Behavioral Interaction between the Fox Squirrel *(Sciurus niger)* and the Pine Squirrel *(Tamiasciurus hudsonicus)* near Boulder, Colorado

Julie Ann Carlson

Interaction and Behavior Between the Fox Squirrel *(Sciurus niger)* and the Pine Squirrel *(Tamiasciurus hudsonicus)*. A Proposal

by Julie Ann Carlson

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June 10, 1992

Interaction and Behavior Between the Fox Squirrel *(Sciurus niger)* and the Pine Squirrel *(Tamiasciurus hudsonicus)*: A Proposal

by Julie Ann Carlson

I am currently a junior at The Colorado College working toward my bachelor's degree in the field of biology. In addition to the courses and oral examination required by the biology major, I have opted to produce a senior thesis in order to graduate with distinction in biology. I have decided to do this particular senior thesis project for several reasons: 1) to explore the interrelationships of the Fox squirrel and the Pine squirrel whose interactive behavior has not been previously recorded, 2) to observe and document whether or not these two aggressive mammalian species do interact, 3) to become familiar with the execution and organization of my own scientific goals, and 4) to further my experience with field work.

Background Information

Animal behavioralists are often interested in the actions of two different species as they come into contact with one another. This is true whether it is contact concerning territorial disputes, competition over existing food and water supplies, or protection of young. It is especially true if the species fill similar niches, as in the case of the Fox squirrel and the Pine squirrel.

There are currently three main species of tree squirrel in the state of Colorado: the Abert's squirrel *(Sciurus aberti)*, found in ponderosa pine *(Pinus ponderosa)* forests; the Fox squirrel *(Sciurus niger)*, found primarily in deciduous/urban environments; and the Pine squirrel *(Tamiasciurus hudsonicus)*, which is found in spruce/fir forests. All three of these species come into contact with each other where their particular ecosystems overlap. However, it has been found that the habitats of the Pine squirrel and the Fox squirrel do not significantly overlap in the state of Colorado. This is due to the Pine squirrel occuring at higher elevations where the spruce/fir ecosystem flourishes, and the Fox squirrel inhabiting much lower elevations where deciduous trees are found, primarily in urban environments. Studies have been done on Fox squirrel and Abert squirrel interrelationships (Littlefield, 1984; R. Farentinos, personal communication), and on Pine squirrel and Abert squirrel interrelationships (Ferner, 1974). According to the literature, no studies have been done on Fox squirrel and Pine squirrel interrelationships.

Recently, a few places have been located where these two animals can be found in close proximity (within 1/4 mi.) of one another. A couple of those places are near the city of Boulder, Colorado. (D. Armstrong, personal communication; M. Snyder, personal communication; personal observation).

One can be found southwest of the National Center for Atmospheric Research, along Bear Creek and south of Bear Creek Canyon on Boulder County's Open Space Land. My proposed project involves a study of the Pine and Fox squirrels found in this area (please see maps, pp. 6-7).

Description of Study

The project consists of several parts; a) preliminary literature research, b)live-trapping and marking of both species of squirrel, c) radio tracking and observing of selected animals, d) re-trapping of same individuals (to remove collars), and e) scientific write-up to submit as my senior thesis.

The preliminary research will be an extensive investigation of the current literature on the behaviors of the Fox squirrel and the Pine squirrel. This includes intraspecific feeding, mating, territorial disputes, and seasonal changes in each species of squirrel. This preliminary research will take place in the spring of 1992. (It has already taken place.)

The live-trapping and marking of the squirrels will involve the area mentioned above. Four squirrels, two of each species, will be radio collared. Any animals caught will be marked with a distinctive mark using Lady Clairol hair dye. The live-trapping and marking will occur during the month of July, 1992.

The animals who have been collared will be located with radio telemetry and then observed. Lone behavior will be recorded and any interactions with other squirrels will be documented as well. This will occur during the months of August and September. The same animals will be re-trapped after the study in order to remove the collars, and will then be released.

The information gathered during this project will be processed and analyzed by the student under the supervision of two thesis advisors. These are Drs. Alexandra Vargo and James Enderson, both of the Department of Biology at The Colorado College. This will include examination and organization of field notes, slides, and any other pertinent information. The finished paper will be submitted to the Biology Department at The Colorado College, the Tutt Library, the County of Boulder, and the Colorado State Division of Wildlife to report any significant findings, as well as any recommendations for further study.

This proposed project is a preliminary, exploratory study. It has a small sample size due to the time, manpower, and funds available for the study. It has been designed under the direction of Drs. Vargo and Enderson, with an undergraduate thesis style in mind. The project is funded in part by a grant from the Venture Funds at the Colorado College.

Purpose of Study

Previous studies have shown that both the Fox squirrel and the Pine squirrel are aggressive animals (MacClintock, 1970). Both have been shown to act dominant over the Abert's squirrel, but how they react toward each other is not well known.

From the beginning of the twentieth century, the Fox squirrel's range has expanded westward from Kansas into Colorado (Littlefield, 1984). As humans planted deciduous trees farther and farther west, the Fox squirrels easily followed. As explained earlier, Fox squirrels are now found in many parts of the state, where there are urban environments and deciduous trees. Because they are aggressive squirrels -- especially toward intruders -- and because the Fox squirrel is a relative newcomer to the state, the interactions between the Fox squirrel and the Pine squirrel will provide valuable insight into the relationships between dominant mammalian species that have not had time to evolve a specific interaction.

Methodology

Procedures and Methods: Both species will be located by sight at the location mentioned above, and then live-trapped using Tomahawk live traps (16 x16 x 48 cm) (Boutin & Schweiger, 1988; Sullivan, 1990) with chunky peanut butter and sunflower seeds as bait. Eight traps will be used to successfully trap a total of up to ten squirrels, four of which (two from each species) will be radio collared. The animals not radio collared will be marked, measured, sexed, and weighed for reference.

Once the squirrels are trapped, the trap will be approached from behind and then a black shroud will be placed over the trap to ease the aggitated animal. A "sleeve" or cone made of heavy duty canvas and velcro will be placed over the end of the trap. The sleeve is long enough to encompass all of the animal and at the other end has a small opening for the nose of the squirrel to poke through. The sleeve is split from one end to the other and held together with strong velcro for easier access to the animal. The animal will move into it as the shroud is removed from the rest of the trap. Once the squirrel is all the way inside the sleeve, it will be secured using additional velcro straps.

At this time, the animal will be administered an inhalant anesthetic (Metofane brand methoxyflourane) (Dr. Robert Strand, personal communication; Dr. Ann Wagner, personal communication; Farentinos, personal communication; Littlefield, 1984). A plastic bag containing a cotton ball and two to three mls of the anesthetic will be held over the nose of the restrained animal until the heart has slowed down slightly and there is no longer tension in the hind legs (R. Farentinos, personal communication, P. Dussault, personal communication, and Littlefield, 1984). The animal's weight, body length, tail length, and sex will all be determined at this time

using a metric tape measure and a Chatillon Tubular Instrument & Laboratory Scale.

The animals will be marked along their shoulders and back using a common over the counter hair dye, Lady Clairol Ultra Blue, and water. Each individual will have a different marking. While still anesthetized, four of the animals will also be fitted with a radio collar (Wildlife Materials, Inc., Carbondale, Illinois). For the Fox squirrels, a battery-powered transmitter (#SOM-2380-MVS multivibrator 1.5 volt 2-stage) will be fitted, and for the Pine squirrels, a smaller battery-powered transmitter (#SOM-2070-MVS multivibrator subminiature 1.5 volt 2-stage) will be fitted as well.

The captured squirrels will then be released back into the wild (with especially close observations during the next day to make sure there are no lasting ill effects from the anesthesia).

During the next two months, the animals will be located using the radio collars, a hand-held antennae, and a receiver. Once located, the squirrel's behavior will be observed using binoculars (Minolta 10x), a camera (Nikon Fe 35mm) and the student's eyes, and it will be recorded until dark and/or the time when the squirrel is no longer active. These observation times will allow the observer to locate the ranges of the squirrels, and determine if any interactions are occurring or could occur -- at least among those specific squirrels at the site chosen.

At the end of the study, the animals will be located with radio telemetry and/ or by their markings and will be re-trapped to remove the collars. The squirrels will be weighed and measured again, and then released.

Time Table: July 1992 . . . . . live-trapping and marking
August . . . . . observations
September . . . . . observations
October -- ? . . . . . re-trapping and collar removal
November -- March 1993 . . . . . writing thesis
April . . . . . submit thesis to institutions and agencies

Collecting: All collecting to be done is described above.

Anticipated Impacts: Very little impact is anticipated. Great pains will be taken to ensure the safety and health of the animals involved. The number of animals that are to be disturbed in any way is small (less than ten), and the anesthetic to be used is considered safe by many experts. No animals will be killed and/or transplanted to another site. All squirrels will be re-trapped to remove the collars, and then released. I do not anticipate any significant impacts on the squirrels I will be dealing with, nor on the habitats I will be in.

Presentation of Results

The results of my project will be in scientific format and will be presented as an undergraduate thesis to the institutions and agencies mentioned above. I also plan to present any findings to The Colorado College community in Colorado Springs, Colorado, at Biology Day Seminar in the Spring of 1993.

Literature Cited

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MacClintock, Dorcas, Squirrels of North America, Van Nostrand Reinhold Company, New York, 1970

Sullivan, Thomas P., Responses of Red Squirrel Populations to Supplemental Food, Journal of Mammalogy v. 71 n. 4, 1990

Personal Communication

Armstrong, David, Curator of the Museum, University of Colorado, Boulder, March 1992

Dussault, Peg, graduate student (Fox squirrels), University of Colorado, Boulder, June 1992

Farentinos, Robert C., PhD (Abert squirrels), Environmental Communication Associates, inc., Boulder, Colorado, June 1992

Snyder, Mark, post-doctorate student (Abert squirrels), University of Colorado, Boulder, April 1992

Strand, Robert D., D.V.M., M.S., Alpine Hospital for Animals, Boulder, Colorado, June 1992

Wagner, Ann, Dr. of Anesthesiology, Veterinary Teaching Hospital, Colorado State University, Fort Collins, Colorado, May, 1992

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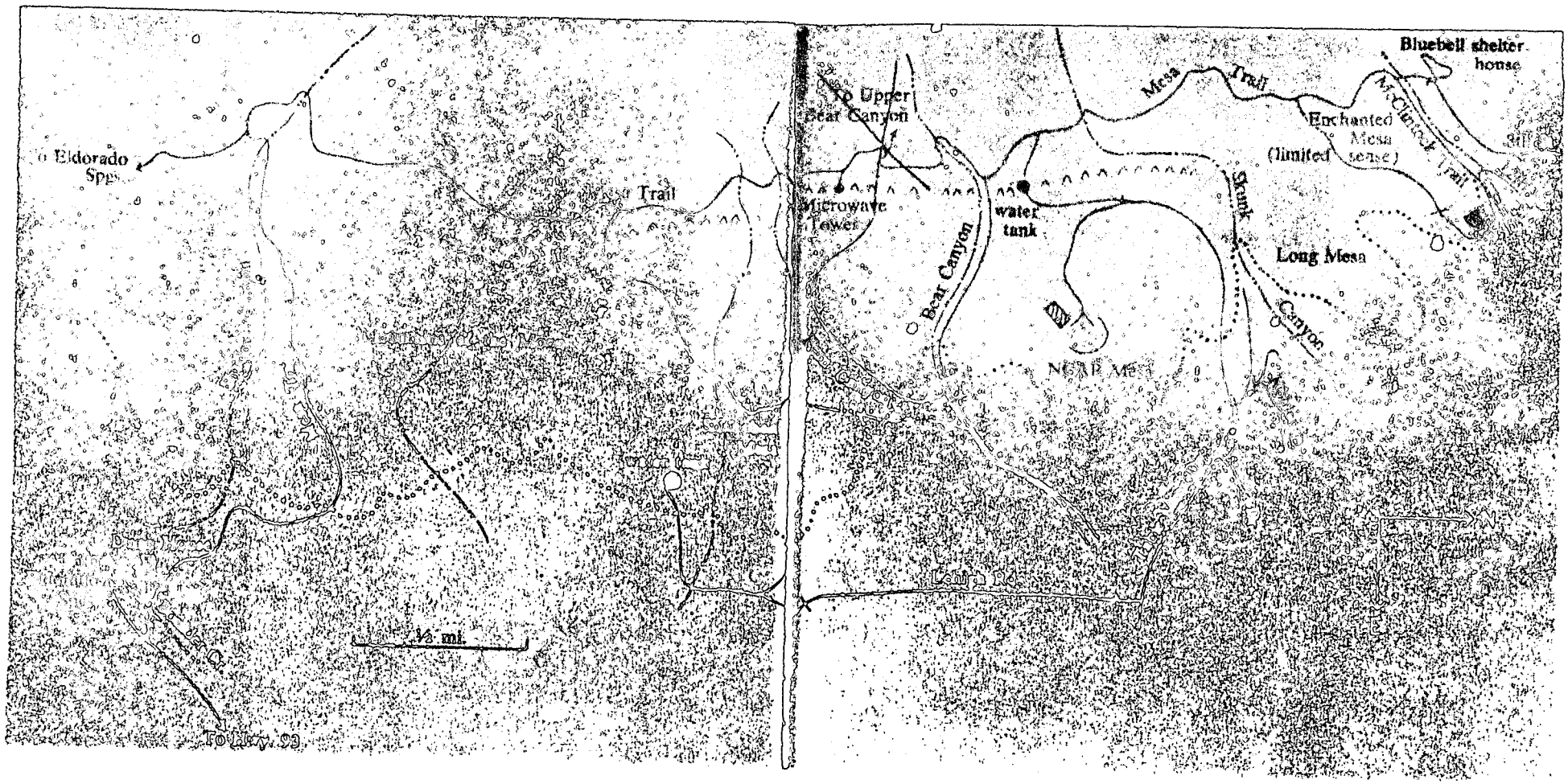


X chosen study site

LEGEND

- 5800 ft. contour
- streams (mostly intermittent)
- Dakota hogback
- major roads and trails
- Barrier to motor vehicles (locations frequently changed)

The so-called Mesa Trail lies, for most of its length, just west of the mesa country, often in a valley west of the Dakota hogback. From the trail, and from such access areas or points as the City reservoir (that lies on the southerly continuation of 12th Street), the west end of Kohler Drive, the Bear Canyon Road, the south end of Lehigh Road, and the parking area near Dunn House, which is a mile east of Eldorado Springs, there originates a maze of small trails and abandoned wagon and motor vehicle tracks that cover the mesas. Most of these are not shown on this map. Except for parts of the steep ridge of the Dakota hogback, which marks the west edge of most of the mesa country, the Enchanted Mesa is easily passable with or without trails.

Often the 5800 foot contour lies near the foot of the mesa, the 6000 foot line near the eastern edge of the mesa top.

Lanham, Url, The Enchanted Mesa 1974

This aerial photo, taken in 1971, was furnished by the U. S. Geological Survey

X chosen study site

1. Dunn House
2. Shadow canyon
3. Hillside pond
4. Clearing for transmission line
5. City water tank
6. Pollywog pond
7. Abbey pond
8. Salamander pond
9. Shanahan pond
10. Fern canyon
11. Microwave tower
12. Bear canyon
13. NCAR
14. NCAR water tank
15. Skunk canyon
16. Electric power substation
17. City reservoir
18. Bluebell picnic area
19. The Slab (a "Flatiron", Fountain formation)

Lanham, Url, The Enchanted Mesa, 1974

The Colorado College

Victor Nelson-Cisneros
Asst. Dean of the College
Chair of the Venture Grant Committee
The Colorado College
Colo. Sprgs., Co 80903

February 25, 1992

Dear Dean Nelson-Cisneros:

This letter is a recommendation for Julie Carlson. She is applying for a Venture Grant to support her summer research on interactions between the Fox Squirrel and the Red Squirrel. This research will be the basis for her Senior Thesis in Biology. I have known Julie since November 1990, when she took my Field Zoology Course (By 203). Since then I have become her adviser and will also be one of her committee members for this thesis.

I enthusiastically recommend her well-organized and thoughtful proposal for this research. She and I know that her proposed budget is well over the possible $ 850 grant she can obtain, but she has been planning to do a thesis for over a year and has saved approximately $ 1000 for this summer.

Julie is more mature and more organized than the average Colorado College student. This statement is true both socially and academically. She is a very intelligent, dedicated and capable young biologist and woman. In the far future she plans to become a biology teacher and attend graduate school. Her performance in Field Zoology strongly suggests that this research will be very professional and excellent, making her a better student, biologist and researcher.

Sincerely,

Alexandra Vargo

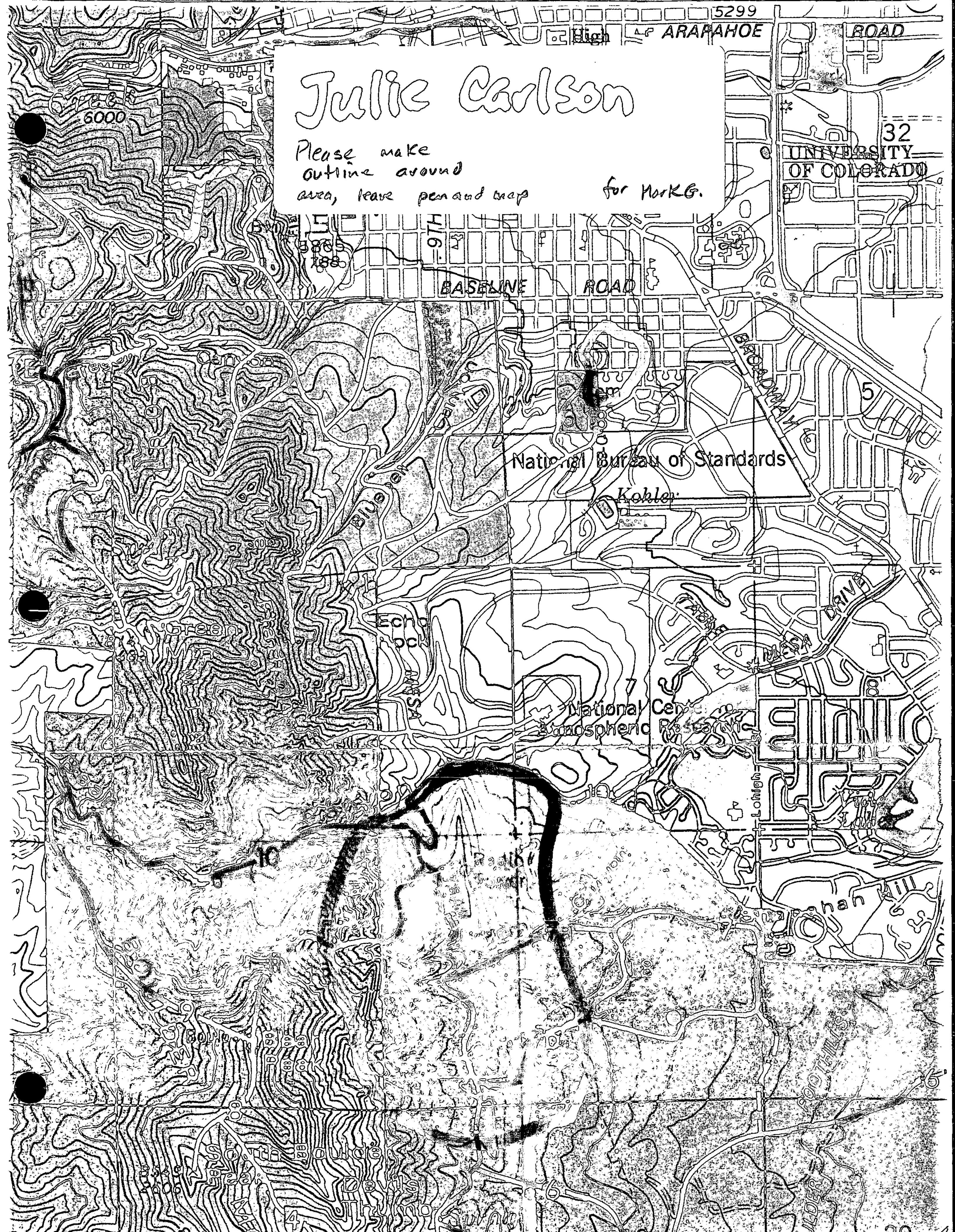
Alexandra Vargo
Assoc. Prof. in Biology
The Colorado College

719-389-6000

14 East Cache La Poudre, Colorado Springs, Colorado 80903-3298 • 719-389-6000

Julie Carlson

Please make outline around area, leave pen and map for MarkG.



City
of
Boulder

Open Space/Real Estate Department
Post Office Box 791 Boulder, CO 80306
(303) 441-3440

July 8, 1992

Julie Ann Carlson
3050 East Euclid Ave
Boulder, CO 80303

Dear Julie:

Your proposal to study the interaction and behavior between the fox squirel and the pine squirrel has been reviewed by this office. Based upon the information provided in your proposal, the Open Space Department approves of the project. This authorization is valid for a period of one year.

Although your project is authorized by the Open Space Department, this does not eliminate the requirement that you obey applicable Federal, State and local regulations. Find enclosed a sheet listing some of the regulations enforced by the Open Space Department. Please note that deviations from the original proposal could require a further review.

Should at any time during the study it become evident that there is a significant safety hazard or natural resource concern, the Open Space Department must be notified immediately.

Good luck with your study. I look foward to reading your report.

Sincerely,

Mark Gershman
Wetlands/Wildlife Coordinator

cc: Operations Supervisor
Volunteer Coordinator
Kathi Green, Colorado Division of Wildlife

City
of
Boulder

Open Space/Real Estate Department
Post Office Box 791 Boulder, CO 80306
(303) 441-3440

July 8, 1992

Julie Ann Carlson
3050 East Euclid
Boulder, CO 803

18 MAY, 1993
Left message @ Julies house
spoke w/ Alexandra Varga

Dear Julie:

Your propc x squirel and the
pine squirrel has b provided in your
proposal, the Ope orization is valid
for a period of on

Although y nt, this does not
eliminate the requ ocal regulations.
Find enclosed a he Open Space
Department. Plea require a further
review.

Should at e is a significant
safety hazard or n must be notified
immediately.

Good luck

Sincerely,

Mark Gershman
Wetlands/Wildlife

cc: Operations Supervisor
Volunteer Coordinator
Kathi Green, Colorado Division of Wildlife

611 N. Cascade #9
Colo. Springs, CO 80903
May 25, 1993

Mark Gershman
Wetlands-Wildlife Coordinator
Open Space/ City of Boulder
P.O.Box 791
Boulder, Colorado 80306

Dear Mr. Gershman.

I apologize for not writing to you sooner, but with graduation from Colorado College and the task of finishing my thesis, I have been pretty busy. Enclosed is the copy of my thesis entitled, "Behavioral Interaction between the Fox squirrel (Sciurus niger) and the Pine squirrel (Tamiasciurus hudsonicus), near Boulder, Colorado," that you have been asking for. I want to thank you for all your help and if you need any more information from me, I will be moving to Boulder on the first of June and can be reached at 2895 E. College # 33, 80303 at that time. Again, thank you.

Sincerely,

Julie Ann Carlson

Julie Ann Carlson

Enclosure

Behavioral Interaction between the Fox Squirrel (*Sciurus niger*) and the Pine Squirrel (*Tamiasciurus hudsonicus*) near Boulder, Colorado

A Senior Thesis

submitted to the

Department of Biology

The Colorado College

by

Julie Ann Carlson

April 19, 1993

Approved by:

Alexander Vargo

James H. Enderson

Behavioral Interaction between the Fox Squirrel (*Sciurus niger*) and the Pine Squirrel (*Tamiasciurus hudsonicus*) near Boulder, Colorado

A Senior Thesis

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April 19, 1993

Approved by:

_____

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Abstract

Abert's squirrels (Sciurus aberti), fox squirrels (Sciurus niger) and pine squirrels (Tamiasciurus hudsonicus) are the three species of tree squirrel that inhabit Colorado. Previous studies indicate that the distribution of the introduced fox squirrel and the indigenous pine squirrel do not significantly overlap in Colorado. The purpose of present research was to locate an area where these two species coexist, and to observe the resulting interactive behavior. Individuals of both species were located near Boulder, Colorado. Squirrels were watched from mid-May to the first of October, 1992. Individuals were trapped, radio-collared, and tracked using radio telemetry. Sightings of each squirrel were marked on a map of the study area. Observations were made to determine foodstuffs were consumed, daily behaviors, animal species each squirrel encountered, and resulting behaviors. Study results indicate that the smaller pine squirrel defends its territory from the larger fox squirrel.

Introduction

In Colorado the Abert's squirrel (Sciurus aberti) is found primarily in Ponderosa pine (Pinus ponderosa) forests, the fox squirrel (Sciurus niger) is found in riparian/deciduous urban environments, and the pine squirrel (Tamiasciurus hudsonicus) is found in spruce-fir (Picea engelmannii and Abies lasiocarpa) forests of the Rocky Mountains (Chapman and Feldhamer 1982). All three species are members of the order Rodentia and family Sciuridae and

come in contact where their habitats overlap. However, the pine squirrel and the fox squirrel do not yet significantly overlap in Colorado (Fig.1). The pine squirrel is generally found at higher elevations where the spruce-fir community flourishes, while the fox squirrel usually inhabits much lower riparian and deciduous tree habitats, primarily in urban environments.

Fox squirrels are larger than most tree squirrels found in the United States and possess larger, fuller tails. The pelage of the fox squirrel is more varied than any other North American squirrel (Cahalane 1947). In Colorado, the pelage is buffy gray, sprinkled with black hairs and brownish orange to tawny underparts, but some individuals are nearly black. The tail is mixed black, gray, and tawny rufous. Adult fox squirrels grow to a length of 71cm (including tail), and weigh up to 1200g (Chapman and Feldhamer 1982, Cahalane 1947). Fox squirrels once ranged over the eastern half of the United States but slowly have moved west. Currently, their range extends into Michigan, North Dakota, eastern Colorado and Texas (MacClintok 1970) (Fig.2).

Since 1900, the fox squirrel's range has expanded westward from Kansas into Colorado (Littlefield 1984, MacClintok 1970). Large numbers of fox squirrels first appeared in Colorado along the South Platte River valley in the 1930s (Warren 1942); later their range extended range to the foothills. Earlier, four deliberate introductions of the fox squirrel were made in Colorado: in Greeley and Denver before 1908, near Sterling in 1921, and in Fort Collins

before 1927 (Lechleitner 1969). Potential fox squirrel and pine squirrel contact is growing.

The pine squirrel is the smallest diurnal tree squirrel in North America. It averages 31cm in length and 225g in weight (Burt and Grossenheider 1980). The winter coat is rusty-brown to dark brown; the summer coat is more olive colored, and the belly is white (Parker 1990). The pine squirrel occupies boreal forest (Chapman and Feldhamer 1982), and unlike the fox squirrel, it is indigenous to Colorado (Fig.3).

Interrelationships between fox squirrels and Abert's squirrels as well as interrelationships between pine squirrels and Abert's squirrels have been researched (Littlefield 1984, R. C. Farentinos, personal communication 1992) (Ferner 1974). However, no research has been published on interrelationships between fox squirrels and pine squirrels.

This study was conducted from May 18 to October 8, 1992 and focused on competition, territoriality, and aggression where the two species coexist near Boulder, Colorado. In this study, I attempted to locate an "ideal" field site where fox squirrels and pine squirrels come together. After locating a suitable site, the two species were observed, trapped, radio-collared, and tracked using radio telemetry.

Study Area

The study area of approximately 36ha exists in part of the Boulder Mountain Parks and the City of Boulder Open Space areas. It is located 0.75km southwest of the National Center for Atmospheric

Research (NCAR) just southwest of Boulder, Colorado (Fig. 4). Elevation of the area is 1830m and slopes steeply upward to the west. It is bordered on the east by an outcrop of the Dakota formation at 1950m in elevation. Bear Creek bisects the study area, as does a radio tower service road. The area is also transected by well-used hiking trails.

Materials and Methods

Observations were taken on 59 days between mid-May and early October. I recorded my observations on microcassette tapes which were then transcribed onto computer disks. Approximately 25hrs/week of squirrel activity were recorded. Recordings included weather conditions, arrival and departure times, number of hours spent observing, numbers of traps set and numbers of trap hours accumulated, numbers of free-ranging and live-trapped squirrels encountered, squirrel behaviors, and locations within the study site. Lone behavior was recorded as well as any interactions with other squirrels.

Information was collected with the aid of Minolta (10x) binoculars and a Nikon 35mm camera. Eight 16 x 16 x 48cm Tomahawk live-traps (Tomahawk Live Trap Company, Tomahawk, Wisconsin), and four battery powered radio transmitter collars (2 model #SOM-2380-MVS and 2 model #SOM-2070-MVS, Wildlife Materials, Inc., Carbondale, Illinois) were used for trapping and telemetry data collection.

Visual Observations. - In May and June I located a suitable study site where both Douglas fir and riparian ecosystems converge and both species could be found. The area west of Boulder, Colorado is one of the locations in Colorado where these ecosystems regularly meet. After 3-4 weeks of searching a 12.8km stretch of the foothills west of Boulder, two potential areas were found: one northwest of Boulder near Chautauqua Park (Gregory Canyon); the other just southwest of Boulder near NCAR. In both areas, both species were observed. However, at the NCAR site, more individuals of each were found and were easier to follow than at the other site. Therefore, research was focused on the NCAR site after July 6.

At the NCAR site, two areas with significant populations of squirrels were located. Two general procedures for the daily observation of squirrels were implemented: stationary observation, without moving; and mobile observation, with moving.

I located squirrels by sight (movement in the brush or trees) or by sound (calling or barking) to begin daily observations. Behavioral data (including eating, resting, foraging, harvesting, storing, cheek-rubbing, nest-building, drinking, chasing, mating, moving or calling) were recorded until the squirrel was out of sight. This was done without moving, thus the term "stationary", until squirrels were no longer seen. "Mobile" observation required following squirrels throughout the study site, or actively searching for new squirrels on the move.

Trapping. - Trapping began July 22 in accordance with the policies of the City of Boulder, Colorado Open Space Department, and the State of Colorado Division of Wildlife (Scientific Collecting License No. 92-0493). Eight Tomahawk live traps (Boutin and Schweiger 1988, Sullivan 1990) were set early in the morning and checked every 0.5 -1 hrs in Ponderosa pine/Douglas fir habitats as well as in deciduous/riparian habitats where both species were previously seen. Each trap was baited with chunky peanut butter. Other bait used during the study included apples, Twinkies, immature Douglas fir cones, sunflower seeds, commercial birdseed, and shelled peanuts.

Traps with squirrels were covered with black cloth to quiet the animals (Littlefield 1984). A "sleeve" or cone made of black, heavy canvas and velcro was fitted around the door end of the trap (Figs. 5-6) (R. C. Farentinos, personal communication 1992) which enabled easier handling of the squirrels. Within the sleeve, the squirrels were secured with additional velcro straps. The animals were then anesthetized using an inhalant anesthetic (Metofane brand methoxyflourane, Pitnam-Moore, Inc., Washington Crossing, New Jersey) (R. D. Strand, A. Wagner, R. C. Farentinos, personal communication 1992, Littlefield 1984). A plastic bag containing cotton swabs and 1-3 mls of Metofane was held over the nose of the restrained squirrel. After 2-3 minutes, the anesthetic was removed and the animal's level of consciousness was determined. This was repeated until the squirrel became noticeably affected.

The fox squirrels and pine squirrels reacted differently to the Metofane. Fox squirrels took up to 30 minutes to react to the drug, and most did not lose consciousness; this could be due to the conservative manner in which the anesthetic was administered. "Affected" animals were determined by slowed heart rate and minimal tension in the hind legs with continued normal breathing. The fox squirrels were affected to the point where they could be handled, but continued to twitch and move throughout the collaring process (Littlefield 1984). Pine squirrels reacted much faster to the drug and became unconscious within 10 minutes. Pine squirrels were very docile in the sleeve and did not move nearly as much as the fox squirrels. Unfortunately on one occasion, as soon as the pine squirrel's heart rate slowed and movement ceased, death occurred. Because the pine squirrels did not move as much as the fox squirrels in the sleeve, detection of unconsciousness was not as easy and an overdose resulted in one case.

Individuals were weighed, sexed, classified as juvenile or adult, measured for length, and fitted with one of two kinds of radio collar, depending upon the size of the squirrel. After this procedure, the squirrel was observed for 15 minutes until it had fully recovered from the anesthetic, and was then released.

Radio Telemetry. - Two fox squirrels were successfully outfitted with transmitters. Transmitter frequencies ranged between 216.012 and 216.083 Mhz. Expected battery life of the collars was 150 days. Range for detection was up to 1km, depending

upon conditions. The radio collars were secured around each squirrel's neck with a small bolt and two nuts. Each collar was tight enough so that it would not slide off, but loose enough to insert a finger between the collar and the squirrel's neck (Mech 1983).

A portable, AA battery-powered radio receiver (RB-4 "The Falconer", Custom Electronics, Urbana, Illinois) was used to track the movements of the two collared squirrels. Connected to the receiver was a hand-held, collapsible antenna which was used to determine the direction of the signal emitting from the collared squirrels. The same observational procedures previously described were used with the added dimension of the telemetry.

A collared squirrel was located in the following manner: after arrival at one of the concentrated areas, the antenna was assembled and connected to the receiver; the receiver was then turned to the specific channel of the collared squirrel to be located. The antenna was held parallel to the ground and rotated until the signal began to sound. The signal was in the form of a "beep" or "blip" and would get louder as the antenna was pointed closer to the direction of the collared squirrel. After determining the direction of the squirrel from the study area, the squirrel was pursued until it was spotted or until it was no longer possible to distinguish the strongest direction of the signal. Loss of signal direction frequently occurred because the study site has many tall trees, steep slopes, and rocky ledges off of which, the signal "bounced." Once the collared squirrel was located, its position was noted, and it was followed and observed.

Statistics. - Five interactions/chases between the fox squirrel and the pine squirrel were observed. I calculated the exact probability of all 5 chases being dominated by one species or the other. In this study, all 5 were dominated by the pine squirrel.

Results

A total of 59 days were spent in the field, resulting in 347 hrs. Data from observations gave information on fox and pine squirrel behaviors and habitat use. A total of 171 squirrel sightings were recorded.

Total # Fox Squirrel Sightings	45
Total # Pine Squirrel Sightings	126

Locations of squirrel sightings are given in Figure 7.

A total of 6 interactions between the fox squirrel and the pine squirrel were observed. Of these, 5 resulted in chases where the pine squirrel chased the fox squirrel out of the pine squirrel's territory. The sixth time, the fox squirrel spied the pine squirrel and froze. The pine squirrel never saw the fox squirrel. Once the pine squirrel was far enough away, the fox squirrel slowly went on its way. In addition to the 6 interactions observed, there were 3 additional occurrences where both species were within the same immediate area at the same time, but interaction was not witnessed.

Visual Observations. - A total of 1024 squirrel behaviors were observed.

Total # Fox Squirrel Behaviors Observed	225
Total # Pine Squirrel Behaviors Observed	809

The observed behaviors were divided into Maintenance Behaviors and Social Behaviors. Of the 809 observed pine squirrel behaviors, 241 were chrr calls, which fox squirrels do not make. These were removed from the data so as not to skew the results toward pine squirrels. Maintenance and social ethograms for both species are given in Appendices 1-2. Tabulations of observed behaviors are found in Tables 1-2, and corresponding graphs can be found in Figures 8-9.

Trapping. - There were 1402 total trap hours logged for the study. A total of 9 squirrels were successfully trapped, and 31 trap tamperings were recorded. Three different species of squirrel were trapped:

Fox Squirrels (Sciurus niger) trapped	4
Pine Squirrels trapped (Tamiasciurus hudsonicus)	1
Rock Squirrels (Citellus variegatus) trapped	4

Three Steller's jays (Cyanocitta stelleri) were accidentally trapped during the study.

Radio-telemetry. - Three squirrels were successfully collared. Two fox squirrels and one pine squirrel were outfitted with battery-

powered radio transmitter collars (Wildlife Materials, Inc., Carbondale, Illinois), although the pine squirrel died soon after. Locations of the fox squirrels using radio-telemetry are combined with visually observed locations in Figure 7. Telemetry was useful in obtaining fox squirrel data, but squirrel location was very difficult to determine because of the large number of mature trees and steep slopes surrounding the study area.

Statistics. - I tested the probability of all 5 interactions/ chases between fox squirrels and pine squirrels being dominated by one species.

Null Hypothesis:	chases would be dominated equally between the 2 species; 50%:50%.
Probability all dominated by fox squirrel:	.5 x .5 x .5 x .5 x .5 = 0.03125
Probability all dominated by pine squirrel:	.5 x .5 x .5 x .5 x .5 = 0.03125
Result:	0.03125 + 0.03125 = 0.0625 (approximately 0.06), where $p<0.05$, <u>almost</u> significant at 95%.

Discussion

The two questions I attempted to answer with this study were: 1) Are the fox squirrel and the pine squirrel coming together? And if they are, 2) What happens when they meet?

This study shows that the two species are coming together. Fox squirrels were seen 45 times and pine squirrels were seen 126

times within the study area of approximately 36ha. Why were there more pine squirrel sightings?

One reason for more pine squirrel observations is that nearly one-fourth of the pine squirrel behaviors recorded were chrr calls. Fox squirrels don't make chrr calls, and therefore cannot be located as easily as the louder, more obtrusive pine squirrel.

A second reason for more pine squirrels observed than fox squirrels is that the pine squirrel is very territorial compared to the fox squirrel. If a pine squirrel was found in a particular location one day, it would more likely than not be near that location on subsequent days. Therefore, because pine squirrels are territorial, they can be found more easily than fox squirrels.

This territoriality exhibited by pine squirrels can also explain why all 5 chases were dominated by pine squirrels. Single individual pine squirrels defend a feeding territory against all intruders using vocalizations and chasing. (C. Smith 1968). Before fox squirrels came into Colorado, the pine squirrels had another intruder to worry about -- the Abert's squirrel. Like the pine squirrel, the Abert's squirrel is also indigenous to Colorado, and interactions between pine and Abert's squirrels show the pine squirrel to be dominant (Ferner 1974). One chase between a domineering pine squirrel and an Abert's squirrel was observed in this study. Perhaps the pine squirrels are just interacting with the fox squirrels as they have programmed themselves to do with the Abert's squirrels. Pine squirrels may not even be aware that the fox squirrels are a different species than the Abert's squirrels.

Visual Observations. - Of the 1024 behavioral observations made, 241 were pine squirrel chrr calls and were not included so as not to skew the data unnecessarily toward pine squirrels. The behaviors were divided into two groups -- maintenance and social -- to better understand how the squirrels spent their time. There were 564 maintenance behaviors and 219 social behaviors observed (Tables 1-2). Looking at Tables 1-2 and their corresponding graphs in Figures 9-10, fox squirrels were observed spending most of their time moving (30.9%), feeding (23.0%), and foraging (12.8%). The pine squirrels were observed spending their time barking (28.3%), moving (26.4%), and feeding (9.6%). Why this difference in time budgets? Both spend a great deal of time moving and feeding, but the pine squirrel spends the most of its time barking which, according to Lair et al. (1990), means it is actively defending its territory. This behavior is not as strongly developed in fox squirrels.

Trapping. - Squirrels were difficult to trap in the study area as shown by the number of squirrels trapped: 9 out of the 1402 trap hours logged. This could be for several reasons: 1) the squirrels were "trap-shy" or afraid of the traps for some unknown reason; 2) the squirrels were not attracted to the bait used; or 3) the traps were not positioned in "ideal" locations for capture of the most squirrels. Chunky peanut butter attracted the most animals. Fox squirrels and rock squirrels were more attracted to peanut butter than pine squirrels. Steller's jays were also attracted to the peanut butter, which explains their accidental trappings. Douglas fir cones,

a staple of the pine squirrel's diet, were tried in order to entice more pine squirrels, but the pine squirrels were still not attracted to the traps. In future studies, a larger number of traps would be ideal. This would enable a larger area to be trapped at one time.

Radio Telemetry. - The telemetry aspect of the study was not utilized as much as first intended. Problems with trapping reflected onto telemetry; if squirrels were not trapped, squirrels were not collared, and could not be tracked with telemetry.

The successful trapping, collaring, and tracking of the two fox squirrels did help in the understanding of fox squirrels -- how they manage their time, and how they move throughout the study area. Neither location of 3 fox squirrel nests nor the observation of many fox squirrel behaviors including moving, resting, eating, etc., would have been possible without radio telemetry. However, because the study area contained many mature trees, steep slopes and rocky outcrops, location of collared squirrels was difficult. Again, in future studies, trapping and telemetry could be utilized to a fuller extent than in this study.

Statistics. - The exact probability of all 5 observed chases to be dominated by one species was calculated to be 0.06, which is <u>almost</u> significant at a 95% level ($p<0.05$). If a larger sample size had been acquired, statistical significance at this level may have been achieved. However, for all practical purposes in this study, the null hypothesis is rejected and pine squirrels are considered

behaviorally dominant when the two species come together. In future studies, a larger sample size is desired.

Conclusion

This study has shown that the fox squirrel and the pine squirrel are converging in Boulder, Colorado. The pine squirrel is considered behaviorally dominant when the two species interact. This dominance could be due to the territoriality of the pine squirrel, which is known to chase intruders -- namely conspecifics and Abert's squirrels in Colorado -- out of their territories (Smith 1968). It is not surprising, then, to witness this behavior repeated with the newcomer, the fox squirrel.

Further study of the relationship between the fox squirrel and the pine squirrel is warranted for several reasons: 1) to obtain a larger sample size of fox/pine squirrel interactions so pine squirrel dominance can be statistically proven; 2) to determine whether the pine squirrel's aggressive behavior toward intruders is species-specific or if it is instinctual and the same when aimed at any intruder, no matter what species squirrel it is; and 3) to determine if interaction causes changes in the otherwise, unaffected behaviors of fox and pine squirrels when alone in their own specific habitats.

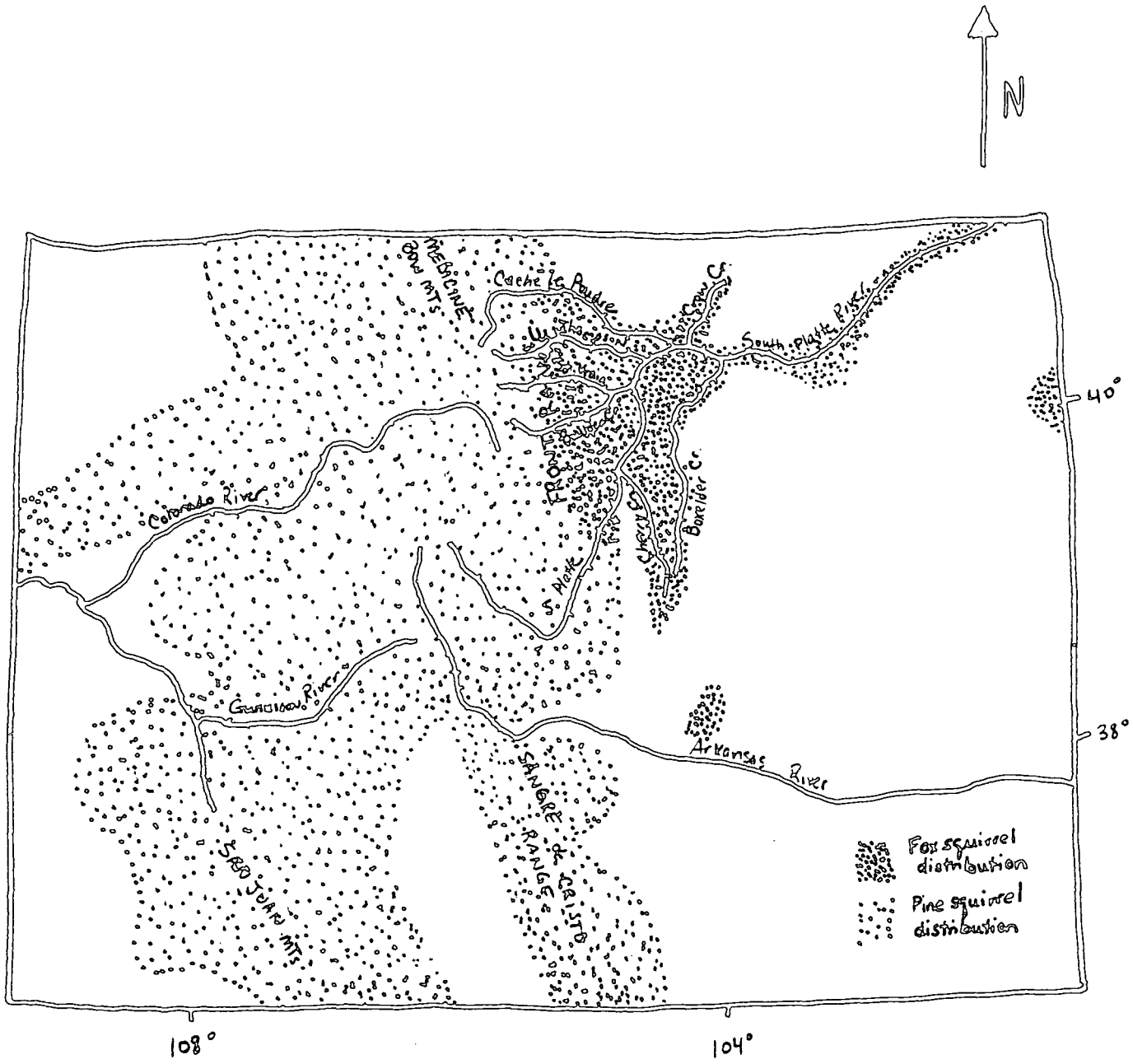

Figure 1. Fox squirrel and pine squirrel distribution in the state of Colorado.
(After Littlefield 1984, Armstrong 1972, Hoover and Yeager 1953, and Hall and Kelson 1959)

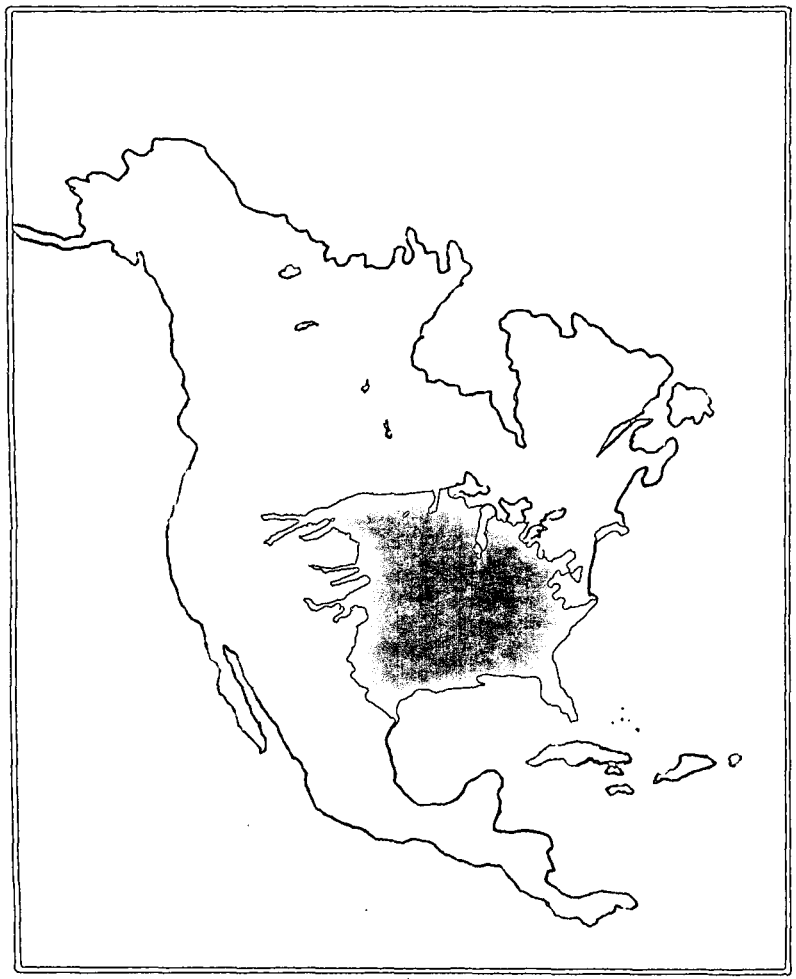

Figure 2. Fox Squirrel distribution in North America.
(After Chapman and Feldhamer 1982)

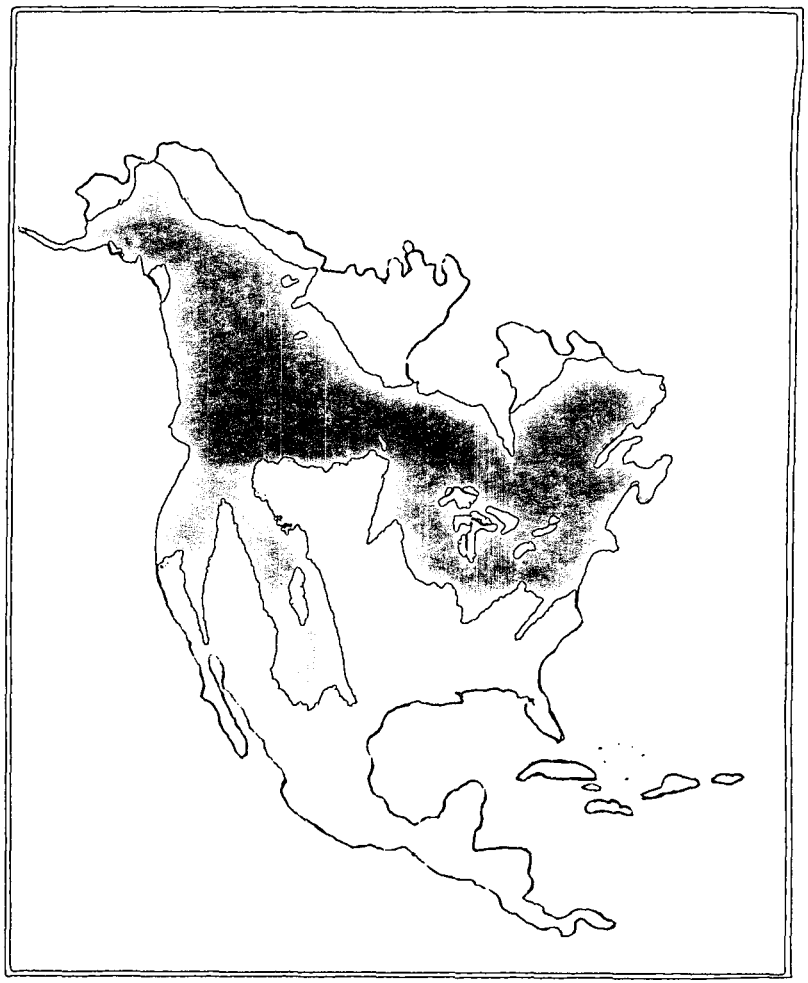

Figure 3. Pine Squirrel distribution in North America.
(After Chapman and Feldhamer 1982)

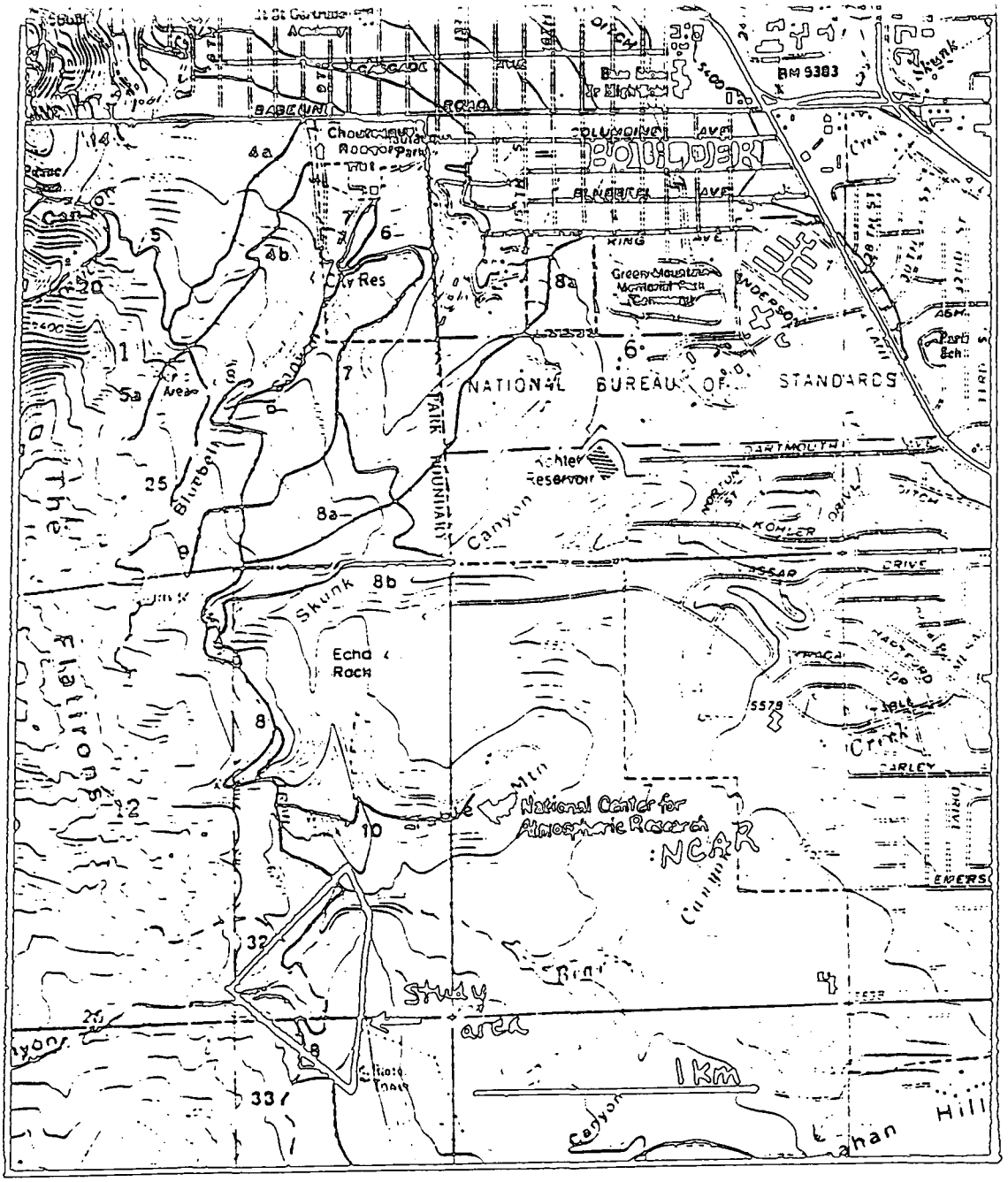

Figure 4. Study area southwest of Boulder, Colorado.

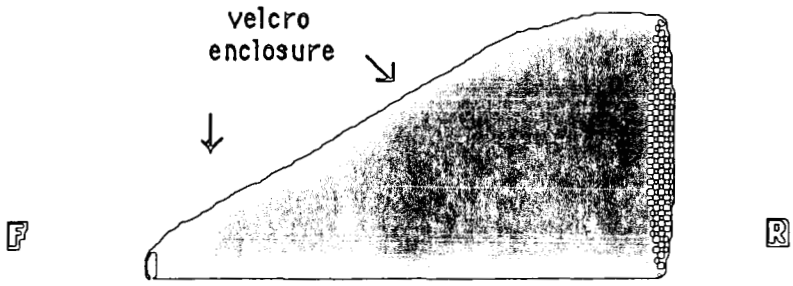

Figure 5. Sleeve, side view, rolled up. Made of black, heavy denim with white velcro. Each squirrel subject was held inside the sleeve with their head facing to the front (F) of the cone, and their tail to the rear (R) of the cone. Additional strips of velcro were wrapped around the sleeve for added security while the animal was inside.

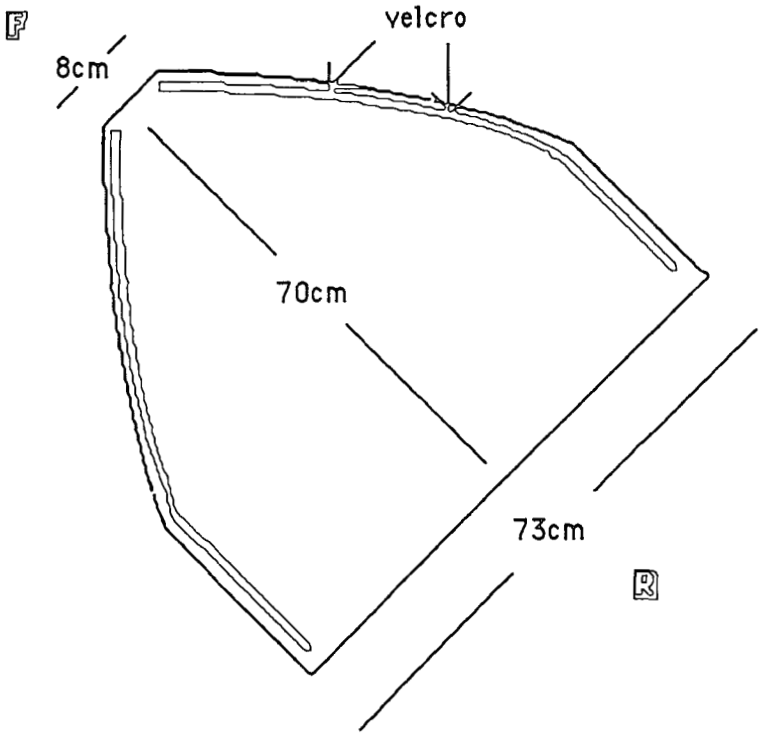

Figure 6 : Sleeve, open, flat-view. The sleeve is held together in the rolled manner above by the two velcro strips along each side. (Design courtesy of Farentinos, 1992)

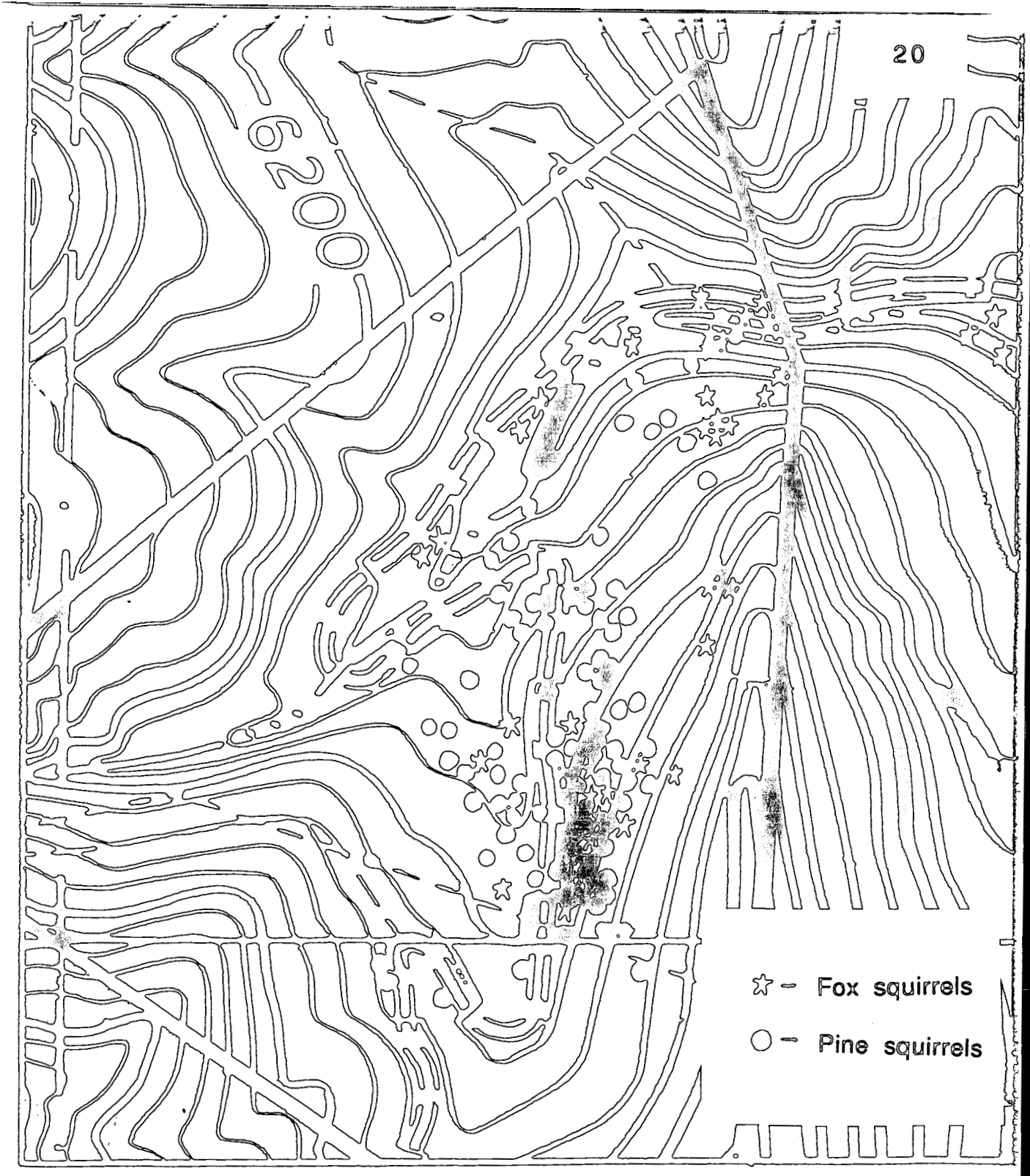

Figure 7. Fox squirrel and pine squirrel distribution within the study area southwest of the National Center for Atmospheric Research (NCAR). Locations determined visually and with radio-telemetry.

TABLE 1: Maintenance Behaviors

Maintenance Behaviors	Fox Squirrel Total # Obs.	Pine Squirrel Total # Obs.	Fox Squirrel % Totals	Pine Squirrel % Totals
feeding	52.0	55.0	23.0	9.6
foraging	29.0	36.0	12.8	6.4
harvesting	0.0	28.0	0.0	4.9
storing	0.0	36.0	0.0	6.3
cheek-rubbing	9.0	2.0	4.0	0.3
resting	26.0	32.0	11.6	5.6
moving	70.0	150.0	30.9	26.4
other	12.0	27.0	5.0	4.9
Totals	225.0	568.0	100.0	100.0

* # Obs. = number of observations

TABLE 2: Social Behaviors

Social Behaviors	Fox Squirrel Total # Obs.	Pine Squirrel Total # Obs.	Fox Squirrel % Totals	Pine Squirrel % Totals
barking	15.0	161.0	6.7	28.3
froze	8.0	3.0	3.6	0.5
chasing non-squirrel sp.	0.0	2.0	.8	0.4
chasing same-sp. squirrel	3.0	17.0	1.3	3.0
chasing other-sp. squirrel	0.0	5.0	0.0	0.8
interactions with birds	0.0	8.0	0.0	1.4
other	1.0	6.0	0.3	1.2
Totals	225.0	568.0	100.0	100.0

* sp. = species
* # Obs. = number of observations

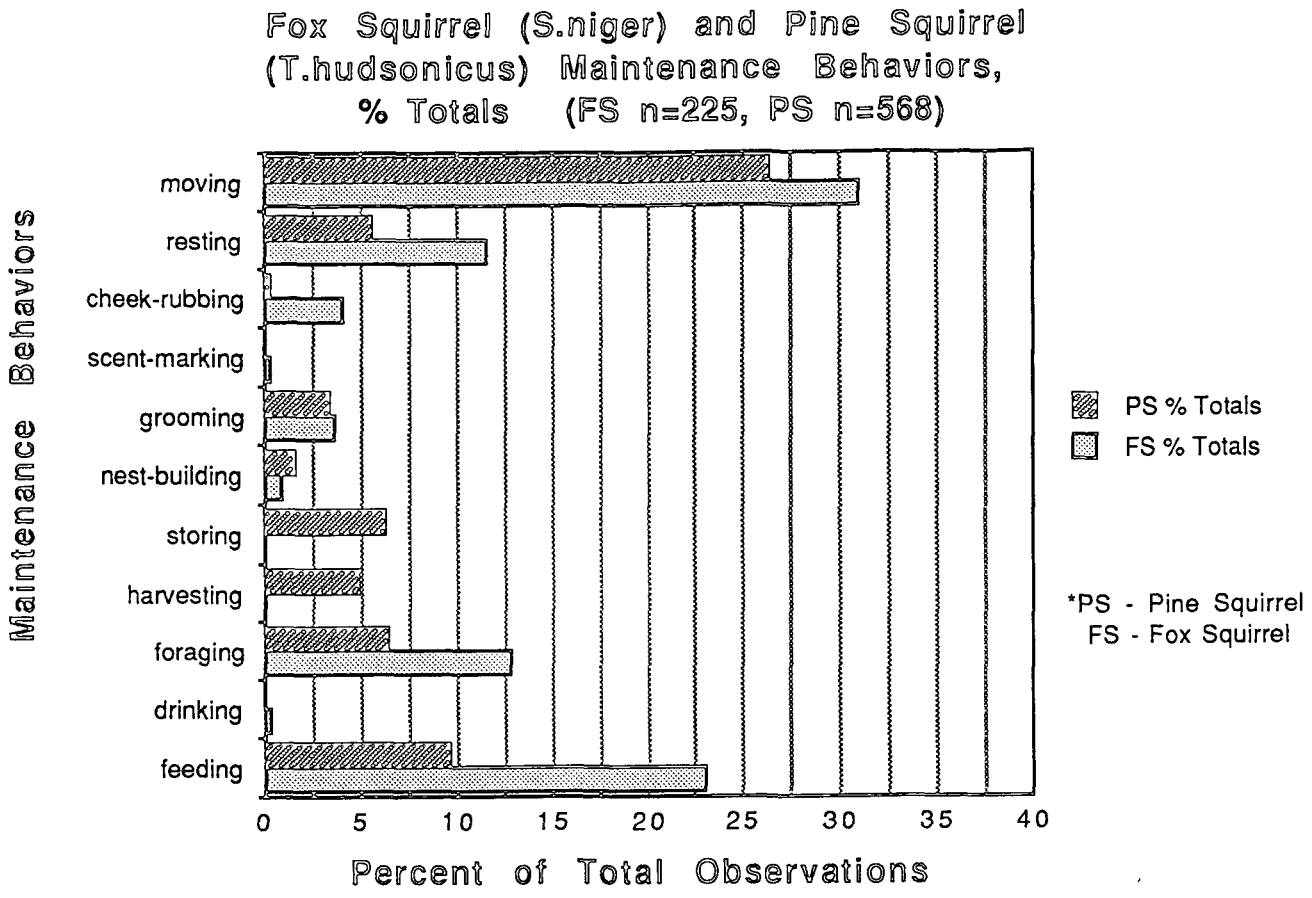

Figure 8. Graph. Fox squirrel and pine squirrel maintenance behaviors.

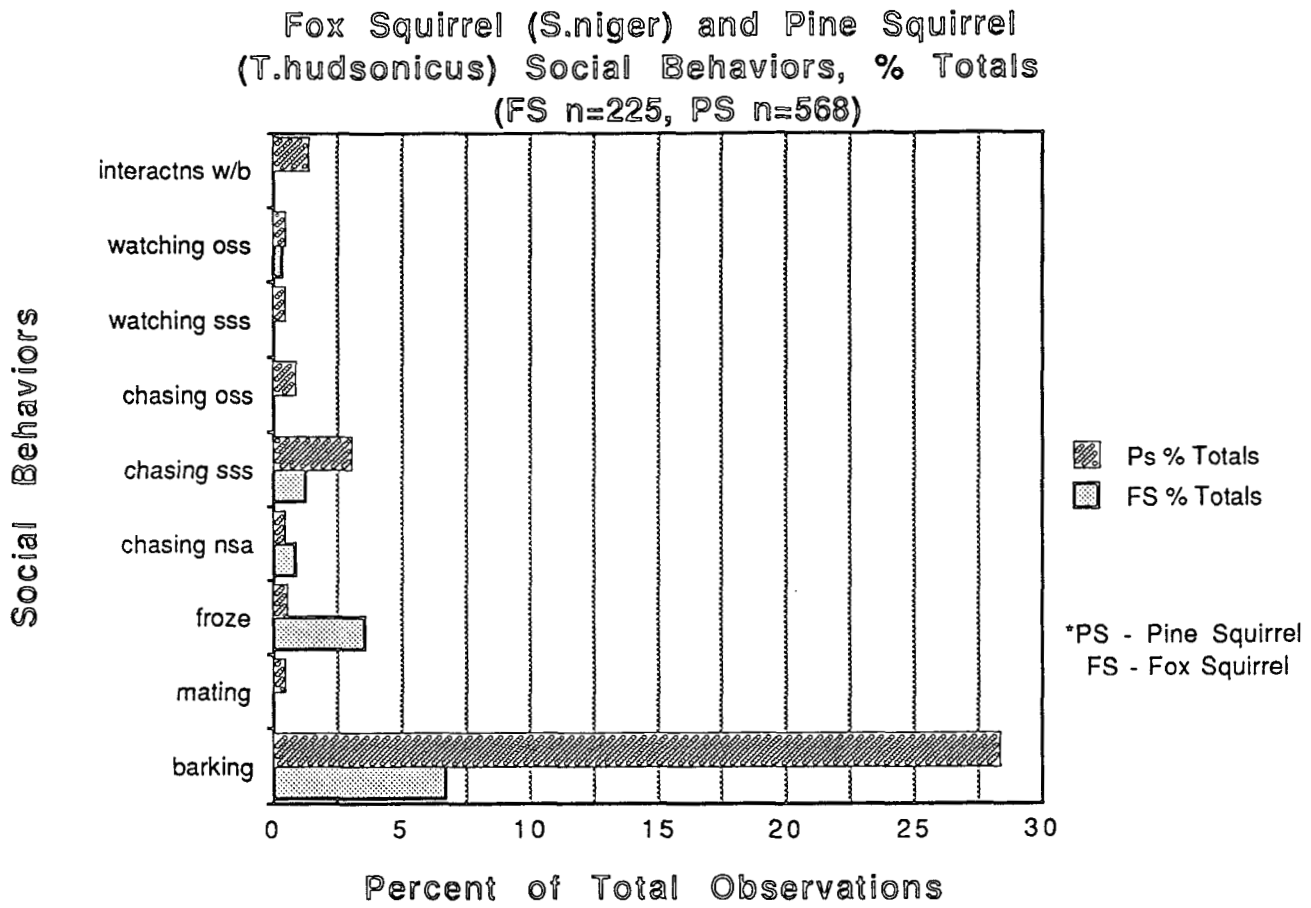

Figure 9. Graph. Fox squirrel and pine squirrel social behaviors.

Appendix 1: Ethogram for Pine Squirrel (T.hudsonicus) and Fox Squirrel (S.niger) Maintenance Behaviors

feeding -- putting foodstuffs in mouth resulting in chewing and ingestion; eating

drinking -- taking water into the mouth and swallowing

foraging -- actively "searching" ground, bushes, foliage, trees for food; usually resulting in immediate ingestion of what is found

harvesting -- picking cones from evergreen trees, letting them drop to the ground to eventually store for later use

storing -- picking up fallen/harvested pine cones or other foodstuffs and caching them in nests, trees, middens, or other holes in the ground for later consumption

nest-building -- gathering twigs, grasses, leaves, and/or other items and organizing them into a structure for shelter and hiding

grooming -- cleaning face, tail, body with teeth or front paws; also includes scratching, rolling in dirt

scent-marking -- rubbing anus on branches/twigs to leave a scent

cheek-rubbing -- touching cheek(s) to a branch or tree in which the squirrel is sitting/standing in order to leave a scent

resting -- inactivity for more than 3 minutes

moving -- running, crawling, climbing in a specific direction for a purpose outside of other behavioral categories

Appendix 2: Ethogram for Pine Squirrel (T.hudsonicus) and Fox Squirrel (S.niger) Social Behaviors

tail-flicking -- deliberate movement of the tail; usually in conjunction with aggressive behavior

chrr calling -- long vocal calls (more than 3 seconds) of the pine squirrel; usually in conjunction with aggressive behavior

barking -- short vocal yips/sounds made by squirrels

mating -- copulation/intercourse between male and female squirrels of the same species

froze -- activity ceases immediately in response to danger or other strong stimuli

chasing non-squirrel animal -- squirrel aggressively chases animal that is not a squirrel

chasing same species squirrel -- squirrel chases another individual of its same species

chasing other species squirrel -- squirrel chases another squirrel of a different species

watching same species squirrel -- squirrel observes another squirrel of its same species

watching other species squirrel -- squirrel observes another squirrel of a different species

interactions with birds -- squirrel chases, barks at, or otherwise disturbs birds in its immediate area OR birds fly at, mob, or otherwise disturb a squirrel

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