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# Movements and Activity Patterns of the Plains Pocket Gopher (Geomys bursarius) in Nebraska

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# MOVEMENTS AND ACTIVITY PATTERNS OF THE PLAINS POCKET GOPHER (*GEOMYS BURSARIUS*) IN NEBRASKA

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## ABSTRACT

Twenty-three plains pocket gophers (*Geomys bursarius*) were fitted with radiotransmitters using a subdermal implant technique to determine home range and activity patterns. Gophers were located in the field by using a portable receiver and yagi hand-held antenna and tracked by following the animal from a short distance. Mean hourly distances traveled and number of active 60 minute periods increased throughout the day with peaks during late morning and afternoon and decreased at dusk. Seasonal changes in daily activity periods and mean hourly distances traveled were not found. Male home ranges were smaller than female. Monthly ranges of an animal varied but no seasonal patterns appeared. Aboveground feeding and mound building activity of gophers was observed 33 times during the study.

# INTRODUCTION

Pocket gophers (Geomyidae) are fossorial rodents restricted to North America which range from Central Alberta in Canada to Panama in Central America. Within the family are eight genera, thirty species and three hundred subspecies (Hall and Kelson 1959). As a group they have reached the pinnacle of adaptation to the fossorial mode of life. The allopatry of several subspecies (Vaughan and Hansen 1964) attests to the great specialization which has occurred within the group.

The plains pocket gopher (*Geomys bursarius*) ranges from the prairie provinces of Canada south to the Gulf of Mexico and from Indiana and Illinois west to Eastern Colorado and Arizona. This area roughly coincides with the Great Plains and True Praire ecosystem of the United States.

Until recently, most knowledge of pocket gopher movements has been attained through studies of mountain pocket gophers (*Thomomys talpoides*) (Tietjen et al. 1967) and valley pocket gophers (*Thomomys bottae*) (Hansen 1962; Howard and Childs 1959; Hansen and Remmenga 1961; Vaughan 1963; Vaughan and Hansen 1964). Plains pocket gophers, however, have been the subject of few studies purporting to examine their movement and activities (Adams 1966; Artmann 1967).

Artmann used telemetry to determine home ranges and activity patterns for the plains pocket gopher in Minnesota. A triangulation method was used for obtaining radiolocations of animals in the field. Radiotransmitters were sewn into the posterior portion of the cheek pouch of each animal.

The purpose of this study was to determine differences in home ranges and activity patterns of the plains pocket gopher. Differences in sex and age groups were sought as well as differences among animals occurring on differing habitat types.

Study Areas

All three study areas were located in Lancaster County, Nebraska. Soils in the study areas are Pawnee and Burchard silty clay loams lying above Kansan till. One area consisted of 9.7 ha of alfalfa field approximately 8 years old located at the northwest city limits of Lincoln, Nebraska (Fig. 1). This area was used only during May, June, and July, 1976, the first year of the study.

Another area located on Yankee Hill Special Use Area at Denton, Nebraska was used from August 1976 through June, 1977 (Fig. 2). It consisted of two major habitat types, alfalfa, and old field. The alfalfa field covered a triangular area approximately 0.5 ha with the alfalfa stand in poor condition and many forbs present. Adjacent to the alfalfa field was an old field of cool-season grasses

Figure 1. Umberger Study Area--Lincoln, Nebr.

Figure 2. Yankee Hill Special Use Area--Denton, Nebr.

(Bromus) and forbs, primarily alfalfa and hemp (<u>Cannibus sativa</u>). Alfalfa appeared to be an invader in the area.

Immediately east of the old field was another alfalfa field under private ownership. This field was not used as a study area after it was scraped with an earth leveling machine and all vegetation removed in October, 1976 when the land was being prepared for irrigation.

A third study area was located at Twin Lakes Migratory Waterfowl and Game Refuge, Reserve and Sanctuary at Pleasant Dale, Nebraska (Fig. 3). The study area consisted of warm-season grasses and a variety of forbs. The major grasses were big bluestem (<u>Andropogon gerardi</u>), switchgrass (<u>Panicum virgatum</u>), Canada wildrye (<u>Elymus canadensis</u>), and tall dropseed (<u>Sporobolus asper</u>). Indian grass (<u>Sorghastrum nutans</u>), Kentucky bluegrass (<u>Poa pratensis</u>), prairie dropseed (<u>Sporobolus heterolepis</u>) and porcupine grass (<u>Stipa spartea</u>) also occurred in the area. Major forbs were leadplant (<u>Amorpha canadensis</u>), gayfeathers (<u>Liatris</u>), heath aster (<u>Aster ericoides</u>) and Illinois tick clover (<u>Desmodium</u>).

The area was burned in early March, 1977 to prevent the spread of eastern red cedar (<u>Juniperus</u>). This study site was used during July through September, 1977.

<u>Equipment</u>

<u>Telemetry System</u>

Two telemetry systems were evaluated in the study (Fig. 4 and 5). The first system was a low range frequency

Figure 3. Twin Lakes Migratory Waterfowl and Game Refuge, Reserve and Sanctuary--Pleasant Dale, Nebr.

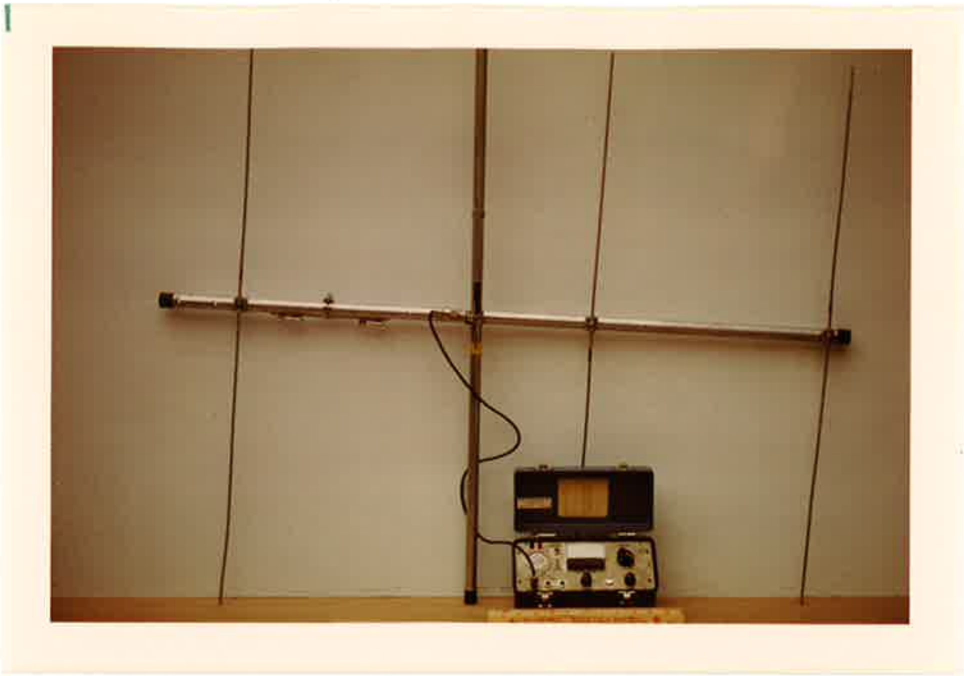


Figure 4. AVM High Frequency Telemetry System

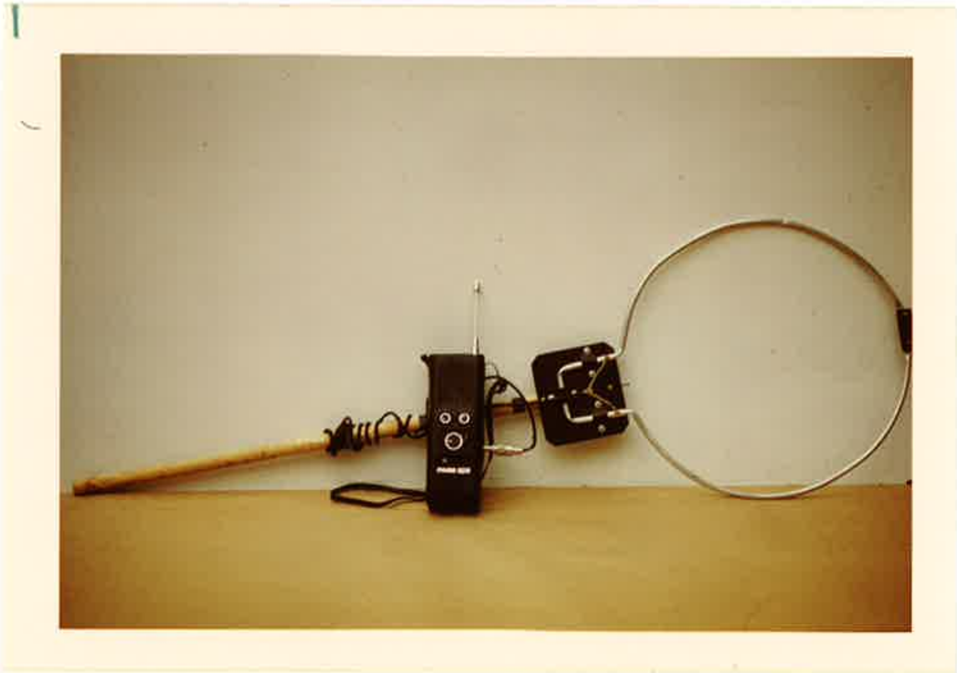


Figure 5. Wildlife Materials Low Frequency Telemetry System

(27 MHz) transmitter obtained from Wildlife Materials (Route 3, Box 36, Carbondale, Illinois) and Pace 150 citizen's band transceiver equipped with a handheld loop antenna.

The second system used a 12-channel receiver and handheld yagi antenna. The transmitters were high frequency (151 MHz ) and were obtained from AVM (3101 West Clark Road, Champaign, Illinois).

Although a comparison of the two systems showed that the first system could operate at longer distances and greater depths, the second system proved more suitable in meeting my objectives with the least investment of time and equipment. The first system's transmitter package was too large (10 grams) for my method of transmitter attachment, compared to the 3.6 average weight of the AVM SM1 transmitter package. The high frequency system was also preferred because of interference in the citizen's band range of the 27 MHz system.

Transmitter

The AVM SM1 transmitter was imbedded in dental acrylic, an inert material, to prevent infection under the skin on the animal (Fig. 6). Weight of the transmitter, .05 grams, constituted a small portion of the total weight of the package. Various batteries weighed from 0.6 grams for the RM 312 to 4.1 grams for the Px 13. Beeswax, used to coat


Figure 6. AVM SM1 Transmitter and Wildlife Materials
Low Frequency Transmitter

the transmitter, and dental acrylic represented the remainder of the package weight. Total package weight ranged from 3.3 grams to 6 grams.

The antenna of the SM1 transmitter was modified from a short, whip to a loop to gain better signal reception at greater soil depths. This was necessary in the winter months due to the animals' movement into deeper tunnel systems.

During the last 2 months of the study a third transmitter company (Bioelectronics Lab, Cedar Creek Natural History Area, Bethel, Minnesota, 55005) provided transmitters for the study. These units were similar in effectiveness to the transmitters of AVM, operating on the same frequency, but were structurally different in components and materials.

Battery Life

Four sizes of mercury batteries were tested in the AVM transmitter package (Fig. 7). The RM 312 was the first battery tested but its life expectancy of 25 days was considered too short for a seasonal study. A desired increase in battery life was accompanied by an increase in battery size. These size restrictions were especially acute for the subcutaneous implant method of transmitter attachment. The larger RM 575 (1.2 grams, 1.2 cm. diameter) and RM 675 (2.4 grams, 1.2 cm. diameter) batteries increased battery life to approximately 50 and 75 days, respectively.


Figure 7. Mercury batteries used in SM1 Transmitter

During the last stages of the study, it was found that most animals could accommodate a larger mercury battery, the Px13 (4.2 grams, 1.5cm diameter) beneath their skin without interference with their normal behavior. The expected life for this battery was 100 days.

Traps and Tools

Trap types used in the capture of live gophers are shown in Figure 8. Sherman (Sherman 1941), Baker (Baker and Williams 1972), and Sargeant (Sargeant 1966) live traps proved inadequate for capturing animals. Baiting traps seemed of no value. Tunnels at trap sites were either left open or closed with dirt. No change was detected in the animals' response to the trap.

Many trap sites visited by gophers were plugged with dirt without the traps being tripped. Animals were believed not to have entered most trap sets but plugged tunnels only up to the trap itself.

A kill trap (Death Klutch, P. W. Mfg. Company, P. O. Box 784, Tulsa, Oklahoma) used in a previous study, was modified to become a moderately effective live trap. The trap was blunted at the prongs with electrical tape which prevented them from piercing the animal. With the modification, the trap could spring and close over the animal usually posterior to the forelimbs. These traps were originally designed to pierce the animal on either side. However, with the tape, the prongs would slip over

Figure 8. Live capture traps used in the study.

the top of the animal's back and secure it. The trap spring was also weakened by rotating the spring lever backwards from its normal set position.

## Methods

### Laboratory Procedure

Captured animals were taken immediately from the field to the lab and held in wire cages. Cages contained strips of burlap for nesting material and concentrated alfalfa pellets and carrots for feed.

Rapid weight loss was characteristic during an animal's stay in lab. Weight loss may have been due to stress of capture and handling. Weight loss ranged from 0 to 42 grams and averaged 19.1 grams for nine animals. This represented an average loss in body weight of 6.2% and a range of 0 to 12.1%.

### Implant Operation

Early in the study, AVM transmitters were used in the lab as components of collars or harnesses which were attached around the neck and midsection of the animal. All such attempts failed in that the gopher quickly slipped off the device. Removal by the animal was achieved either by chewing through this material or by manipulation with the forelimbs. Both the structure of the animal and its subterranean mode of existence demanded a less obstructive method of transmitter attachment.

A minor operation on a gopher involving a subcutaneous implant was a useful technique and effective in attaching a transmitter (Fig. 9). Gophers were anesthetized with intramuscular injections of ketamine hydrochloride (Ketaset, 100 mg/ml, Bristol Lab, Syracuse, New York) administered at a rate of 21-31 mg/kg. Animals became immobile within 1 to 3 minutes and remained incapacitated for 16-25 minutes.

For the operation, each animal was placed in a ventral side down position with forelimbs forward along each side of the head. An area above the scapula was scrubbed with ethanol and the body hair removed with a razor. A 1.5 cm longitudinal incision was made between the scapulae. The loose skin of the animal was then lifted up and the transmitter inserted posteriorly into position on top of the back. Four sutures closed the incision. Autopsies of implanted animals along with replacement of transmitters on recaptured animals showed that body fascia enveloped the transmitter and no apparent infection occurred.

A combiotic containing an aqueous solution of penicillin and dihydrostreptomycin was used during the first few weeks of the study but was later abandoned when two animals died within 2 weeks after the injection. Their deaths may have been due to an adverse response of the gopher's intestinal micro-fauna to the antibiotic.

a

c


b

Figure 9. Implant Operation for a pocket gopher. (a) anesthetic (b) implant of transmitter (c) antiseptic/healant

Field Procedure

The AVM 151 MHz 12-channel receiver and the handheld yagi antenna were carried onto the study area. Signals were received from directly over the animal to 30 m distant. By following each animal from a short distance away, precise measurement of its movements could be obtained (Fig. 10).

This method has an advantage over the triangulation method where each location is found by 'fixes' at two of the nearest permanent tracking stations. 'Direct' monitoring was particularly advantageous for pocket gopher activity. Its activity is almost entirely below ground and no interaction occurs between observer and animal to influence results. This lack of observer influence was substantiated by the fact all animal movements appeared normal and aboveground feeding occurred on several instances throughout the study.

By direct monitoring a continuous tracking of the animal could be obtained. Tracking periods were of either 15, 30, or 60 minutes for each animal with up to a possible four animals monitored each hour.

Tracking sessions varied from 2 to 12 hours. Some tracking sessions monitored only a single animal nonstop for the entire length of the session. Tracking sessions occurred almost every week for a period of 1 year. Sessions were attempted at all hours of the day and night with a predominance of sessions occurring during midday hours.

Figure 10. Radiotracking pocket gophers on Yankee Hill Study Area using a portable receiver and Yagi hand-held antenna.

A grid system of numbered flags at 5 m intervals was set up in each study area to record animal position and movement. The grid system was also used as a reference in recovery of lost transmitters in the field.

Field data sheets (graph paper with each square representing 1 $m^2$) were used to record time of tracking, certain environmental conditions and location of each animal. This information was later placed into a format suitable for data analysis using a computer.

Each animal location was measured to the nearest meter. Locations of an animal were represented as dots and movements as lines connecting dots. Often the line of movement, representing tunnel systems used, coincided with each other. In these cases dots at each major change in direction of the line were labeled and used to record movements of the animal. These dots were lettered and later mapped on X-Y coordinates using the letters as locations from which movement and activity could be determined.

Toe Clipping

While the animal was still anesthetized from the implant operation a toe was clipped from a hind foot to identify the animal for future field work. An antiseptic healant (Newskin, Newskin Company Inc., Plainview, Wyoming) was placed on the clipped toe and on the implant incision area. Animals were also sexed and weighed at this time.

After the implant operation and toe removal, specimens were returned to their cages. Animals were kept in the lab from 1 to 3 days after the implant to observe them for possible side effects of the operation.

Sources of Error

Telemetry systems are inherently responsible for certain sources of error. Triangulation contains an additional source of error (Artmann, 1967). The telemetry system used in this study reduced error in that triangulation was not used. A direct monitoring of the animal and plotting its location on graph paper resulted in increased accuracy.

Direct monitoring may have a disadvantage in indirectly influencing an animal's activity through trampling of above-ground vegetation by the observer. This destruction was regarded as minor because the gopher utilizes aboveground material primarily pulling down a plant through a small opening to the surface. Vibrations through the soil caused by movements of the observer across the surface were assumed to be minor.

Plotting of lines and points depicting animal movement was another source of error. Constant monitoring of the animal during rapid movements was difficult. Interpolation between consecutive points of location was sometimes needed.

Since grid flags were placed in the field at 5 m intervals, observer bias may have led to some error in judging an animal's distance from a flag. As already stated all points on the field data sheets were placed at the nearest whole meter from any flag.

Vegetation and soil type had little influence on refracting signal tranmission at such close ranges as in this study. Signal reception was affected by air temperature which altered pitch and by other transmissions on the same frequency which completely blocked out signal transmissions for short lengths of time. Signal volume was affected by the condition of both transmitter and receiver batteries, depth of the transmitter below the ground and by orientation of the transmitter in the animal.

## Results and Discussion

### Data Source

Twenty-three pocket gophers were implanted with radiotransmitters and released for observation during the course of study. Five were recaptured on subsequent dates and reimplanted. Losses were high with seven animals dying in the field and all but nine of the remaining individuals either disappearing from the study area or losing radio contact before adequate data were obtained.

Table 1 summarizes the sex and age of animals that were captured and implanted with transmitters in the study. Animals #1 through #9 were used in analysis of home range and activity. A skewing of the sex ratio is evident from the total number of animals captured during the study. Only 6 of the 23 individuals implanted were males. Four males were captured in August and September and two in November and December.

Disproportionate sex ratios have been reported by others. Dalles pocket gophers (Thomomys talpoides quadratus) had a ratio as high as 1:1.5 males to females (Moore and Reid 1951) and valley pocket gophers (Thomomys bottae mewa) 1:1.7 males to females (Howard and Childs 1959). In the plains pocket gopher, sex ratios ranged from 40 to 73 percent females depending upon time of year trapping data were collected (Vaughan 1962). Kennerly (1958) reported sex ratios for Geomys bursarius attwateri in Texas to be 42.8 percent males to 57.2 percent females.

Various methods have been used for determining age of pocket gophers. Resorption of the pubic symphysis at puberty (8 months) is used as a criterion for aging females (Hisaw 1924). For males, size and appearance of the testes and seminal vesicles as well as the presence or absence of sperm are used in separation of adults and juveniles (Vaughan 1962). Differences in juvenal and adult pelage is another criterion for age.

Body weights have been used in age determination, although this is less precise than the above methods. Adams (1966) chose 200 grams and 220 grams as the weights separating adults from juveniles in June and July, respectively. Body lengths less than 180 mm and 195 mm in June and July were considered to be juveniles. Body weights used alone, however, are a poor criterion for separation of adults and juveniles due to species and subspecies variation as well as variation in nutritional levels within a given population.

Animals in this study were aged on the basis of body weight and pelage coloration. Body weights ranged from 203 grams to 387 grams (Table 1). The mean weight for 22 animals captured in this study was 270 grams. Pelage suggested that all animals were adults when captured. No effort was made to classify animals as to year classes. Gophers were weighed when captured. Initial capture weight was greater in two animals and less in two others than their recapture weights. Those losing weight were believed to be in good health as substantiated by little change in their mean hourly distances traveled.

Table 1 also shows the habitat type in which each animal was found. No home range extended into more than one habitat type although one animal not radio-equipped appeared to make a series of mounds from the old field habitat to the alfalfa habitat on the Yankee Hill study area.

Vegetative differences between the alfalfa and old field habitats at Yankee Hill were not distinct. The

Table 1 Animals Tracked May 1976 to June 1977.

| Animal Number | Sex | Month Captured | Weight (Grams) | Habitat Type | Date | Fate of Animal |
|---|---|---|---|---|---|---|
| 1 | Female | February | 244 | Alfalfa[a] | May 3 | died in field |
| | | March | 303 | Alfalfa[a] | | |
| 2 | Male | November | 387 | Old Field[a] | Jan 20 | lost signal |
| 3 | Male | December | 271 | Old Field[a] | May 7 | lost signal |
| | | February | 244 | Old Field[a] | | |
| 4 | Female | October | 227 | Alfalfa[a] | | lost signal |
| | | February | 234 | Alfalfa[a] | | |
| | | March | 258 | Alfalfa[a] | | |
| | | July | 274 | Alfalfa[a] | | |
| 5 | Female | October | 227 | Old Field[a] | Oct 18 | lost signal |
| 6 | Male | September | 274 | Alfalfa[a] | Oct 7 | died in field |
| 7 | Female | October | 341 | Old Field[a] | May 3 | died in field |
| | | February | 279 | Old Field[a] | | |
| | | March | 283 | Old Field[a] | | |
| 8 | Female | May | 259 | Alfalfa[a] | June 29 | lost signal |
| 9 | Female | May | 250 | Alfalfa[a] | June 27 | expelled transmitter |
| 4422 | Female | June | 280 | Alfalfa[b] | June 30 | lost signal |
| 4430 | Male | September | 296 | Old Field[a] | Oct 4 | expelled transmitter |
| 4431 | Female | September | 204 | Alfalfa[a] | Sept 14 | died in field |
| 4432 | Male | September | 203 | Alfalfa[a] | Sept 10 | lost signal |
| 4434 | Female | September | 325 | Alfalfa[a] | Oct 4 | died in field |

Table 1 Animals Tracked May 1976 to June 1977.

| Animal Number | Sex | Month Captured | Weight (Grams) | Habitat Type | Date | Fate of Animal |
|---|---|---|---|---|---|---|
| 4436 | Female | October | 215 | Alfalfa[a] | Oct 14 | died in field |
| 4446 | Female | December | 327 | Old Field[a] | Mar 10 | lost signal |
| | | February | 340 | Old Fielda | | |
| 4450 | Female | December | 346 | Old Field[a] | Mar 13 | lost signal |
| | | February | 297 | Old Field[a] | | |
| | | March | 243 | Old Field[a] | | |
| 4500 | Female | May | 234 | Old Field[a] | May 16 | died in field |
| 4590 | Female | June | 231 | Native Pasture[c] | Aug 1 | lost signal |
| 4591 | Female | June | 244 | Native Pasture[c] | June 30 | died in field |
| 4593 | Female | July | 260 | Native Pasture[c] | Aug 11 | lost signal |
| 4594 | Male | August | 237 | Native Pasture[c] | Aug 15 | lost signal |
| 4600 | Female | September | 255 | Native Pasture[c] | Sept 10 | lost signal |

$\bar{x}$ = 270.2 g      S. D. = 50.4

a = Yankee Hill study area

b = Umberger's study area

c = Twin Lakes study area

borderline between the two types was actually a gradation of vegetative change. Alfalfa was a major contributor to the mosaic of grasses and forbs existing in the old field and bromegrass was predominant in certain areas of the alfalfa field.

Insufficient data were collected on the third study area to compare differences in animal home range and activity on its native grass habitat with the alfalfa and old field habitats of the other two study areas. Only one animal (Gopher#9) was used in the analysis from the alfalfa habitat of the Umberger study area.

Tracking Periods

Pocket gophers were monitored on 72 different dates over the course of 12 months from June 1976 to June 1977. Animals were also tracked during July and August 1977 but little information was obtained due to transmitter failure and recapture problems.

Each animal was continuously monitored for periods of 15, 30, or 60 minutes. During 12 months there were nine 15-minute periods, three hundred-seventy 30-minute periods, and one hundred-four 60-minute periods recorded. Tracking shifts ranged from 2 to 12 hours and varied as to hour of day tracked (Table 2). Total tracking time was 290 hours for nine individuals (Table 3).

Table 2
Time in hours when nine pocket gophers were tracked
from June 1976 to June 1977.

| Hour | June | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | June | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0000 | 1.0 | | | 1.0 | | | | | 0.5 | | | 2.5 |
| 0100 | 1.0 | | | 1.0 | | | | | 1.0 | | | 3.0 |
| 0200 | 1.0 | | | 1.0 | | | | | 1.0 | | | 3.0 |
| 0300 | 1.0 | | | 1.0 | | | | | 1.0 | | | 3.0 |
| 0400 | 1.0 | | | 1.0 | | | | | 1.0 | | | 3.0 |
| 0500 | 0.5 | | 0.75 | 0.5 | | | | | 1.0 | | | 2.75 |
| 0600 | 0.5 | 0.5 | 1.25 | 0.5 | | | | | 2.5 | | | 5.25 |
| 0700 | 2.0 | 0.5 | 1.5 | 1.5 | 2.0 | 0.5 | | 1.5 | 2.5 | | 2.0 | 14.00 |
| 0800 | 2.0 | 0.5 | 1.5 | 2.5 | 3.0 | 1.5 | 1.0 | 4.5 | 3.0 | 0.5 | 2.5 | 22.5 |
| 0900 | 2.0 | 0.5 | 1.25 | 2.5 | 2.0 | 3.0 | 1.0 | 6.5 | 3.0 | 3.5 | 4.5 | 29.75 |
| 1000 | 2.0 | 0.5 | 1.25 | 2.5 | 2.0 | 3.0 | 1.0 | 7.5 | 3.0 | 4.5 | 2.5 | 27.75 |
| 1100 | 1.0 | 0.5 | 0.5 | 2.5 | 2.0 | 3.0 | | 7.0 | 3.0 | 3.5 | 1.0 | 24.00 |
| 1200 | 1.0 | 0.75 | 0.5 | 2.5 | 3.0 | 5.0 | 1.0 | 4.0 | 4.0 | 4.0 | 1.0 | 26.00 |
| 1300 | | 0.5 | 0.5 | 1.0 | 3.0 | 3.0 | 1.0 | 4.0 | 4.5 | 3.0 | 1.0 | 21.50 |
| 1400 | | 0.5 | 0.5 | 2.0 | 3.0 | 2.0 | 1.0 | 4.0 | 5.5 | 1.5 | 0.5 | 20.50 |
| 1500 | 0.25 | 0.5 | | 2.0 | 4.0 | 2.0 | 1.0 | 4.5 | 4.0 | 1.0 | | 19.25 |
| 1600 | 1.0 | 0.5 | 1.0 | 1.0 | 4.0 | 1.5 | 1.0 | 4.5 | 2.0 | | | 16.50 |
| 1700 | 2.25 | 0.5 | | 1.5 | 3.5 | 1.5 | 1.0 | 2.5 | 2.0 | | | 14.75 |
| 1800 | 1.0 | | | 2.0 | 3.0 | 1.0 | | 2.0 | | | | 6.0 |
| 1900 | | | | 2.0 | 1.0 | 1.0 | | 1.0 | | | | 6.0 |
| 2000 | | | | 2.0 | 1.0 | 1.0 | | | | | | 4.0 |
| 2100 | 0.5 | | | 2.0 | 1.0 | 1.0 | | | | | | 4.5 |
| 2200 | 1.0 | | | 1.0 | 0.5 | 1.0 | | | | | | 3.5 |
| 2300 | 0.5 | | | 1.0 | | | | | | | | 1.5 |
| TOTAL | 22.50 | 6.25 | 10.5 | 37.5 | 38.0 | 31.0 | 9.0 | 53.5 | 44.5 | 21.5 | 16.0 | 290.25 |

Table 3

Time in hours spent tracking individual pocket gophers from June 1976 to June 1977.

| Animal Number | June | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | June | Animal Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | 16.5 | 18.5 | | | 35.0 |
| 2 | | | | 9.0 | 16.0 | 0.5 | | | | | | 25.5 |
| 3 | | | | | 7.0 | 30.5 | 9.0 | 2.0 | | | | 48.5 |
| 4 | | | 3.0 | 24.5 | 15.0 | | | 10.5 | 14.0 | 2.5 | | 69.5 |
| 5 | | | 4.0 | | | | | | | | | 4.0 |
| 6 | | 6.25 | | | | | | | | | | 6.25 |
| 7 | | | 3.5 | 4.0 | | | | 24.5 | 12.0 | | | 44.0 |
| 8 | | | | | | | | | | 19.0 | 16.0 | 35.0 |
| 9 | 22.5 | | | | | | | | | | | 22.5 |
| Hours | 22.5 | 6.25 | 10.5 | 37.5 | 38.0 | 31.0 | 9.0 | 53.5 | 44.5 | 21.5 | 16.0 | 290.25 |

Animals also varied as to month and season of year tracked. Gophers #5, #6, and #9 were tracked during one month each while animal #4 was tracked over six different months. These differences reflect the degreee of ease in capture for each animal, functioning of the transmitter, and weather and soil conditions.

Activity Patterns

Great variation occurs in distances traveled between tracking sessions of different animals and between different trackings of the same animal (Artmann 1967). He calculated distances traveled for 15-min intervals and determined daily means. He found a range of means from 3.0 to 10.7m per day between animals and from 3.7 to 10.7 m within an individual's tracking sessions. I have calculated the mean hourly distances traveled for each animal (Table 4).

The irregularity in the duration of the tracking session and time of day that successive tracking sessions were made offers a poor means of comparing the mean daily distance traveled for each animal. I have chosen not to show each daily distance traveled due to the resulting complexity of the table but have averaged all hours tracked for each animal each month. A direct comparison of mean daily distances between animals cannot be made from Table 4 but could be interpreted from the hourly distances given.

Table 4

Mean hourly distance traveled (meters) for nine gophers from June 1976 to June 1977.

| Animal Number | June | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | June | Animal Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | 44.5 | 32.9 | | | 38.4 |
| 2 | | | | 14.6 | 22.8 | 17.9 | | | | | | 19.8 |
| 3 | | | | | 12.8 | 22.9 | 8.7 | 12.0 | | | | 18.4 |
| 4 | | | 14.7 | 15.1 | 17.7 | | | 25.5 | 14.5 | 19.8 | | 19.3 |
| 5 | | | 2.3 | | | | | | | | | 2.3 |
| 6 | | 11.3 | | | | | | | | | | 11.3 |
| 7 | | 37.4 | 18.7 | | | | | 27.8 | 26.4 | | | 27.3 |
| 8 | | | | | | | | | | 5.3 | 2.0 | 3.7 |
| 9 | 22.5 | | | | | | | | | | 22.5 | 22.5 |
| Monthly Mean | 22.5 | 11.3 | 17.5 | 15.4 | 19.8 | 22.8 | 8.7 | 34.2 | 26.7 | 6.9 | 2.0 | |

The mean hourly distances in Table 4 suggest no differences between months although March and April have higher means than other months. This may be the result of individual variation rather than an increase in activity in these months. This is supported by the monthly distances traveled by Gopher #3. It should also be noted that all animals tracked during March and April were females, negating the possibility of increased activity being due to males during breeding season.

Table 5 shows the standard deviations for each animal each month and the monthly mean standard deviations. The standard deviations are based on distances traveled in 30-min. periods, and include inactive periods. Distances and standard deviations in tables 5 and 6 were based on 30-min. rather than 60-min. periods because of more consistent use of this interval for all animals throught the study. Distance traveled by an animal varied from no movement for several hours to over 108 m traveled in 30 minutes.

Table 6 compares mean 30-min. distances of males and females. No significant difference between sexes in mean distances traveled was detected ($t \geq .05$)

Mean hourly distance for each hour of the day was calculated and averaged for nine animals (Fig. 11). Distance traveled increased gradually for daylight hours, peaking at 1730. A sharp decrease in distance traveled

Table 5

Monthly and animal movement standard deviations for distances traveled during 30-minute periods

| Animal Number | June | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | June | Animal Std. Dev. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | 31.48 | 19.36 | | | 26.70 |
| 2 | | | | 20.41 | 20.12 | --[a] | ---[a] | | | | | 20.23 |
| 3 | | | | | 11.38 | 14.96 | 1.05 | 7.24 | | | | 10.06 |
| 4 | | | 6.22 | 9.95 | 10.44 | | | 14.47 | 18.61 | 9.44 | | 13.27 |
| 5 | | | | | | | | | | | | 0 |
| 6 | | 7.21 | | | | | | | | | | 7.21 |
| 7 | | | 19.47 | 13.11 | | | | 18.81 | 20.79 | | | 19.14 |
| 8 | | | | | | | | | | --[a] | ---[a] | ---- |
| 9 | 16.9 | | | | | | | | | | | 16.9 |
| Mean | 16.9 | 7.21 | 14.02 | 12.74 | 15.44 | 14.96 | 1.05 | 24.74 | 19.21 | 9.44 | --- | |

[a]insufficient data obtained due to few or no 30-minute periods recorded.

Table 6. Mean distances traveled (meters) during 30-minute periods for male and female gophers (number of 30-minute periods).

| Males | | Females | |
|---|---|---|---|
| Animal Number | Distance Traveled | Animal Number | Distance Traveled |
| 2 | 16.2 (45) | 1 | 18.2 (67) |
| 3 | 9.2 (36) | 4 | 10.0 (114) |
| 6 | 5.2 (12) | 7 | 14.9 (74) |
| | | 9 | 12.0 (9) |
| $\bar{x}$ = 13.1 | | $\bar{x}$ = 13.3 | |

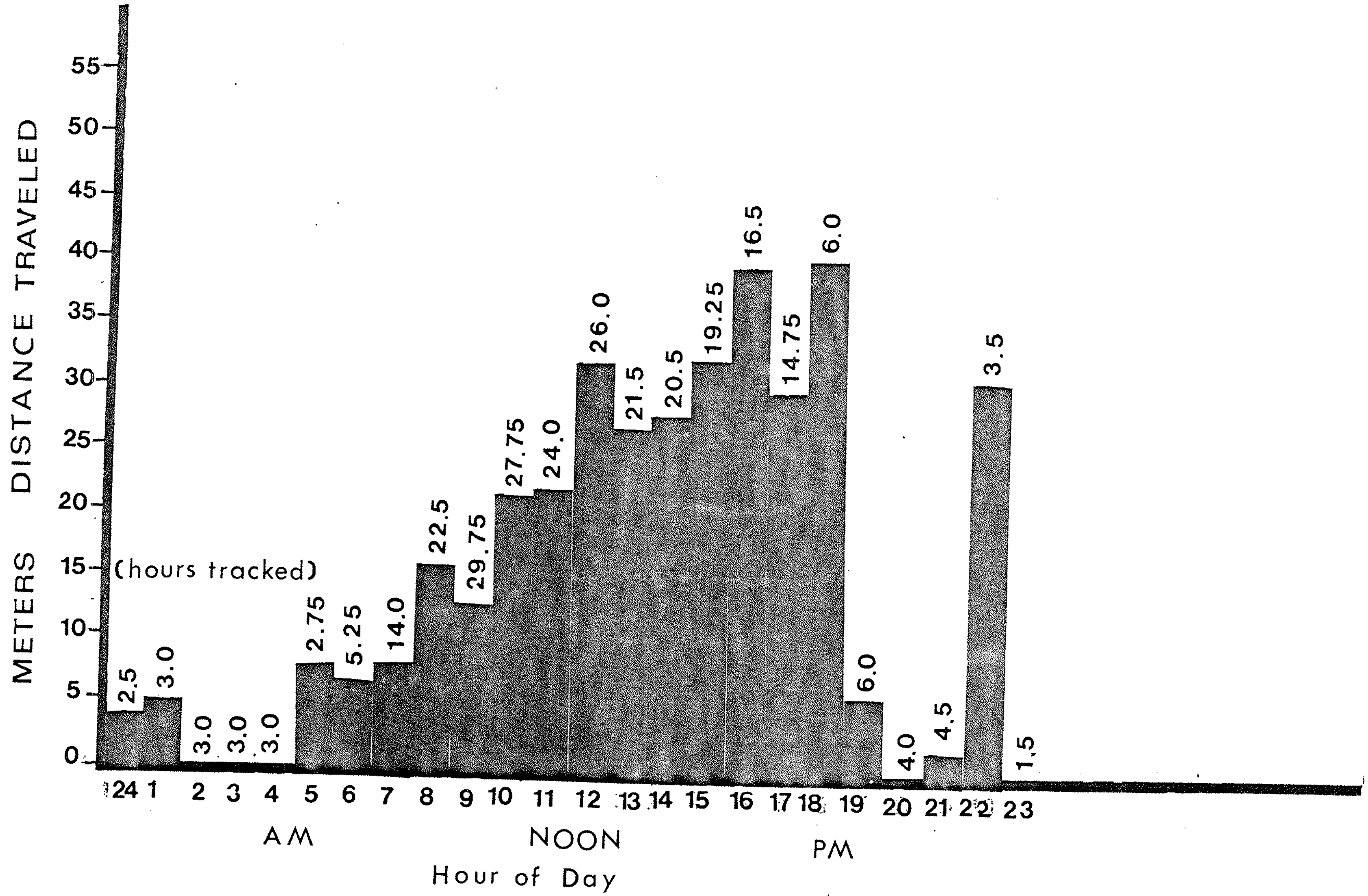



FIGURE 11. MEAN HOURLY DISTANCE TRAVELED FOR NINE GOPHERS

occurred at 1830 and low activity persisted until early morning (0430). The exception at 2130 was due primarily to Gopher #9 who traveled over 60 m during this hour. However, some activity was shown during this hour by two other animals and during all four months (Nov., Dec., Jan., and June) in which data were taken for this hour. A larger sample size may be needed to substantiate an increase in activity. The small sample sizes which occur at all nighttime hours may be insufficient to test for nighttime activity patterns. However, seldom in my observations did an animal move from its resting place during late night tracking sessions.

Vaughan and Hansen (1961) reported periodic activity throughout the day and night for three gophers (*G. bursarius*) placed in next boxes in the lab. Photoperiod in the lab simulated that under natural conditions for the corresponding time of year. Artmann (1967) also reported a similar pattern of activity of interspersed activity throughout a 24-hour period.

Length of active and inactive periods was not calculated in this study due to the method of data collection. (Each animal was monitored for 30-min. each hour. Therefore if an animal was active until the end of a period, it was impossible to know if the activity had continued until the following hour.) I have defined activity as movement of more than 2 m. Activity periods usually lasted less than 60 min. and often less than 30 min. Periods of inactivity usually lasted the full 30-min. period. Some late evening and nighttime periods of rest lasted for several hours. Vaughan and Hansen (1961) found periods of activity averaging 36 min. and inactivity, 60 min. Conversely, Artmann (1967) found periods of activity to be slightly longer than inactive ones (66 percent of active periods were longer than 45 min. compared to less than 50 percent for inactive periods). Both reports noted certain extensive periods of inactivity although not being predominant at any time of day or night.

Percent activity, calculated on a monthly basis for nine animals, is shown in Figure 12. The figure includes only daylight hours (0600 to 1800) because nighttime tracking shifts occurred in only four months and, as shown earlier, had relatively little activity. Percent activity was obtained by dividing the number of 30-min. tracking periods in which an animal was active by the total number of tracking periods. For instance, in September animals were active in 6 of 12, 30-min. periods or 50 percent.

Insufficient data were collected for February and June. The lower degree of activity in May may be due to the smaller sample size. Gopher #8, one of two animals tracked during this month, however, had one of the lowest occurrences of activity of the nine animals studied (Table 7).

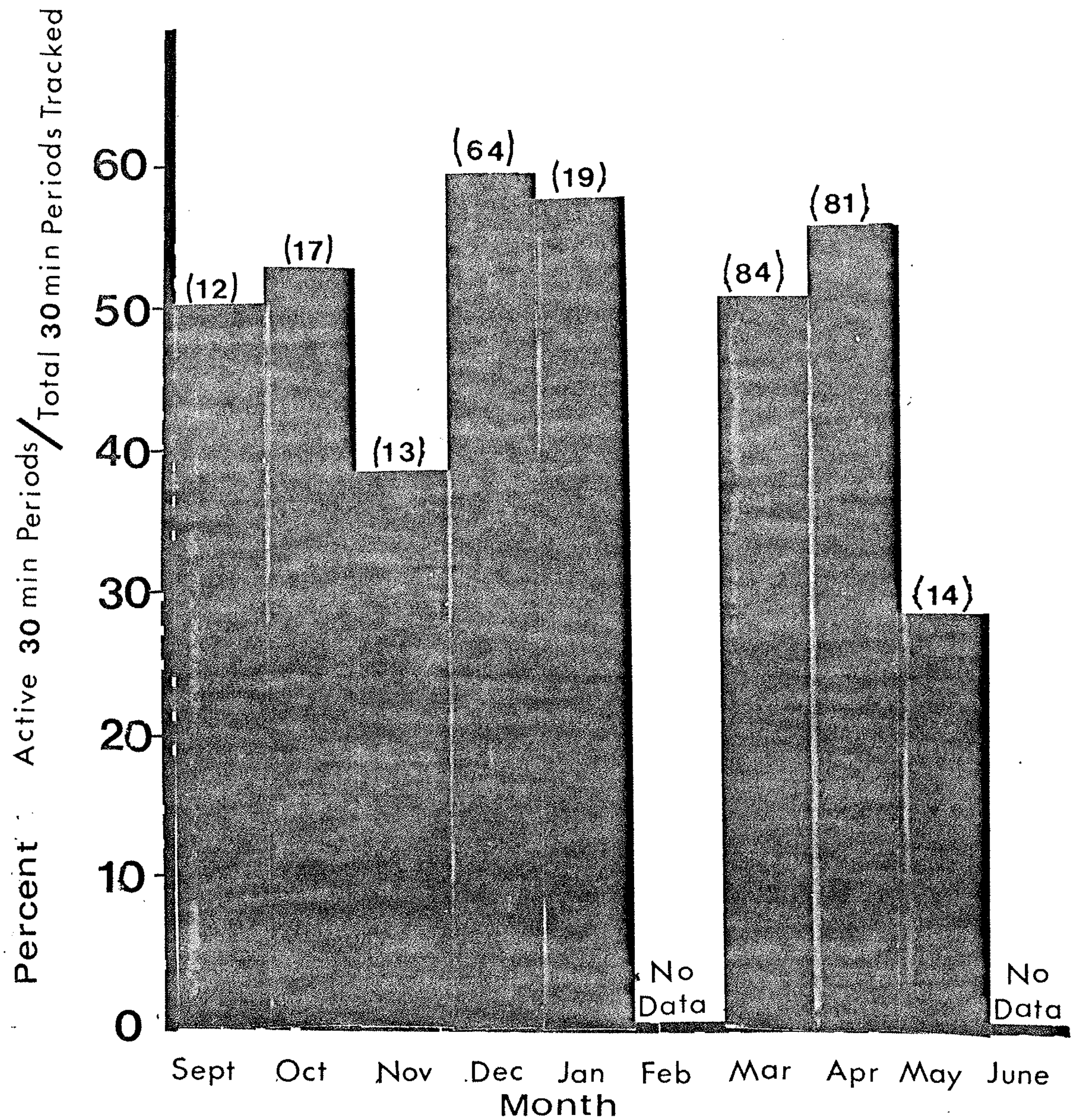



FIGURE 12. PERCENT OF ACTIVE PERIODS DURING DAYLIGHT HOURS[1]

(number of 30-min tracking periods)

1/ 0600 hours to 1800 hours

Table 7

Percent Active 30-min. periods for each animal
(Number of 30-min. periods)

| Animal Number | June | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | June | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | 50 (28) | 51.3 (39) | | | 50.7 (67) |
| 2 | | | | 41.7 (12) | 43.9 (32) | 100 (1) | | | | | | 44.4 (45) |
| 3 | | | | | 57.1 (14) | 55.6 (18) | | 50 (4) | | | | 55.6 (36) |
| 4 | | | 66.6 (6) | 19 (21) | 58.1 (31) | | | 60.9 (23) | 51.7 (29) | 60 (5) | | 50.4 (115) |
| 5 | | | 0 (5) | | | | | | | | | 0 (5) |
| 6 | | 50 (12) | | | | | | | | | | 50 (12) |
| 7 | | | 71.4 (7) | 50 (8) | | | | 48.6 (35) | 45.8 (24) | | | 50 (74) |
| 8 | | | | | | | | | | 11.1 (9) | 0 (4) | 7.7 (13) |
| 9 | 33.3 (6) | | | | | | | | | | | 33.3 (6) |
| TOTAL | 33.3 (6) | 50 (12) | 50 (18) | 31.7 (41) | 51.9 (77) | 57.9 (19) | | 52.2 (90) | 50 (92) | 28.6 (14) | 0 (4) | 47 (373) |

This animal was tracked for 30 days and was in good health at the time of transmitter failure. I can give no explanation as to the unusually low activity although individual variation has been reported in both amount of activity and duration of activity periods (Artmann 1967; Vaughan and Hansen 1961).

The mean monthly percent active periods, calculated from Figure 12, is 52.4 percent. This was thought to be a high estimate due to the interpretation of an activity period as one containing any movement over 2 m. A large number of active periods containing little movement would overestimate the actual activity of the animal. Therefore the amount of movement within a given period (30-min., 60-min.) was calculated and ranked by intensity (A, B, or C) (Fig. 13). All 'A' movements included any distance less than 10 m within a 30-min. period or less than 20 m in a 60-min. period. 'C' movements included distances greater than 50 m per 30-min. period or greater than 100 m per 60-min. period. 'B' movements included all distances longer than the 'A' and shorter than the 'C' movements. Most active periods (61 percent) had movements of moderate intensity, although a large number (26-28 percent) contained little movement.

Percent active periods, was calculated on a 24-hr basis in Figure 14. There was a gradual increase in number of active periods throughout the day peaking at 1600. A

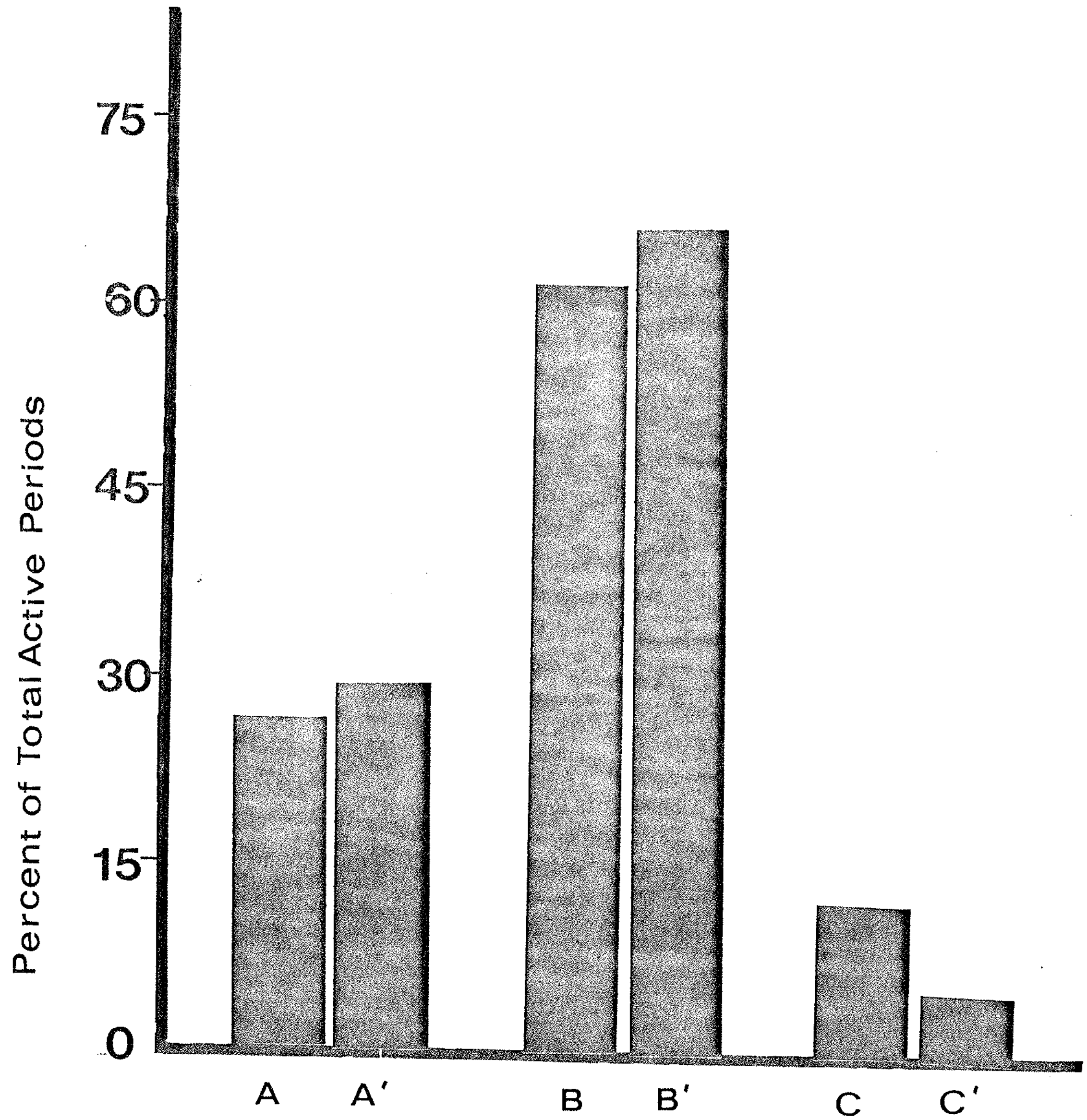



FIGURE 13. INTENSITY OF ACTIVITY

A = < 10m /30min  A' = < 20m /60min
B = 10 - 50m /30min  B' = 20 - 100 /60min
C = > 50m /30min  C' = > 100 /60min

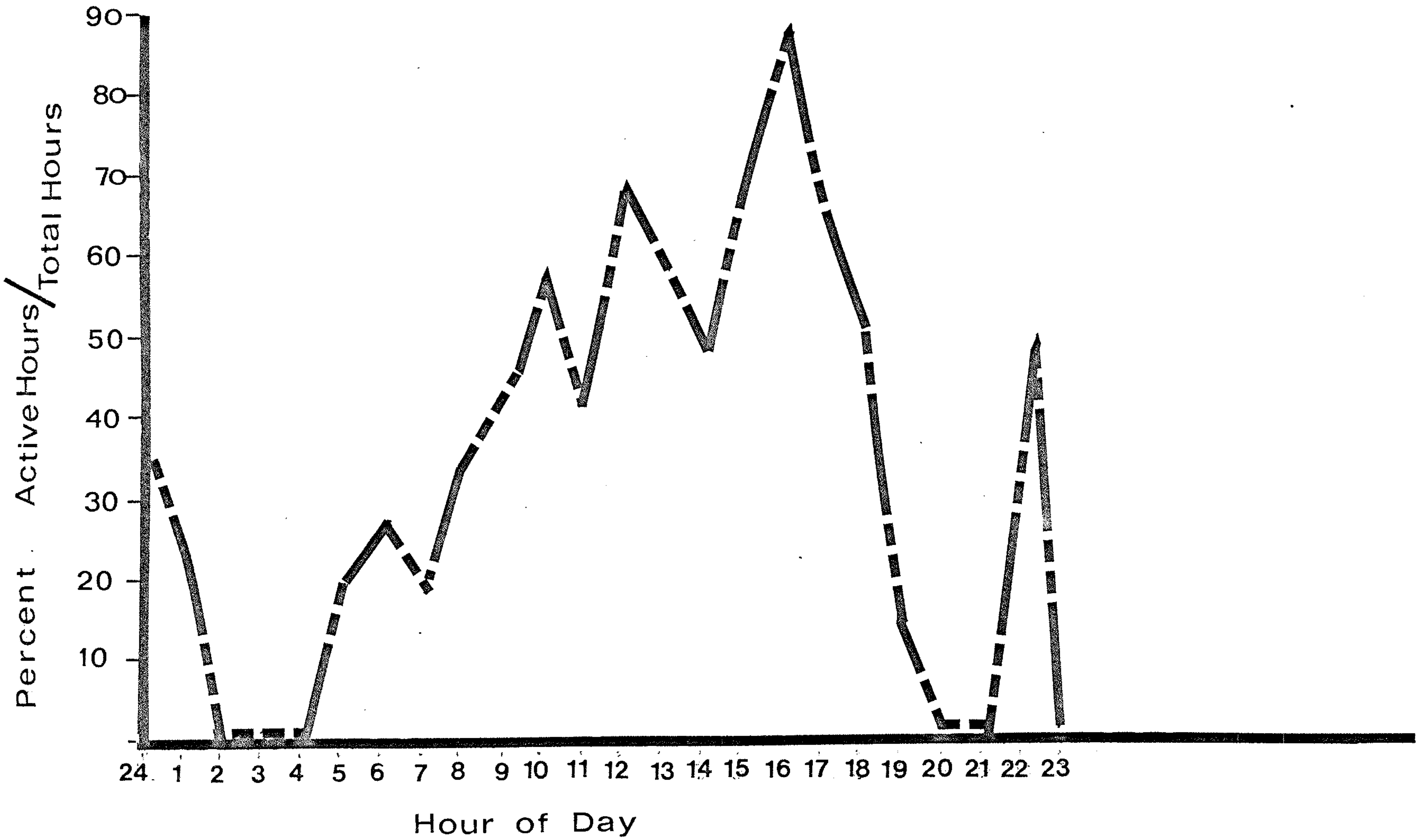



FIGURE 14. PERCENT OF ACTIVITY PERIODS ON A 24-HOUR BASIS

sharp drop occurred after 1800. Activity periods at 2200 and 2400 represented small sample sizes. This overall trend of increasing frequency of active periods as the day progresses and then a sharp drop at dusk correlated well with the increasing hourly distances traveled in Figure 11.

Home Range

Home range has been defined as the area "traversed by an individual in its normal activities of food gathering, mating, and caring for young." (Burt 1943). Home range, however, is subject to change over the course of an animal's lifetime and even over the course of a few months.

To define home range, its purpose in applied management practices should be recognized. If it is to be a useful concept it should be applicable to estimating the population density and the carrying capacity for a particular species for a given habitat. The ability of a species to fill a particular favorable habitat, however, may depend on other factors that are not reflected in the animal's home range.

In pocket gophers, the home range has been stated to be coincidental with the territory of the animal due to the restrictiveness of the gopher's burrow system (Ingles 1949). However, the territory of a gopher may extend beyond the confines of the burrow system to areas that have been previously occupied. Aversive odors in these areas as well as a depletion of the food supply may serve to exclude conspecifies (Mohr 1947).

Several methods have been used in calculating home range for pocket gophers. Scheffer (1940) calculated the 'real use' of a home range by determining the area of a tunnel system 155.4 m long and 7 cm in diameter (16.4 $m^2$ or 0.0012 ha). Clearly this measurement does not reflect the use of home range as a predictor of population density.

A more applicable method of calculating home range is the construction of a polygon from the outermost capture points of an animal. This minimum home range method was first described by Dalke (1942). It allows for no weighting of trap sites where the animal has been captured more than once.

Other methods are modifications of the minimum home range method. Most consist of choosing a suitably sized area (circular, triangular, or square) around each of the capture sites. The size of area chosen depends upon the systematic arrangement of the traps; the radius of the area being one-half the distance between adjacent traps. Those areas are summed to obtain an overall estimate of a home range (Burt 1940; Haugen 1942). Choosing the number and arrangement of traps and the area or grid around each trap site may be the major limitation of these methods.

The maximum grid size that will correlate closely was found to be 2.5 percent of the minimum home range area (Mohr 1947). Methods using grids are suitable for data collected from trapping results but not for data collected from a continuous monitoring of an animal's movements.

A modification of the minimum home range method was used by Harvey and Barbour (1965) with Microtus. For this method a polygon is constructed as in the minimum home range method but the outside points are not connected if the distance between them is greater than 0.25 the home range length. The home range length is simply the distance between the two most distal locations in an animal's movements. Outside points are included in the area by drawing lines to points outside of the polygon 30 cm wide. Area is calculated for these lines and added to the enclosed area of the polygon. This is the method I have used in this study.

Figure 15 compares the home range of Gopher #1 using the minimum area method and the Harvey and Barbour method.

Harvey and Barbour (1965) estimated their method enclosed only 50 percent of the area of the minimum home range method. However, difference in estimates for these two methods depends upon shape and size of the home range. Mohr (1947) found a greater variation in more linear home ranges when comparing the minimum home range method with a grided estimate of home range.

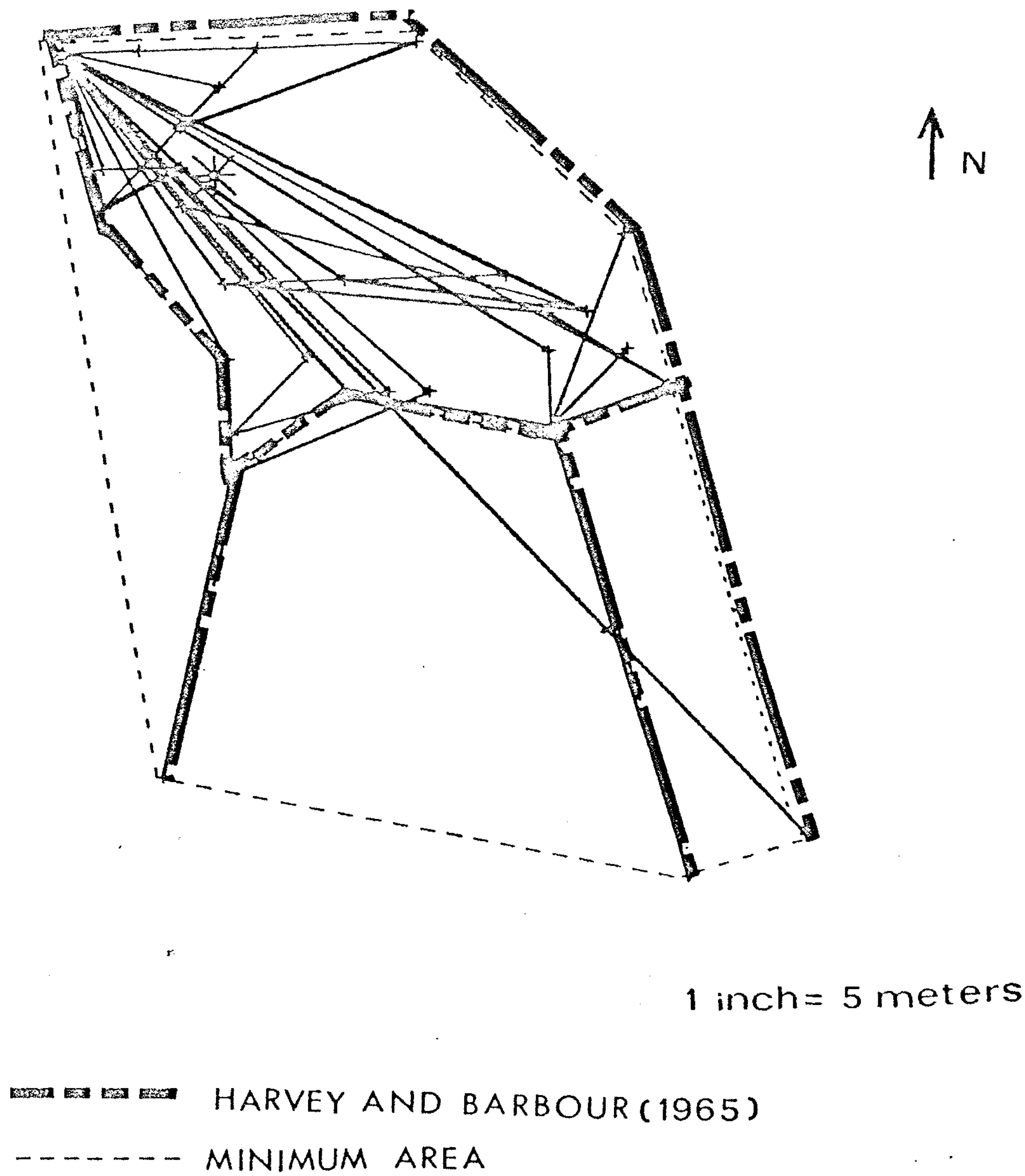



Figure 15. Home Range of Gopher #1 for April.

Figures 16a through 16i show movements of nine animals in the study and the polygons formed by the Harvey and Barbour (1965) method of estimating home range. As can be seen, the polygons are quite varied in shape and size. Too few movements of Gopher #5 were obtained to calculate home range by the Harvey and Barbour (1965) method (Fig. 16e).

I calculated the home range length and width and determined the linear ratio (length/width) for each of nine animals in my study (Table 8). Only once was the ratio greater than 3:1, although Artmann (1967) reported a 3:1 overall ratio for all animals in his study and one 10:1 ratio. My largest ratio was 6.17:1. Artmann's study, as well as mine, suggested no differences between sexes in linearity of home range.

A final method of home range determination is the ellipse method (Gipson and Sealander 1972) which draws an ellipse about all radiolocations or points of capture for an animal. This is, perhaps, the largest estimate for home range and is used in this paper only as a comparison to the minimum area and Harvey and Barbour (1965) methods (Table 9).

The ellipse method was consistently the largest and the Harvey and Barbour (1965) method, the smallest of the three methods examined. The ellipse method and the minimum area methods were essentially equal in estimating the home

Figure 16a - 16i. Calculation of home range by the Harvey and Barbour(1965) method (bold dashed line) for nine gophers. Solid lines represent all recorded movements for each animal between the inclusive dates listed below.

| | |
|---|---|
| 16a | March 15 - April 25, 1977 |
| 16b | November 19, 1976 - January 10, 1977 |
| 16c | December 15, 1976 - March 3, 1977 |
| 16d | October 27, 1976 - May 3, 1977 |
| 16e | October 13, 1976 |
| 16f | September 28 - September 30, 1976 |
| 16g | October 19, 1976 - April 14, 1977 |
| 16h | May 15 - June 24, 1977 |
| 16i | June 4 - June 5, 1976 |

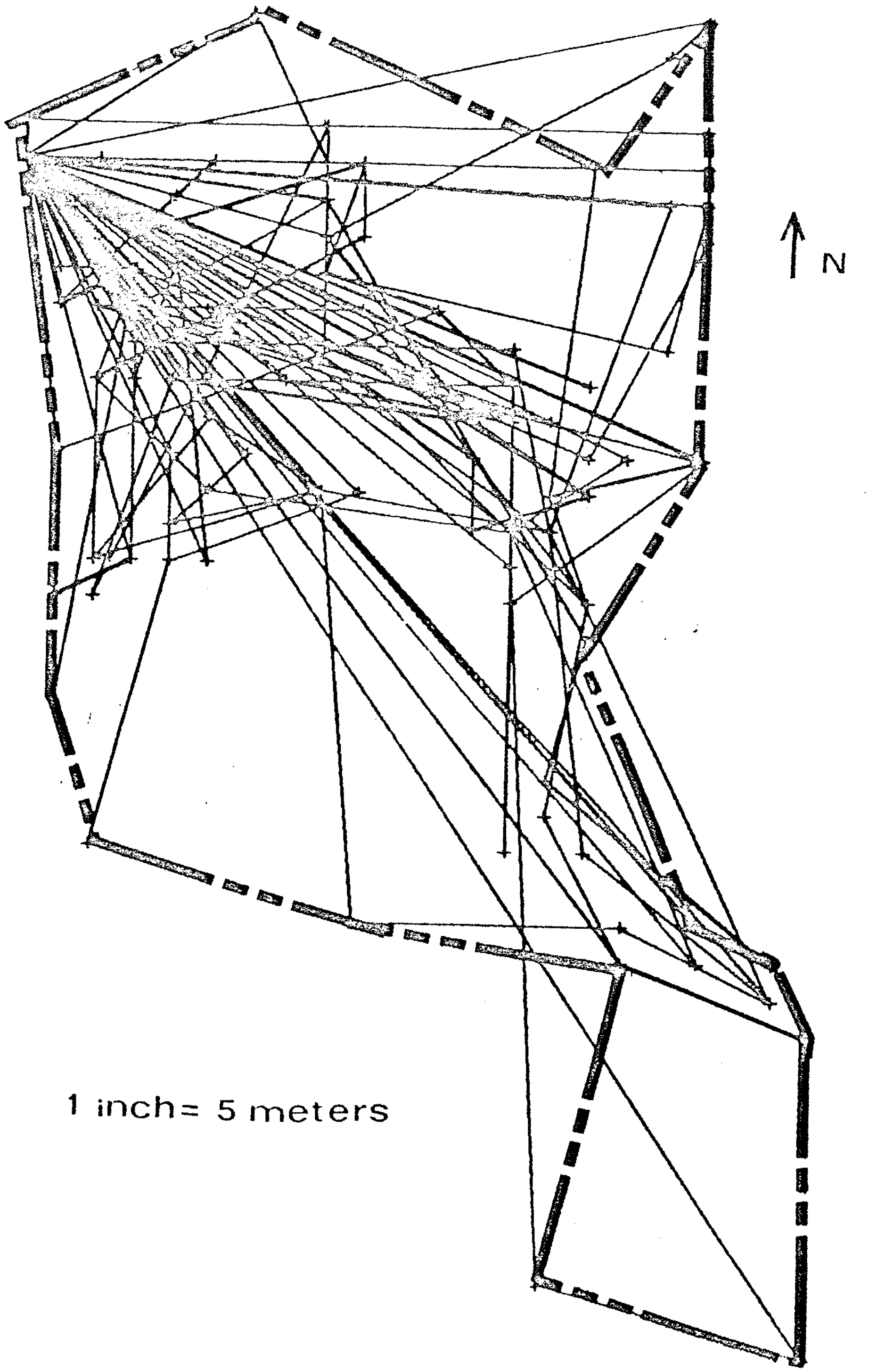
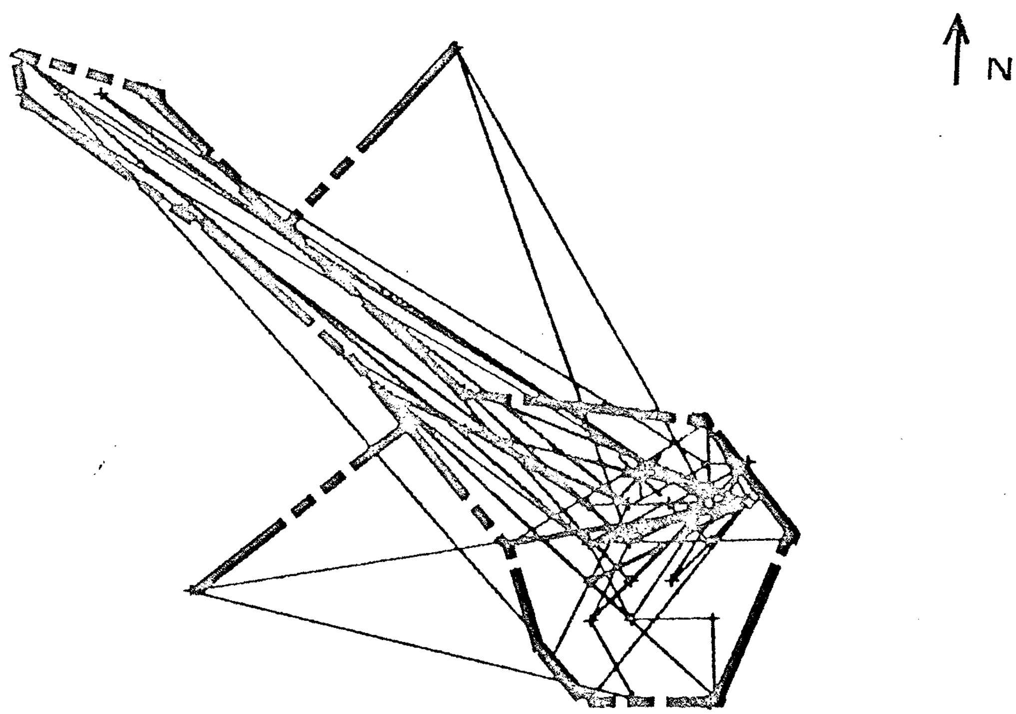


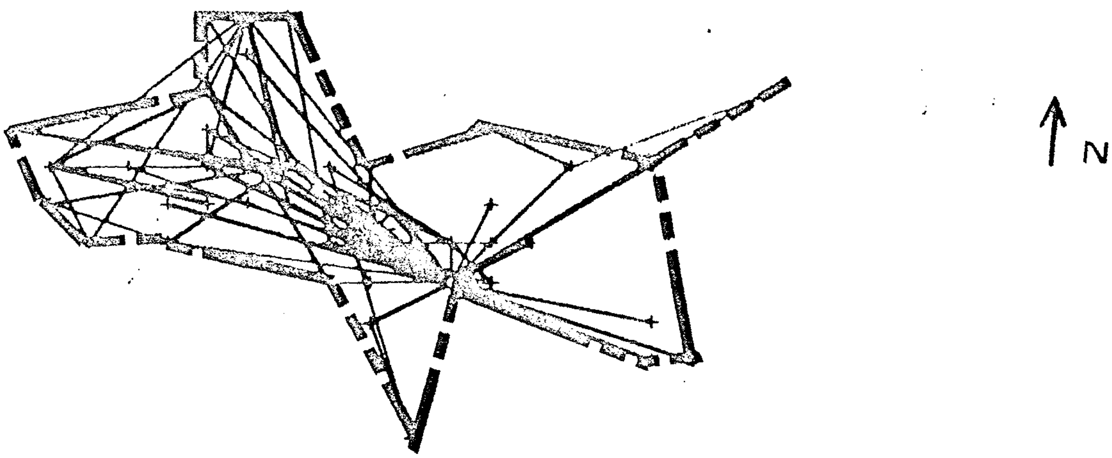

FIGURE 16a. HOME RANGE OF GOPHER #1.

( Harvey and Barbour Method ) (1965)



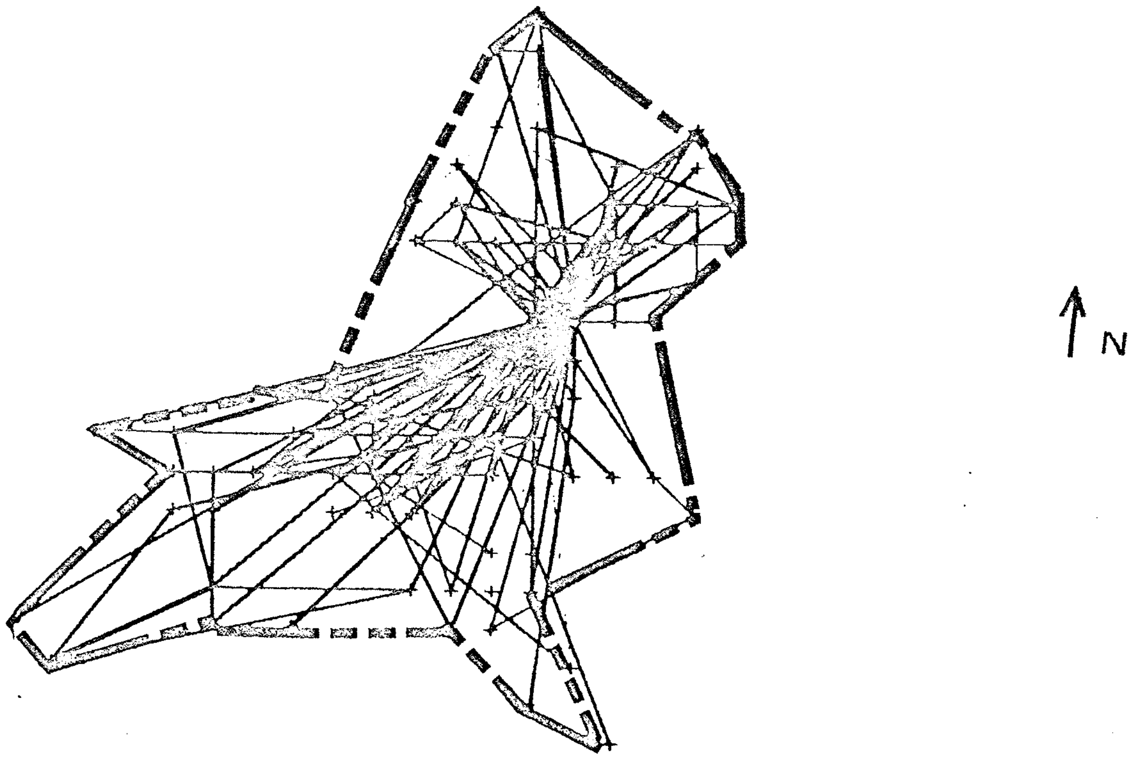

1 inch= 5 meters

FIGURE 16b. Gopher #2



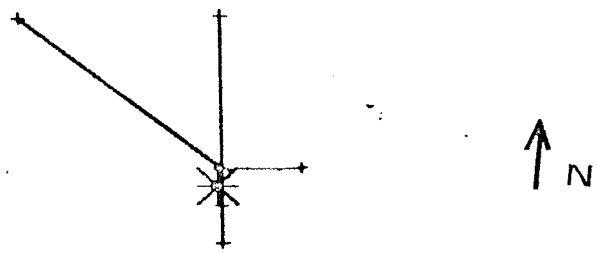

1 inch= 5 meters

FIGURE 16c. Gopher #3



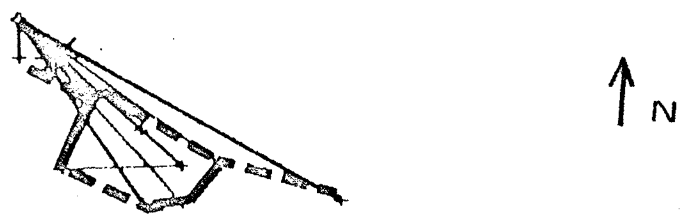

1 inch= 5 meters

FIGURE 16d. Gopher #4



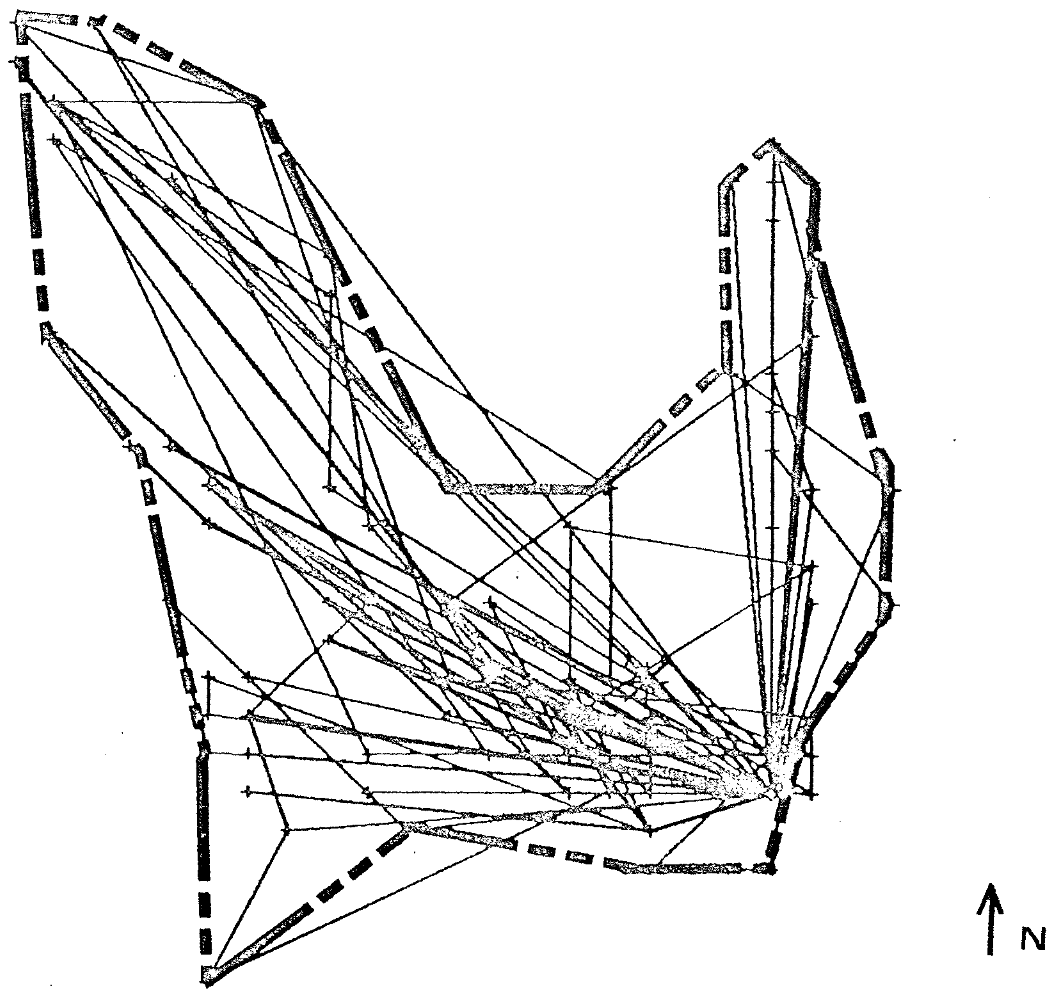

1 inch= 5 meters

FIGURE 16e. Gopher # 5



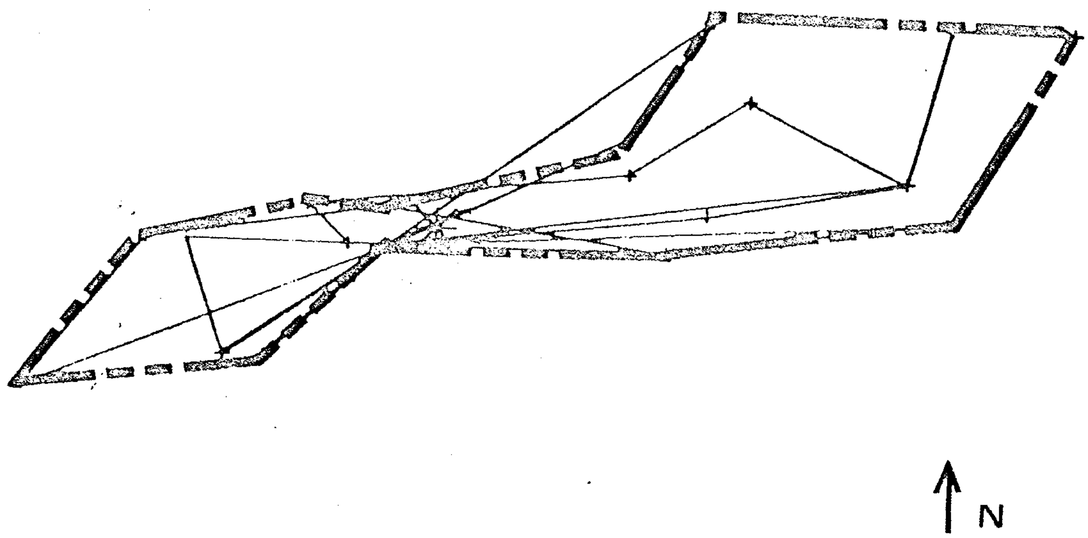

1 inch= 5 meters

FIGURE 16f. Gopher #6



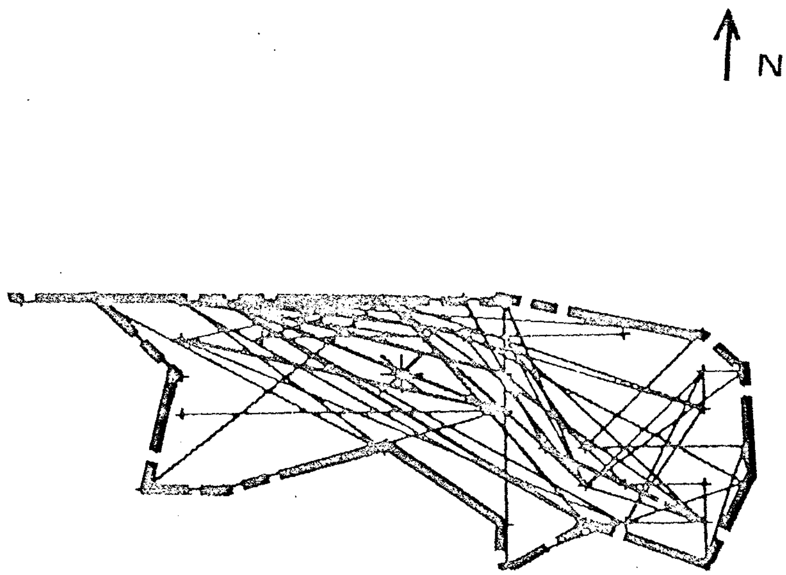

1 inch= 5 meters

FIGURE 16g. Gopher #7




1 inch= 5 meters

FIGURE 16h. Gopher #8




1 inch= 5 meters

FIGURE 16i. Gopher # 9.

Table 8. Linear ratios of home range for nine gophers.

| Animal Number | Sex | Home Range Length (meters) | Width (meters) | Linear Ratio |
|---|---|---|---|---|
| 1 | Female | 40.4 | 23.2 | 1.74:1 |
| 2 | Male | 23.0 | 11.8 | 1.95:1 |
| 3 | Male | 19.6 | 11.6 | 1.69:1 |
| 4 | Female | 21.4 | 15.4 | 1.39:1 |
| 5 | Female | 8.2 | 4.8 | 1.71:1 |
| 6 | Male | 9.6 | 3.8 | 2.58:1 |
| 7 | Female | 29.6 | 25.4 | 1.17:1 |
| 8 | Female | 28.4 | 4.5 | 6.17:1 |
| 9 | Female | 17.2 | 8.2 | 2.1:1 |

Table 9. A comparison of methods measuring home range ($m^2$).

| Animal Number | Harvey and Barbour(1965) (number of locations) | Ellipse Method Gipson and Sealander(1972) | Minimum area (Dalke 1942) |
|---|---|---|---|
| 1 | 440 (344) | 784 | 591 |
| 2 | 60 (164) | 288 | 191 |
| 3 | 83 (286) | 180 | 142 |
| 4 | 144 (632) | 291 | 216 |
| 5 | -- | 27 | 23 |
| 6 | 7 (57) | 22 | 19 |
| 7 | 233 (282) | 577 | 420 |
| 8 | 69 (99) | 146 | 122 |
| 9 | 73 (161) | 101 | 101 |
| | $\bar{x}$ = 138 | $\bar{x}$ = 268 | $\bar{x}$ = 225 |

range of Gopher #9. In this case, the polygon drawn for the minimum area method closely resembled an ellipse.

The minimum area method averaged 63 percent greater than the Harvey and Barbour (1965) method. Gophers' #6 and #2 showed the greatest differences when comparing these two methods; the minimum area method being 2.5 and 3.2 times greater than the Harvey and Barbour method. This may be due to the small home range of Gopher #6 and the method of data collection in the field. As noted above, the Harvey and Barbour method excludes points located greater than 0.25 the home range length from the polygon. With the rapidity of an animal's movement in the field, a point could only be plotted at the end of an animal's run. If the run was longer than 0.25 the home range length, it was excluded from the polygon according to the Harvey and Barbour method. Obviously, a series of these long runs in an animal's movements would create a large discrepancy in the estimates of the two methods. This is exemplified by the monthly home ranges of Gopher #2 (Fig. 16b) in which the series of runs towards the upper left portion of the graph are not included in the Harvey and Barbour (1965) method but are included in the minimum home range method.

To overcome the inadequacies of these two methods in properly representing the longer runs in an animal's home range and to more efficiently utilize data collected by the continuous monitoring method, I have developed a method that may be intermediate in estimating home range. A grid is placed over the lines of movement in an animal's home range and hash marks intercept them. These hash marks are then used in the Harvey and Barbour (1965) method as additional locations which can be used in drawing the polygon. Figure 17 shows the grid and the relationship between the two methods. Points labled 'a' are used as additional locations to draw the polygon in the modified method. Points labeled 'b' are excluded from the polygon as in the Harvey and Barbour method due to their distance being greater than 0.25 the home range length from the nearest point in the polygon. The grid used in this analysis consisted of 1 $m^2$ units.

With the modification of the Harvey and Barbour (1965) method, there is a mean 14 percent increase in the area of the polygon when compared to the original method (Table 10). This increase is a result of an enlargement of the polygon about the central core of points in an animal's home range. A larger area is also enclosed where a distal run leads away from the core area. All locations of the animal are included in the polygon as in the original method.

Monthly home ranges were calculated to see whether there were seasonal differences in home ranges (Table 11).

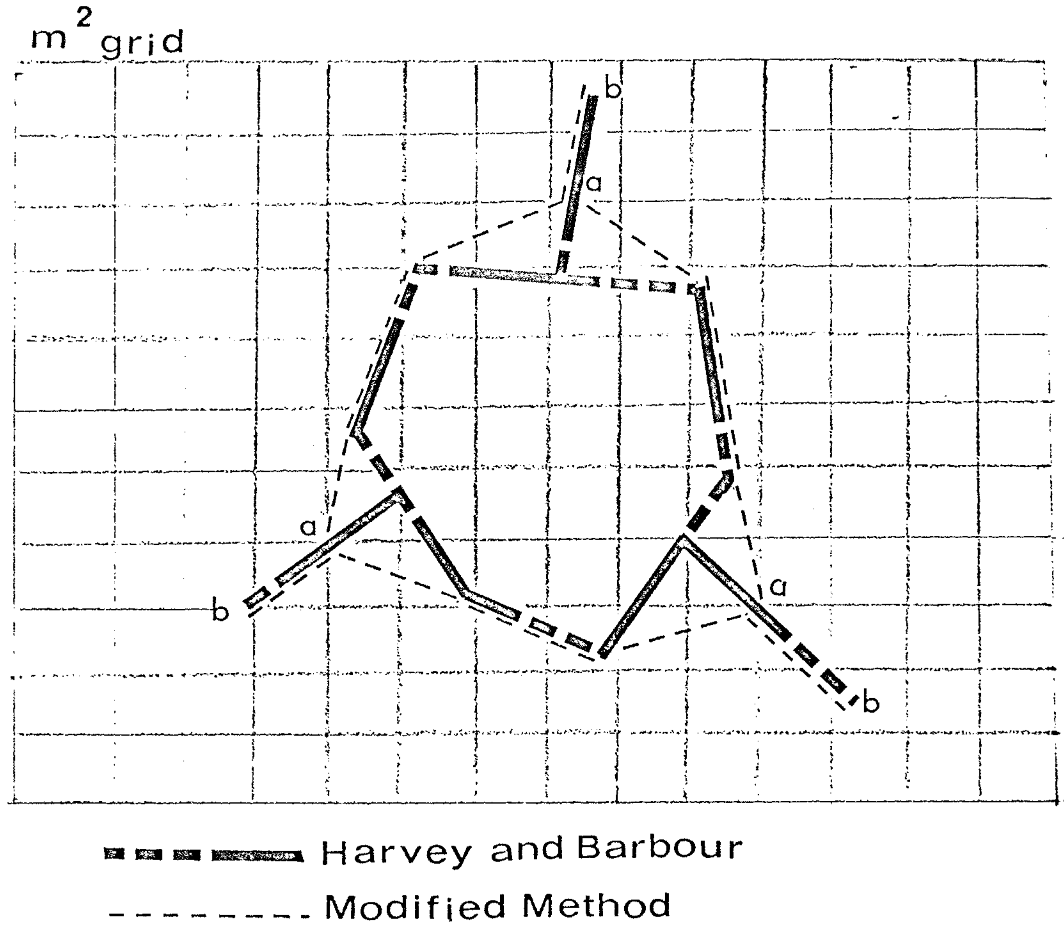



FIGURE 17. A Diagramatic Representation Comparing the Harvey and Barbour Method (1965) and its Modification

Table 10

A Comparison of the Harvey and Barbour (1965) Home Range Method and the Grided Modification

| Animal Number | Harvey and Barbour ($m^2$) | Modified Harvey and Barbour ($m^2$) | Percent Increase |
|---|---|---|---|
| 1 | 440 | 515 | 17 |
| 2 | 60 | 157 | 162 |
| 3 | 83 | 88 | 5.5 |
| 4 | 144 | 168 | 17 |
| 5 | ----[a] | 6 | --- |
| 6 | 8 | 14 | 82 |
| 7 | 233 | 307 | 32 |
| 8 | 69 | 93 | 36 |
| 9 | 73 | 82 | 12.5 |
| | $\bar{x}$= 138 | $\bar{x}$ = 159 | 14.7 increase |

[a]too few data points available to form a polygon by this method.

Table 11

Monthly home ranges for nine gophers

Harvey and Barbour Monthly Home Range[a] (No. of locations)

| Animal | June | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | 272 (196) | 119 (148) | |
| 2 | | | | 87 (51) | 59 (113) | | | | | |
| 3 | | | | | 17 (50) | 56 (201) | --- | | | |
| 4 | | | ---- | 57 | 48 | | | 67 | 65 | --- |
| 5 | | | 27 (29) | | | | | | | |
| 6 | | 22 (57) | | | | | | | | |
| 7 | | | 52 (29) | -- | | | | 169 (163) | -- | |
| 8 | | | | | | | | | | 83 (99) |
| 9 | 73 (161) | | | | | | | | | |
| Monthly Mean | 73 | 22 | 40 | 72 | 41 | 56 | | 169 | 92 | 83 |

[a]expressed in $m^2$

--- insufficient data

In general, animals monitored for less than 10 hours in a given month have insufficient data for calculation. Monthly home ranges ranged from 17 $m^2$ to 272 $m^2$ with an overall mean of 80 $m^2$. Lowest monthly mean home ranges occurred in September (27 $m^2$) and October (40 $m^2$) with the highest occurring in March (169 $m^2$). The high mean in March is due primarily to the large home range of Gopher #1, a female, which had the largest range of any in the study. It is noteworthy that none of the animals tracked in March were males, and therefore the increase in home range during this month could not be due to increased breeding activity of males. An increase in female activity during this month may occur, although too little data are available to substantiate. Perhaps, both sexes increase activity during these months to promote the possibility of an encounter with the opposite sex.

Data were not sufficient to compare differences between sexes in size of home range on a monthly basis but an overall comparison was made (Table 12). Female home ranges (195 $m^2$) averaged more than twice that of males (86 $m^2$) in the study. This is similar to the findings of Artmann (1967) in which female gophers averaged 173 $m^2$ and male gophers only 125 $m^2$.

It appeared that larger animals, regardless of sex, had correspondingly larger home ranges (Gophers #1, 2, and 7).

Table 12

A comparison of home ranges (modified Harvey and Barbour method) comparing two habitat types and male and female gophers.

Habitat Alfalfa

| Males: Animal Number | Males: Body wt. (grams) | Males: Home Range | Females: Animal Number | Females: Body wt. (grams) | Females: Home Range |
|---|---|---|---|---|---|
| 6 | 274 | 14 $m^2$ | 1 | 273 | 515 $m^2$ |
| | | | 4 | 248 | 168 $m^2$ |
| | | | 8 | 259 | 93 $m^2$ |
| | | | 9 | 250 | 82 |

Habitat Old Field

| Males: Animal Number | Males: Body wt. (grams) | Males: Home Range | Females: Animal Number | Females: Body wt. (grams) | Females: Home Range |
|---|---|---|---|---|---|
| 2 | 387 | 157 $m^2$ | 5 | 227 | 6$m^2$ |
| 3 | 257 | 88 $m^2$ | 7 | 301 | 307 $m^2$ |

However, an analysis revealed no significant correlation between body weight and home range ($r=.239$, $p \geq .05$, d.f. $=7$). A correlation between these variables may be a reflection of dominance due to age or the result of more demand being made on their environment. It is noteworthy that Gopher #1 increased in body weight by 25 percent during the months of February and March while Gopher #4, an animal with a home range lying adjacent to gopher #5, gained only 10 percent these months. A repression of growth rate and size of home range may be speculated.

Territoriality

At no time during the study did the home ranges of two animals overlap. Gophers #2 and #3, however, apparently had home ranges that were within 2 m. of each other during December and January. Their nest sites as determined by telemetry data occurred within 5 to 7 m of each other. When both animals were active at the same time, neither animal's movements seemed to be in response to the other and no interaction of any kind could be detected. Gopher #2 disappeared from its tunnel system during early January and it was not relocated. Gopher #3 was active until early March when transmitter failure occurred.

Habitat Selection

Of nine animals monitored at the Yankee Hill Study Area, five home ranges occurred in alfalfa and four in in the adjacent old field. No home ranges extended into an adjacent habitat type. Home ranges occurring in alfalfa averaged 25 percent greater in area than those in the old field (Table 12), the largest home range occurring in alfalfa.

A trap out of the Yankee Hill Study Area was attempted for determining population density but failed to recover all animals. Eight and nine animals, respectively, were trapped or monitored in the alfalfa and a 2-acre portion of the old field over an 11-month period. It is probable that emigration or immigration could have occurred during this time but was not evident from the trapping data.

Aboveground Feeding and Mound Building

The plains pocket gopher (*Geomys bursarius*) is almost entirely fossorial in habit except for periods of mound building when at least a portion of the animal is exposed and during aboveground feeding when the animal feeds from an opening made to the surface (Grinnel 1923). Aboveground feeding and mound building activity was seen 33 times during the study. The constant monitoring system allowed for close observation of all surface activities of an animal. The original design of the study had included a quantification of the aboveground feeding material taken by gophers but too few data were collected to justify a detailed analysis.

Feeding on aboveground plant parts occurred in every month of the study (Sept. to June) and from 1030 to 2310 with a predominance of feeding sessions in the afternoon. Sessions lasted 5 to 90 minutes with the majority being 20 to 50 minutes in length. Few different plant species were taken with dead stems and leaves eaten in winter and succulent green shoots eaten in spring and summer. Table 13 shows feeding sessions with species and portion of plant eaten.

Most plants were taken in the following manner: a gopher encountered a tap root of alfalfa or a fibrous root of grass in a tunnel system and ate belowground parts. A hole, about 2.5 cm in diameter was made around above-ground shoots to pull the entire plant into the tunnel from below. If the plant was too large, a portion was pulled down, eaten or placed in the cheek pouches and cached nearby and the remainder pulled into the tunnel during subsequent trips. If aboveground stems branched (alfalfa), the base of the plant was pulled into the tunnel and individual stems snipped off and cached. The quarter-sized hole was then plugged or the remaining portion of the plant left in the opening.

The above describes the usual method of feeding. Less often a plant was taken when an animal came through a hole made during mound building. By this method a

Table 13

Feeding sessions observed during the study

| Animal | Date | Hour | Species | Number Plant Part |
|---|---|---|---|---|
| 6 | Sept 30 | 1630 | wild lettuce | |
| | | | *Lactuca sp.* | 3 - 12" stems with leaves |
| | | | *Bromus* sp. | 1 - 6" green stem w/leaves |
| | | | Alfalfa | 14 - 6" green stems w/leaves |
| 4 | Oct 27 | 1600 | Alfalfa | 8- 14" stems |
| 7 | Nov 4 | 1600 | *Bromus* sp. | 4 - 3 ft. stems w/ leaves |
| 4 | Nov 4 | 1300 | Alfalfa | 11 - stems |
| 4 | Dec 9 | 1600 | Unidentified | 17 - stems |
| 4 | Dec 16 | 1600 | Alfalfa | 1 - entire plant |
| 2 | Dec 16 | 1500 | Unidentified | 2 - stems |
| 4 | Dec 18 | 1130 | Alfalfa | 1 - stem |
| 2 | Jan 21 | 1330 | Alfalfa | 1 - entire plant |
| 2 | Jan 25 | 0900 | Unidentified | 3 leaves |
| | | 1000 | Unidentified | 1 - 2 ft. plant |
| | | | | 6 - 6" plants |
| 7 | Mar 7 | 1340 | Alfalfa | roots at surface |
| 7 | Mar 8 | 1300 | Unidentified | entire plant |
| 7 | Mar 10 | 1615 | *Bromus* sp. | stems with leaves |
| 7 | Mar 22 | 1230 | *Bromus* sp. | stems with leaves |
| 7 | Mar 22 | 1630 | *Bromus* sp. | Stems |
| 4 | Mar 31 | 1745 | *Bromus* sp. | 6" leaf |
| 4 | Apr 7 | 1030 | *Bromus* sp. | green shoot |
| | | 1130 | Alfalfa | 6" green shoot |
| 7 | Apr. 7 | 1730 | *Bromus* sp. | 6" shoot |
| 7 | Apr. 12 | 1515 | *Bromus* sp. | 6" leaves |
| 1 | Apr 23 | 1630 | Shephers purse | 10" shoot |
| | | | *Capsella bursa-pastorior* (L) Medic | |
| 4 | Apr 25 | 1430 | Alfalfa | 3 - 10" stems |
| 9 | June 6 | 1805 | Alfalfa | 2 ft. plant |
| 9 | June 7 | 2310 | dandelion | 18" plant |
| | | | *Taraxacum offinale* Weber | |
| 9 | June 9 | 1240 | dandelion | entire plant |

hole was opened to the surface large enough for a gopher to exit and foraging occurred before the hole was plugged at the conclusion of mound building. Only once was an animal seen to completely expose itself on the soil surface. Usually an animal remained with its hindquarters in the tunnel while feeding on nearby vegetation. This method of feeding was observed four times during the study (Sept., Dec., and March) by two different animals. Roots and stems of alfalfa were taken in December, wild lettuce (*Lactuca sp.*) stems in September and both alfalfa roots and an unidentified grass stem in March.

Mound building and plug formation was observed seven times during the study without associated feeding activity. My presence in the study area appeared to have little effect upon mound building behavior, although certain gophers appeared more cautious in their aboveground activity than others. One animal was seen to retreat to noise from wing-beats of birds flying overhead and another to the shrill whistle of a thirteen-lined ground squirrel, (*Spermophilus tridecimlineatus*) which were numerous in the study area.

In both plug and mound building, the duration of time a hole was left open to the surface was less than 1 hour and often a few minutes. In one instance, an animal opened a hole to the surface, built a mound making 20 trips bringing soil to the surface, and plugged the remaining hole, all within 8 minutes. Indeed, speed of movement through a tunnel system is rapid with one animal moving over 30 m within 1 minute.

Conclusion

In this study a telemetry system was adapted for measuring the home range and activity patterns of pocket gophers and other fossorial animals. This system allowed the observer to monitor the subject from very near or directly above its location and eliminated the need for a triangulation to 'fix' a location. Behavioral changes in the animal were not observed using this method.

Advancements in technology allowed for longer battery life of transmitters used in this study as compared to previous studies. Attachment of the transmitter package to the animal was found more effective in reducing behavioral changes as a subdermal implant than as an insertion into the cheek pouch. Proportionately larger packages with longer life expectancies could be implanted.

A modification of the Harvey and Barbour method for calculating home range was intermediate in value between that method and the minimum home range method. The modification allowed for a weighting of distal runs radiating from the core area of the animal without including large areas between them.

The increase in mean hourly distances traveled and number of active periods throughout the day and the sharp decrease at dusk suggests a circadian rhythm. The continued low activity during late evening and nighttime hours suggests a diurnal pattern.

The smaller home ranges found for males may be due to a small sample size or may reflect the increased activity of females. The larger home ranges of female gophers may allow for a greater probability of the sexes meeting during the mating season.

The number of times that aboveground feeding and mound building activity was observed without observer influence shows the telemetry method to be an effective means to obtain information on feeding and mound building behavior. Further study, using telemetry and trapping methods are needed.

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# LITERATURE CITED

Adams,G.D. 1966. Populations and spatial distribution of pocket gophers *Geomys b. bursarius*. Ph.D. Thesis. Univ. of Minn. 136 pp.

Artmann, J. W. 1967. Telemetric study of the pocket gopher *Geomys bursarius*. M.S. Thesis. Univ. of Minn. 80 pp.

Baker, R. J., and S. L. Williams 1972. A live trap for pocket gophers. J. Mammal. 36(4):1320-1322.

Burt, W. H. 1940. Territorial behavior and populations of some small mammals in southern Michigan. Univ. of Mich. Mus. Zool. Misc. Publ. 45, 58 pp.

Burt, W. H. 1943. Territoriality and home range concepts as applied to mammals. J. Mammal. 24(3):346-352.

Dalke, P. D. 1942. The cottontail rabbits in Connecticut. State Geol. Nat. Hist. Surv. Bull. 65, 97 pp.

Gipson, P. S., and J. H. Sealander 1972. Home range and activity of the coyote(*Canis latrans frustror*) in Arkansas. Proc. 26th Annu. Conf. Southeast Assoc. Game and Fish Comm.

Grinnel, J. 1923. The burrowing rodents of California as agents in soil formation. J. Mammal. 4(3):137-149.

Hansen, R. M. 1962. Movements and survival of *Thomomys talpoides* in mima mound habitat. Ecology 43(1):151-154.

Hansen, R. M., and E. E. Remmenga 1961. Nearest-neighbor concept applied to pocket gopher populations. Ecology 42(4):812-814.

Hall, E. R., and K. R. Kelson 1959. The mammals of North America. New York: Ronald Press Co. Vol. I 625 pp.

Harvey, M. J., and R. W. Barbour 1965. Home ranges of *Microtus ochrogaster* as determined by a modified minimum area method. J. Mammal. 46(3):398-402.

Haugen, A. D. 1942. Home range of the cottontail rabbit. Ecology 23(3):354-367.

Hisaw, F. L. 1924. The absorption of the pubic symphysis of the pocket gopher, Geomys bursarius (Shaw) Am. Nat. 58(1):93-96.

Howard, W. E., and H. E. Childs 1959. Ecology of pocket pophers with emphasis on Thomomys bottae mewa. Hilgardia 29(7):277-358.

Ingles, L. 1949. Methods of estimating pocket gopher populations. J. Wildl. Manage. 13:311-312.

Kennerly, T. E. Jr. 1958. Comparisons of morphology and life history of two species of pocket gophers. Tex. J. Sci. 10:133-146.

Mohr, C. O. 1947. Table of equivalent populations of North American small mammals. Am. Midl. Nat. 37:223-249.

Moore, A. W., and E. H. Reid 1951. The Dalles pocket gopher and its influence on forage production of Oregon mt. meadows. U. S. Dep. Agric. Circ. 884 36 pp.

Sargent, A. B. 1966. A live trap for pocket gophers. J. Mammal. 74(4):729-731.

Scheffer, T. H. 1940. Excavation of a runway of the pocket gopher, Geomys bursarius. Trans. Kans. Acad. Sci. 43(4):473-478.

Sherman, H. B. 1941. A box trap for the capture of live Geomys. J. Mammal. 22(2):182-184.

Tietjen, H. P., C. H. Halvorson, P. L. Hegdal, and H. M. Johnson 1967. 2,4-D Herbicide, vegetation, and pocket gopher relationships, Black Mesa, Colo. Ecology 48(4):634-643.

Vaughan, T. A. 1962. Reproduction in the plains pocket gopher in Colorado. J. Mammal. 43(1):1-13.

Vaughan, T. A. 1963. Movements made by two species of pocket gophers. Am. Midl. Nat. 69(2):367-372.

Vaughan, T. A., and R. M. Hansen 1961. Activity rhythm of the plains pocket gopher. J. Mammal.42(4):541-543.

Vaughan, T. A., and R. M. Hansen 1964. Experiments on interspecific competition between two species of pocket gophers. Am. Midl. Nat. 72(1):444-452.

Wilks, B. J. 1963. Some aspects of the ecology and population dynamics of the pocket gopher (G. bursarius) in southern Texas. Tex. J. Sci. 15(3):241-284.