway. Both positions would allow for deposition of soil, thus creating a thicker than expected topsoil (C. R. Ferring, personal communication). Other measured soil parameters, summarized in table 5 are as follows. With a median value of 5.05, pH ranged from 4.03 to 7.12. Although no samples from the current study revealed a basic soil, a broad range is observed from neutral to somewhat acidic. Organic matter ranged from 0.32 to 16% with an average of 6.72%. Pocket gophers may show preference for particle size. Although there is still a broad range of values, extremes seem to deviate more from average than other measurements. Gravel ranged from 0 to 18.64% with an average of 1.87%, sand was observed
Table 5: Summary of texture, soil particle size (gravel, sand, clay, silt), organic matter (O.M.), pH and hydrogen ion concentration (H\(^+\)).

<table>
<thead>
<tr>
<th>Sample</th>
<th>Texture</th>
<th>% Gravel</th>
<th>% Sand</th>
<th>% Clay</th>
<th>% Silt</th>
<th>% O.M.</th>
<th>pH</th>
<th>H(^+)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1</td>
<td>Loamy Sand</td>
<td>0.777</td>
<td>79.020</td>
<td>4.518</td>
<td>16.462</td>
<td>9.000</td>
<td>6.22</td>
<td>1659586.91</td>
</tr>
<tr>
<td>1-2</td>
<td>Loamy Sand</td>
<td>0.570</td>
<td>75.037</td>
<td>3.537</td>
<td>21.426</td>
<td>11.900</td>
<td>6.24</td>
<td>1737800.83</td>
</tr>
<tr>
<td>1-3</td>
<td>Sandy Loam</td>
<td>0.115</td>
<td>70.978</td>
<td>4.099</td>
<td>24.923</td>
<td>9.000</td>
<td>5.12</td>
<td>1318256.67</td>
</tr>
<tr>
<td>2-1</td>
<td>Loamy Sand</td>
<td>1.061</td>
<td>76.970</td>
<td>2.742</td>
<td>20.288</td>
<td>9.000</td>
<td>4.62</td>
<td>41686.94</td>
</tr>
<tr>
<td>2-2</td>
<td>Sandy Loam</td>
<td>0.920</td>
<td>69.981</td>
<td>1.808</td>
<td>28.211</td>
<td>7.750</td>
<td>4.03</td>
<td>10715.19</td>
</tr>
<tr>
<td>2-3</td>
<td>Loamy Sand</td>
<td>2.683</td>
<td>76.382</td>
<td>5.047</td>
<td>18.571</td>
<td>5.890</td>
<td>4.30</td>
<td>19952.62</td>
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<td>3-1</td>
<td>Gravely Sandy Loam</td>
<td>18.644</td>
<td>71.866</td>
<td>3.836</td>
<td>24.298</td>
<td>8.250</td>
<td>4.86</td>
<td>72443.60</td>
</tr>
<tr>
<td>3-2</td>
<td>Loamy Sand</td>
<td>0.586</td>
<td>83.082</td>
<td>3.143</td>
<td>13.775</td>
<td>12.750</td>
<td>4.24</td>
<td>17378.01</td>
</tr>
<tr>
<td>3-3</td>
<td>Loamy Sand</td>
<td>1.831</td>
<td>77.045</td>
<td>5.929</td>
<td>17.026</td>
<td>10.875</td>
<td>5.02</td>
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<tr>
<td>4-1</td>
<td>Sandy Loam</td>
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<td>65.810</td>
<td>6.775</td>
<td>27.415</td>
<td>11.444</td>
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<tr>
<td>4-2</td>
<td>Sandy Loam</td>
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<td>70.612</td>
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<td>24.065</td>
<td>0.319</td>
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<td>8709635.90</td>
</tr>
<tr>
<td>4-3</td>
<td>Sandy Loam</td>
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<td>71.861</td>
<td>5.838</td>
<td>22.301</td>
<td>7.911</td>
<td>7.05</td>
<td>11220184.54</td>
</tr>
<tr>
<td>5-1</td>
<td>Sandy Loam</td>
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<td>68.047</td>
<td>6.005</td>
<td>25.948</td>
<td>3.878</td>
<td>5.85</td>
<td>707945.78</td>
</tr>
<tr>
<td>5-2</td>
<td>Loamy Sand</td>
<td>2.675</td>
<td>76.369</td>
<td>3.288</td>
<td>20.343</td>
<td>4.360</td>
<td>5.96</td>
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</tr>
<tr>
<td>5-3</td>
<td>Gravely Loamy Sand</td>
<td>6.120</td>
<td>72.172</td>
<td>6.293</td>
<td>21.535</td>
<td>3.619</td>
<td>5.72</td>
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</tr>
<tr>
<td>6-1</td>
<td>Gravely Loamy Sand</td>
<td>7.662</td>
<td>76.379</td>
<td>5.914</td>
<td>17.707</td>
<td>3.649</td>
<td>4.24</td>
<td>17378.01</td>
</tr>
<tr>
<td>6-2</td>
<td>Loamy Sand</td>
<td>2.018</td>
<td>76.577</td>
<td>4.610</td>
<td>18.813</td>
<td>3.235</td>
<td>5.05</td>
<td>112201.85</td>
</tr>
<tr>
<td>6-3</td>
<td>Loamy Sand</td>
<td>3.163</td>
<td>80.756</td>
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<td>17.366</td>
<td>5.048</td>
<td>7.12</td>
<td>13182567.39</td>
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<tr>
<td>7-1</td>
<td>Sand</td>
<td>0.950</td>
<td>90.522</td>
<td>2.104</td>
<td>7.374</td>
<td>5.250</td>
<td>4.59</td>
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</tr>
<tr>
<td>7-2</td>
<td>Loamy Sand</td>
<td>1.982</td>
<td>85.142</td>
<td>3.313</td>
<td>11.545</td>
<td>4.471</td>
<td>5.07</td>
<td>117489.76</td>
</tr>
<tr>
<td>7-3</td>
<td>Loamy Sand</td>
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<td>85.794</td>
<td>2.600</td>
<td>14.606</td>
<td>4.250</td>
<td>4.26</td>
<td>18197.01</td>
</tr>
<tr>
<td>Sample</td>
<td>Texture</td>
<td>% Gravel</td>
<td>% Sand</td>
<td>% Clay</td>
<td>% Silt</td>
<td>% O.M.</td>
<td>pH</td>
<td>H⁺</td>
</tr>
<tr>
<td>--------</td>
<td>---------------</td>
<td>----------</td>
<td>-----------</td>
<td>------------</td>
<td>-----------</td>
<td>--------</td>
<td>----</td>
<td>-----</td>
</tr>
<tr>
<td>8-1</td>
<td>Sand</td>
<td>0.023</td>
<td>90.791</td>
<td>4.179</td>
<td>5.030</td>
<td>6.571</td>
<td>4.08</td>
<td>12022.64</td>
</tr>
<tr>
<td>8-2</td>
<td>Sand</td>
<td>0.052</td>
<td>97.438</td>
<td>1.254</td>
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from 41.77 to 97.44% with an average of 74.5%, silt was from 1.31 to 48.17% with an average of 20.97%, and clay was observed from 1.25 to 11.8% with an average of 4.63%.

The southern most location was found in an additional soil series, Sturkie-Peridge. With this addition, five of seven soil series within Izard County, Arkansas are inhabited by the Ozark pocket gopher. Sturkie-Peridge is found only in the flood plains of the White River and is described as “deep, well-drained, loamy soils formed in alluvium” (United States Department of Agriculture, 1984). Alluvium is soil deposited by streams. All 17 study plots were found in four of 20 soil units located within Izard County, Arkansas (United States Department of Agriculture, 1984). Boden is described as “clayey, mixed, mesic Typic Hapludults” that is a deep, well drained gravely sandy loam found on hillsides with a slope of eight to 20 percent. Mesic describes the soil temperature category which ranges from eight to less than 15° Celsius (47-59° F). Typic indicates that this soil is the typical standard from which others of the same soil type are measured. Soil types are broken into three parts. First, Hapl- is an early stage of development, or a young soil with minimally developed horizons. The middle portion of the soil type, -ud-, indicates that this soil is formed in humid environments. Finally the suffix, -ults, indicates that this soil is an utisol, which means last or ultimate. In this case it is a young forest soil with low base status. Base refers to fertility, thus this soil is not good for agriculture. Estate is described as “fine, mixed, mesic Typic Hapludalfs” that are inconsistent with both
deep and shallow soils that are well drained. The suffix –alfs refers to alfisols which are oxide soils laden with aluminum and iron. This is a forest soil of high base status with argillic horizons. Argillic refers to a clay horizon laden with aluminum and iron below the A horizon. Rolling Estate associations are found on slopes of eight to 20 percent while steep Estate associations are found on slopes of 20 to 40 percent. Portia is described as “fine-loamy, siliceous, mesic Typic Paleudalfs” that are deep and well drained on eight to 12 percent slopes. The prefix pale- means old. Finally, Sturkie is described as “fine-silty, mixed, mesic Cumulic Hapludolls” that are deep, well drained soils in the flood plains of the White River with one to three percent slopes. Cumulic means over thickened as a result of quickly accumulating sediments. The suffix, -dolls, indicates this is a mollisol, which means soft. This is a prairie soil. All explanations of soil descriptions were taken from Buol et al. (1989).

Six soil textures were discovered after completing laboratory analyses. Soil texture is derived from the percent of sand, clay and silt. Loamy sand composed 40% of samples, 23% were sandy loam, 17% sand, 10% gravelly sandy loam, 7% loam and 3% silt loam.

Pearson correlation, multiple regression, multiple regression using r-square and stepwise multiple regression were all employed to test for statistically significant relation between number of pocket gophers per hectare and percent gravel, sand, clay, silt, organic matter and hydrogen ion concentration. Although no significant interaction was observed, Pearson correlation returned the
smallest probability between gopher density and hydrogen ion concentration at \( p(r) = 0.08 \). Other parameters were as follows: percent gravel, \( p(r)=0.27 \); percent sand, \( p(r)=0.33 \); percent clay, \( p(r)=0.16 \); percent silt, \( p(r)=0.41 \) and percent organic matter (\( p(r)=0.40 \). Standard deviations were observed only slightly smaller than the mean for pocket gopher density, higher than the mean for percent gravel, approximately 50% of the mean for percent clay, percent silt and percent organic matter. Values for several parameters had high ranges, possibly one reason for which no statistical significance was obtained. Data were then narrowed by selecting the median value for each category by location. Reducing data to median values by field did not considerably alter the outcome. Probabilities are as follows: percent gravel, \( p(r)=0.92 \); percent sand, \( p(r)=0.15 \); percent clay, \( p(r)=0.2 \); percent silt, \( p(r)=0.2 \); percent organic matter, \( p(r)=0.6 \); and hydrogen ion concentration, \( p(r)=0.43 \). Negative results were obtained in all circumstances. Pocket gopher density and percent sand provided the smallest probability among median values, \( p(r)=0.15 \). Stepwise multiple regression returned only one model, pocket gopher density and hydrogen ion concentration with a \( p(f)=0.08 \). Using \( p=0.05 \) as the standard, no statistical significance was identified.

Distance to Stream

Contrary to the needs of pocket gophers (deep, loose sandy soils in areas dominated by grasses) most of Izard County provides a harsh environment. The Ozark Mountains are composed of many steep slopes which contribute greatly to
erosion, creating shallow top soil and the Ozarks are dominated by hardwood forest, not grasses with numerous rocky outcroppings.

Approximately 81,788.5 hectares of Izard County’s 149,447.6 hectares, or 54.7% of the county, is described with a slope of 8% or higher (United States Department of Agriculture, 1984). Soils on these slopes tend to be shallow due to erosion. Flood plains appear to have the most level land which would provide the thickest top soil however they are prone to frequent flooding, a deterrent to pocket gophers. Although cropland in Izard County is limited, the first settlers were primarily farmers. Fields that were cleared for farming are generally found in flood plains as this is where soils are relatively deep and free of gravel, stones and rocky outcroppings (United States Department of Agriculture, 1984). However, soils in Izard County are low in fertility and most of this cropland has been converted to pasture and hay fields. Much of the land not cleared for farming, housing or commercial remains as hardwood forest. It is primarily in the pastures and hay fields within flood plains that the Ozark pocket gopher is located. Their need for deep soil and grasses restrict them to these limited areas.

The mountainous terrain of Izard County is due to “the uplift of Paleozoic rocks and the subsequent erosion and entrenchment of streams and drainage channels” (United States Department of Agriculture, 1984). As mentioned earlier, Izard County is located primarily within the Salem Plateau which is characterized by outcroppings of dolomite and sandstone. Of the county’s total
hectares, 6,111.45 hectares, or roughly 4.1%, are composed of rocky outcroppings (United States Department of Agriculture, 1984). This figure does not include areas of surface stoniness. Because pocket gophers spend their lives burrowing through soil, rocky outcroppings, stones and gravel which impede their progress, are generally avoided, further reducing the amount of habitat suitable to pocket gophers in Izard County.

Methods

Using the June 2002 digital orthophoto quarter quad (DOQQ) image with known locations overlaid in ArcView GIS approximate distance to nearest stream was measured. Distance was determined from all 51 global positioning system coordinates of known fields of inhabitance to the closest visible waterway (stream, creek, or river). Distances in meters were calculated and mean, minimum and maximum values were tabulated.

Results

Distribution maps of *G. b. ozarkensis* indicate a preference for habitat along small creeks and streams. Through analysis of all 51 inhabited field locations using ArcView GIS an average distance to stream was determined at 107.15 meters with a range of 9.82 to 561.95 meters. Table 6 catalogs all known locations of *G. b. ozarkensis*. Locations 1-10 were surveyed for soil and vegetation analysis, locations 1-17 were surveyed for density and all other locations were assigned arbitrary numbers for record keeping.
Table 6: Known locations of *G. b. ozarkensis* and distance (m) to stream.

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Discussion

Aside from wild fires, land-clearing activities have allowed sustained habitation of pocket gophers in the Ozark Mountains, a terrain dominated by hardwood forests. All sampling locations were graze land, hay fields or frequently mowed areas. Fields plowed frequently for agricultural purposes did not support pocket gophers. Luce et al. (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, at time of collection, were dominated by invasive, non-native grass species that are indicative of a
degraded system following human impact (R. R. Buckallew, personal communication). Grasses invade at the beginning of succession and are used by farmers as food crops for livestock. With such a wide array of vegetation it appears the plains pocket gopher does not choose its home range based on specific plant species, but rather on the availability of foodstuff. 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 graze fields. Interestingly, the two highest density fields, fields 3 and 11 with 57.8 and 60.4 pocket gophers per hectare respectively, supported no bermuda grass. The other eight fields, ranging in density from 4.0 to 26.2 animals per hectare, supported from 20 to 73% bermuda grass. The most numerous plant of field 3 was *Sporobolus* species and of field11 *Digitaria* species. Both genera are in the grass family which may point at evidence that pocket gophers do not prefer any one plant species over another, but rather that they prefer a variety of food items. Others have completed studies of the amount of plant types comprising the plains pocket gopher habitat and a variety of grasses may be necessary in the pocket gopher diet. Myers and Vaughn (1964) reported 88% of their study area vegetation as grasses and grasses compose 65.91% of study area vegetation for this survey. Although stomach content analysis was beyond the scope of this project, Luce *et al.* (1980) reported 44.9% grasses in the stomach contents of plains pocket gophers. Certainly grasses outweigh forbs in importance to the pocket gopher however forbs do make up a
portion of the pocket gopher diet. Luce et al. (1980) state that during the growing season forbs may be more important than at other times during the year and may be less important in winter months. Study area for this survey totaled 26.03% forbs, 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. Pocket gopher mounds create an opportunity for plant succession. As vegetation reaches climax communities, annual grasses and forbs and perennial forbs decline. Fields inundated with pocket gophers may be kept at a lesser stage of plant succession and may be an ideal home for organisms that prefer non-climax vegetation type prairies.

Pocket gophers may prefer to burrow in topsoil in part because it is looser, sandier soil than lower horizons. Existing in an area with thickened topsoil allows the pocket gopher much variability in depth of the tunnel system to avoid major temperature fluctuations and frequent cave-ins resulting from shallow burrows. Soil survey data for Izard County, Arkansas (United States Department of Agriculture, 1984) states the topsoil should extend only to 17.78 cm in three of the four soil units, Boden, Portia and Estate, and 71.12 cm in the fourth soil unit, Sturkie. Observing the only visible color change at 25.4 cm is indicative of a thickened A horizon, or topsoil layer (C. R. Ferring, personal communication), most likely due to slope position. Others have found that pocket gopher activity alone increases topsoil depth (Schwartz and Schwartz, 1981 and Jones et al.,
Further research on slope may be warranted as three of four soil units, Boden, Portia and Sturkie, have a minimum eight percent slope and a maximum 40% slope. Some preference may be present for slight to moderate slope which would facilitate water drainage.

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. With the exception of silt, ranges gathered in this study concur with these findings. It is thought that high clay and silt contents are avoided and that soil moisture may be an important variable because these factors reduce the aeration of the soil and gas exchange with the external environment (Moulton et al. 1983). Beck and Hansen (1966) found plains pocket gophers of eastern Colorado to be more abundant in sandy loam soils compared to dune sand while Foster and Stubbendieck (1980) report plains pocket gophers of northwest Nebraska are restricted to sandy, silty soils. This study reveals 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 easily worked by pocket gophers. Loamy soils also have a higher water holding capacity than do sandy soils, which would facilitate ease of digging and plant life. Sandy loam describes only 21% of soil samples from the current study. Sandy loam is a soil with high sand, low clay and moderate silt contents. This may indicate that some
silt may be necessary for pocket gophers to thrive. More accurately, this mix may be necessary for vegetation consumed by pocket gophers to survive.

The Ozark pocket gopher does not appear to be limited by pH. Working on Geomys breviceps in Texas, Davis et al. (1938) also found no correlation between pocket gopher distribution and pH. Ranging from 4.5 to 8.0 their report states that pocket gophers are equally successful in acidic, neutral and basic soils. An expansive range of values is observed for organic matter, leading away from the conclusion that pocket gophers have a strong preference for soil organic matter. Pocket gophers themselves and their activities may elevate soil organic matter.

Natural variation is inherent in the study of biotic communities. Due to this variation, broad values were obtained for each parameter measured. Statistical analyses did not reveal significant relation between pocket gopher density and any measured soil parameter. Homogeneity of sampled fields and wide ranging values for measured soil parameters may be cause for the lack of statistical significance. Results may have been different had non inhabited fields been sampled. Based upon observation though, pocket gophers appear to avoid, or are less numerous in, areas of high gravel content and prefer, or are more numerous in, areas of high sand content possibly to ease the effort of burrowing.

Fields within 600 meters of waterways are critical pocket gopher habitat. As reported by the United States Department of Agriculture (1984), flood plains tend to be more level than lands outside of flood plains. This levelness reduces
geological erosion which increases depth to bedrock as compared to non-flood
plain areas. Due to previous farming practices the majority of open, grassy fields
are located within flood plains as well. Open fields along small waterways such
as creeks and streams are thought to be preferred over fields along rivers as
they are not as prone to flood. Close proximity to a waterway provides a
continuous deposition of sand, creating excellent burrowing conditions. Given
that nearly 59 percent 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,
these fields within flood plains are also where forest has been cleared and
grasses have been allowed and encouraged to grow. Stronger plant
communities may be located within close proximity to waterways as plants would
have needed moisture. Pocket gophers may also utilize this riparian habitat as
movement corridors from one suitable field of inhabitance to another.
Maintaining the natural environment of and around streams near known fields of
inhabitance may allow and even promote movement as the Ozark pocket gopher
seeks more open fields of suitable habitat. Available suitable riparian habitat
serving as corridors may serve to decrease overcrowding in fields of known
inhabitance creating a stronger, healthier population.
CHAPTER V
CONSERVATION IMPLICATIONS

Introduction

Based on data collected the Ozark pocket gopher appears to be more numerous in distribution than originally suggested within Izard County, Arkansas. In 2000, Elrod et al. located the Ozark pocket gopher in just 18 fields. Aerial survey increased this number to 51 known fields of inhabitance. However, the geographical restriction of Geomys bursarius ozarkensis in relation to those of other G. b. species leads to a tentative conclusion that this subspecies may warrant protection by government agencies. Conservation strategies include such methods as minimizing human impact in areas of known inhabitance, reducing the effects of natural disasters and regular monitoring of the population size and distribution.

Pocket gophers provide many benefits from their inhabitance of an area. Often found on rangeland, pocket gophers frequently consume plant species that are of poor forage value to livestock (Luce et al., 1980) and remove weeds (Jones et al., 1983). Reducing species undesirable to livestock allows for more desirable species to flourish. Annual grasses and forbs and perennial forbs were more prevalent in areas of pocket gopher inhabitance (Foster and Stubbendieck, 1980). An increase in primary productivity in areas around mounds of G.
*bursarius* has been positively correlated (Reichman and Smith, 1985) as has plant species diversity (Tilman, 1985; Williams and Cameron, 1986). Zinnell (1992) indicates that pocket gopher activity may increase plant productivity by moving soil and redistributing nutrients.

Pocket gophers highly influence soil. Forsyth (1985) reported that pocket gophers have contributed greatly to the formation of prairie soil. Pocket gophers excavate mass quantities of soil from their tunnel systems. Several authors have reported annual amounts of excavated soil by pocket gophers. Texas Wildlife Damage Management Services (1998) reported that one pocket gopher may move two and a half tons of soil per year to the earth’s surface, Buechner (1942) reports that per 0.4 hectares, Texas *Geomys* move 0.33 metric tons for ungrazed fields and 6.42 metric tons for overgrazed fields and Kennerly (1964) reports for *Geomys* an average of 5.32 metric tons per 0.4 hectare. Soil turnover allows for aeration and mixing of soil, which may benefit many soil dwelling organisms. This level of soil activity also deepens the soil profile, improves drainage, reduces runoff and erosion (Schwartz and Schwartz, 1981 and Jones *et al.*, 1983) and may decrease soil compaction allowing plant roots to penetrate more deeply resulting in an increase in root biomass (Zinnell, 1992). Humus also tends to accumulate in areas of pocket gopher activity, which can make the soil more nutrient rich and create better growing conditions for vegetation (Jones *et al.*, 1983). Soils near nest chambers and food stores tend to have higher nitrogen and other nutrient content from deposition of excrement, urine and
uneaten plant matter, supporting greater root biomass (Zinnel, 1992). Human actions such as deforestation, farming, irrigation and many other activities affect the formation of soils (United States Department of Agriculture 1984). Soil conservation in areas of known inhabitance may detect changes to the organism’s natural environment in time to stop any permanent effects on the Ozark pocket gopher.

Pocket gophers are historically known to coexist with humans. They are often found in gardens, lawns and pastures. Unfortunately the pocket gopher is considered a nuisance by most landowners. One unknown variable in Izard County, Arkansas is the amount of control methods humans are using and the effectiveness of such measures. Many landowners are happy to give accounts of trapping and poisoning efforts to remove the animals from their property. This attitude may have begun in Kansas in the early 1900s through a sequence of governmental events outlined by Scheffer (1910). In 1903 a bounty law was passed, authorizing payment of a premium for pocket gopher scalps. This bounty law met with astounding results when in 1907 Marshall County, Kansas paid out $4,200 for the year and Meeker County, Minnesota paid $14,056 in just 5 months (Scheffer, 1910). Legislature passed House Bill 184 in 1905. This bill was a compulsory extermination law that stated with 10 or more complaints all pocket gophers in a district could and should be destroyed. To further influence Kansas landowners in the decimation of pocket gophers a second bounty law was passed in the special session of 1908. Publications encouraged the use of
trapping to eradicate pocket gophers in farming communities. For example, opening comments in a 1910 paper by Scheffer set the mood and included such as, “…vigilance on the part of every landowner and cooperation with his neighbor – nothing short of this – will rid a community of the pocket gopher.” His paper goes on to compare the size of the animal’s eyes to a bullet and map out all methods of extermination, pointing out the most efficient.

Although information about the type and extent of current pocket gopher control measures utilized in Izard County, Arkansas is unknown it is clear through dialog with local residents that they share Scheffer’s opinion on the species. The vast majority of home and landowners view these animals as pests and would rather rid their property of them than to preserve this unique species. Research is needed to determine the scope and manner of pocket gopher control methods currently employed in Izard County.

Conservation Strategies

Based on the findings of this research, conservation efforts are necessary. Although abundant within its range, the range of *G. b. ozarkensis* is limited to a small portion of Izard County, Arkansas giving Izard County the distinct privilege of being the only known location in the world to support this animal. Current population density is considered healthy however, due to their dependence on open grassy fields and the inherent lack thereof in a predominantly forested habitat steps should be taken to ensure the continued success of this unique taxon.
Numerous studies completed throughout the previous century provide data on soil and vegetative preferences and needs of pocket gophers. To support their subterranean lifestyle they need soft, friable soil in which to burrow with excellent drainage and gas diffusion (Chase et al., 1982; Miller, 1964) and a minimum of 10.16 cm of topsoil to prevent burrow cave-ins (Davis et al., 1938). Soils of this type are generally found along waterways and this study has shown that all known locations of *G. b. ozarkensis* are less than 600 meters from the nearest waterway and sampled fields have a minimum topsoil depth of 25.4 cm. Others have researched vegetational requirements. Pocket gophers are commonly found in pasture, hay fields and lawns. Phillips (1936) discovered moderately grazed lands support larger populations of pocket gophers than do over grazed lands or land devoid of grazing. Regular mowing activity may be a suitable substitute for grazing. Many have indicated grasses as the staple of a pocket gopher’s diet (Myers and Vaughn, 1964; Dale et al., 1980; Foster and Stubbendieck, 1980). This study supports those conclusions in relation to the Ozark pocket gopher. Of the 10 fields sampled for vegetation all were found to be dominated by grass species. In short, open fields dominated by regularly grazed or mowed grasses with soft, friable well drained soils within 600 meters of a waterway are thought to be ideal habitat for the Ozark pocket gopher and consideration should be given to conservation of land matching this description.

Minimizing human impact is one crucial step in preserving these creatures. This can be achieved through education, by banning the destruction
of suitable habitat, conservation of habitat in areas of known inhabitance, and the prohibition of purposeful death by landowners to rid their property of the organisms. In addition, the natural integrity of waterways, specifically associated riparian habitat, currently or potentially utilized as corridors should be maintained and determining methods to reduce genetic isolation and repeated generic extinction may prove invaluable in the conservation of this subspecies.

Because landowners have long since been praised for the destruction of pocket gophers a paradigm shift is needed. One unknown factor is the extent to which pocket gopher control efforts are currently utilized in Izard County. Widespread efforts to educate the public are critical in swaying the prevailing opinion of pocket gophers. Newspaper press releases and mailings may be the most effective means by which to reach residents of Izard County. It will be necessary in these efforts to focus on the ecological benefits pocket gophers provide to soils and rangeland vegetation. Cameron (2000) states the indirect affect of subterranean rodents on soil conditions most likely outweighs the direct affects of their foraging. Also evidenced is the benefit provided to the plant community through the feeding and burrowing of pocket gophers.

The effects of natural disasters and processes such as succession can be lessened by several actions. Conserving prairie habitat should be priority. Pocket gophers are generally found in grassy areas so movement towards more trees and shrubs should be limited in sufficient areas to keep the Ozark pocket gopher population strong. Establishing populations well outside floodplains of
the White River and its tributaries is another point to consider. Extended periods of flood will eventually overwhelm the percolation capacity of the soil. When this happens water would flood burrow systems, drowning the animals. As an extreme last resort, irrigating fields of known inhabitance in exceptionally extended periods of severe drought may be necessary. When vegetation levels fall below that which can support a healthy population for multiple years effort must be taken to ensure survival of sufficient plant matter. Establishing a pocket gopher sanctuary does not appear to be pressing at this time. However, thought should be given to when and where such actions could occur in anticipation of detecting a significant decrease in habitat or increase in control efforts.

Establishing movement corridors will allow this subspecies to find more areas of suitable habitat. Zinnell (1992) noted that unsuitable pocket gopher habitat surrounding an inhabited field made emigration and immigration possible only along roadways. Distribution layouts of *G. b. ozarkensis* indicate their preference for habitat along small creeks and streams. Through analysis of inhabited field locations using ArcView GIS an average distance to stream was determined at 107.20 meters with a range of 9.82 to 561.95 meters. Maintaining the natural integrity of streams near known fields of inhabitance may allow and encourage a range extension as pocket gophers move in an effort to locate more open fields of suitable habitat and decrease overcrowding in areas of known inhabitance. Streamlining creeks and tributaries through straightening and cementing banks decreases the natural process of sand deposition along these
waterways. As soil composition changes so will vegetation and both may affect the suitability of an area for pocket gophers. Efforts to streamline tributaries in and around the current range for the Ozark pocket gopher should be prevented if at all possible. Specifically, land management within 600 meters of waterways should be aimed at preserving open fields associated with riparian habitat.

Regular monitoring of population density and distribution will indicate the need for further action and ensure that the number of animals in each location does not fall dramatically, reaching a dangerously low level. An effective population size for *G. bursarius* was estimated at just under 50 animals with smaller population sizes yielding higher incidences of inbreeding, genetic drift and bottlenecks (Zimmerman and Gayden, 1981). Two of six general locations of the Ozark pocket gopher sampled for density exceed 50 animals. A population of 50 or more animals requires large, unbroken tracts of field habitat which is not common in Izard County, Arkansas. For this reason, smaller population size may be effective for *G. b. ozarkensis* and current populations should be monitored to ensure there are no drastic declines in numbers or size of range.

Residents of Izard County, Arkansas obviously have the enthusiasm to become involved, lending hope for future resident surveys. With a small amount of education on how to identify a pocket gopher by above ground sign these residents may become the best, most efficient way of keeping track of pocket gopher populations.
REFERENCES


Buckallew, R. R., doctoral student, University of North Texas Environmental Sciences Department, Denton, Texas.


Elrod, D. A., adjunct professor, University of North Texas Environmental Sciences Department, Denton, Texas.


Ferring, C. R., department chair, University of North Texas Geography Department, Denton, Texas.


http://www.aiea.ualr.edu/census/censusdata/census2000/county/90-00Co.html


http://anthro.palomar.edu/synthetic/synth_5.htm.


Texas Wildlife Damage Management Services, 1998. Controlling pocket gopher
damage. Texas Wildlife Damage Management Services.

Tilman, D., 1983. Plant succession and gopher disturbance along an

Pocket gophers and Colorado mountain rangeland. Colorado State Univ.

Tyrl, R. J., S. C. Barber, P. Buck, J. R. Estes, P. Folley, L. K. Magrath, C. E. S.
Taylor and P. A. Thompson, 1998. *Identification of Oklahoma Plants: A
Taxonomic Treatment Comprising Keys and Descriptions for the Vascular
Plants of Oklahoma*. Flora of Oklahoma Incorporated, Stillwater, OK.
139 pp.

Counties Arkansas*. Soil Conservation Service, Arkansas Agricultural
Experiment Station, 122 pp.

United States Department of Agriculture, NRCS, 2002. The PLANTS database,
version 3.1 (http://plants.usda.gov). National Plant Data Center, Baton
Rouge, LA 70874-4490 USA.

University of Arkansas, 2002. GeoStor: The on-line Arkansas spatial data
infrastructure, version 2.00.00 (http://www.cast.uark.edu/cast/geostor).
University of Arkansas, Fayetteville, Arkansas, 72701 USA.

Ward, A. L. and J. O. Keith, 1962. Feeding habits of pocket gophers in

University, Stillwater, OK. 244 pp.

Williams, L. R. and G. N. Cameron, 1986. Food habits and dietary preferences
of Attwater’s pocket gopher, *Geomys attwateri*. *Journal of Mammalogy*
67: 489-96.

Zimmerman, E. G. and N. A. Gayden, 1981. Analysis of genetic heterogeneity
among local populations of the pocket gopher, *Geomys bursarius*. Smith,
M. H. and J. Joule, eds., *Mammalian Population Genetics*. University of