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Movement Ecology and Activity Behavior of Black Bears in the Great Smoky Mountains National Park

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To the Graduate Council:

I am submitting herewith a thesis written by David L. Garshelis entitled "Movement Ecology and Activity Behavior of Black Bears in the Great Smoky Mountains National Park." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife and Fisheries Science.

Michael R. Pelton, Major Professor

We have read this thesis and recommend its acceptance:

Boyd L. Dearden, James T. Tanner

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

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

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Accepted for the Council:

L. Evans Roth
Vice Chancellor
Graduate Studies and Research

MOVEMENT ECOLOGY AND ACTIVITY BEHAVIOR OF BLACK BEARS IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK

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

David L. Garshelis
August 1978

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ABSTRACT

Movements and activity behavior of 29 radio-collared black bears (*Ursus americanus*) were monitored between July 1976 and December 1977 in the Great Smoky Mountains National Park. Many bears exhibited home ranges with abrupt seasonal changes, especially between summer and fall. The timing and extent of these range shifts were influenced by sex, age and food availability. During good mast years, the fall ranges of many males overlapped considerably in an area of abundant oaks, while during poor mast years, social intolerance may force many subordinate males outside the Park boundaries in search of food. Fall movements increased the size of annual home ranges above previously reported estimates based strictly on summer data. Mean annual range size was 42 km^2 for adult males and 15 km^2 for adult females. Bears were generally more active in the summer, but traveled greater distances in a day during the fall. This was attributable to extended nocturnal activity in the fall probably associated with increased foraging in preparation for denning. A strictly crepuscular pattern was observed in the spring. Females with cubs were equally active throughout the year and were more active than any other sex-age group. Temperatures above 25 C or below freezing, and precipitation in the form of rain or snow apparently depress the level of activity.

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CHAPTER I

INTRODUCTION

With the aid of radio-telemetry, recent studies have begun to focus more intensely on the habits of cryptic natured species such as the black bear (Beeman 1975, Amstrup and Beechum 1976, Lindzey and Meslow 1976, 1977, Alt 1977, Rogers 1977). Telemetry offers advantages over other widely used techniques (capture-recapture, kill records, observation of natural sign, dye or radioisotope feces tagging, direct visual observation) in that (1) large amounts of data can be collected over a relatively short period of time, (2) individuals can be positively identified both day and night and (3) the method of collecting the information does not affect the natural behavior of the animal. Most researchers presently involved in movement studies of black bears consider telemetry equipment a necessary prerequisite.

Many authors have reported seasonal shifts in range utilization by black bears, presumably in response to food availability. Concentrations of soft mast (Hatler 1967, Piekielek and Burton 1975), hard mast (Davenport 1951, Sauer et al. 1969, Beeman 1975, Rogers 1977), or artificial food sources (Rogers 1977) may provide the stimulus for extensive range expansion especially during the late summer and throughout the fall. These range expansions may be the cause for increased mortality from hunting and poaching in many areas (Erickson et al. 1964, Beeman and Pelton 1977). Significant seasonal shifts in elevation were recognized by Hatler (1967), Jonkel and Cowan (1971) and Amstrup and Beechum (1976). Altitudinal movements may occur concurrently with or in lieu of linear range expansion. Other patterns of seasonal home range utilization by black bears are discussed by Lindzey and Meslow (1977) and Alt et al. (1977).

Home range size for black bears has been dealt with in numerous studies. Unfortunately, the results are not directly comparable due to differences in methodology. Erickson et al. (1964), Sauer et al. (1969), Jonkel and Cowan (1971), Piekielek and Burton (1975) and Rogers (1977) referred to home range primarily on the basis of the greatest linear distance between 2 locations. Most authors connect the outermost points in the scatter of locations to enclose what has been termed the minimum home range (Mohr 1947). This method was used by Poelker and Hartwell (1973), Rieffenberger (1974), Amstrup and Beechum (1976), LeCount (1977), Lindzey and Meslow (1977), Reynolds and Beechum (1977), and in the Great Smoky Mountains by both Beeman (1975) and Eubanks (1976). The biases inherent in this technique are discussed by Hayne (1949), Davis (1953), Stickel (1954), Brown (1956) and Sanderson (1969). Especially prevalent arguments against the minimum area method include (1) the subjectivity involved in deciding exactly which points to connect (the restriction is often imposed that only those points are used which, when connected by line segments form all convex angles), (2) the underestimation of actual utilized area by not allowing for movement outside the observed range and (3) the lack of consideration for the frequency with which the animal utilizes each point in its range.

In an effort to meet these difficulties, several probabilistic models have been developed which measure home range in terms of an individual's total utilization distribution (Jennrich and Turner 1969, Van Winkle 1975) in the habitat rather than location of peripheral points. Confidence limits can be set to allow for a given level of utilization outside the observed range. By eliminating subjectivity and accounting for differences in the relative frequency distribution of location points (as a result of differences in habitat, sampling technique, etc.), home range sizes derived by probabilistic models can be compared from study to study more justifiably than can estimates derived by other more classical techniques. Alt et al. (1976) and Lindzey et al. (1976) used the probabilistic model of Jennrich and Turner (1969) to measure home range sizes of Pennsylvania black bears. Other such models are compared by Van Winkle (1975).

Daily movement patterns have attracted surprisingly little attention compared to the intensive studies of seasonal and annual movements. Heezen and Tester (1967) emphasized the need for short sampling intervals when observing short term (daily or hourly) movements, yet past studies of black bears were usually designed with sampling rates of only once or twice a day. Shorter sampling intervals were often difficult to achieve (Beeman 1975), or simply not practical. Some recent studies, however, have met with greater success, allowing continuous (hourly) tracking for up to 16 days at a time (Rieffenberger 1974, Rogers 1977, Robert Hamilton, University of Georgia, pers. comm.).

Conflicting patterns of activity behavior of black bears have been reported in the literature. Differences may be explained in part by habitat, food supply, time of year and method of observation or interpretation. Direct observations may be biased toward a few animals which are easily visible. Such was the case in a study of campground bears in Yellowstone National Park by Barnes and Bray (1967). For this reason, most studies of activity behavior of black bears have utilized some form of radio-telemetry with varying degrees of success. Beeman (1975) and Alt et al. (1976) used distance between sequential radio-locations as an index to activity. Such movement data are hampered by the limited accuracy of the direction-finding equipment. Mech et al. (1966), for example, found that movements of less than 50-200 feet could not be detected by even a sophisticated automatic tracking system. Other drawbacks of this technique include the necessity for simultaneous readings from 2 or more stations to determine hourly activity, and its misleading assumption that a relatively stationary animal is inactive.

Cochran and Lord (1963) devised a system to detect movement of a transmittered animal by audible changes in the signal strength and frequency. This allows activity monitoring from only 1 station and enhances recognition of extremely localized motion by the animal. Most attempts to monitor activity of black bears have therefore involved an adaptation of this technique (Poelker and Hartwell 1973, Amstrup and Beechum 1976, Lindzey and Meslow 1976, 1977). Using this method in combination with location data and visual observations, Lindzey and Meslow (1977) found a bias towards activity which was substantial enough to preclude an accurate evaluation of the activity data. Rogers (1977) noted that activity could not be detected by modulation in signal quality during aerial tracking.

In order to overcome the difficulties inherent in the previous methods, various types of motion transducers have been incorporated into radio-transmitters (Kolz et al. 1973). Such devices have proven useful in studies of blacktail jackrabbits (_Lepus_ _californicus_) (Knowlton et al. 1968), whitetailed deer (_Odocoileus_ _virginianus_) (Jackson et al. 1972), Formosan monkeys (_Macaca_ _cyclopis_) (Kawai and Mito

1973), and mallards (Anas platyrhynchos) (Swanson et al. 1976). Eubanks (1976) found them to be instrumental in studying black bear activity behavior in the Great Smoky Mountains National Park.

This study was designed as an expansion of work done by Beeman (1975) and Eubanks (1976) concerning the movement ecology and activity behavior of black bears in the Great Smoky Mountains National Park (GSMNP or Park). Specific objectives included:

1. Identification of patterns involved in the utilization of the annual home range.
2. Determination of ecological factors influencing home range dynamics.
3. Interpretation of size and shape of annual and seasonal ranges.
4. Quantification of diel movement parameters.
5. Evaluation of factors affecting activity behavior.

CHAPTER II

STUDY AREA

The Great Smoky Mountains National Park comprises 2072 km^2 of eastern Tennessee and western North Carolina. It is part of the Unaka Mountain Range in the southern division of the Appalachian Highlands (Fenneman 1938). The Park is divided into 4 easily recognizable areas. A prominent ridge runs approximately northeast-southwest delineating the Tennessee-North Carolina boundary, and a transmountain road cuts perpendicular to the State line from Gatlinburg to Cherokee. This study was conducted primarily in the region west of the transmountain road on the Tennessee side, encompassing parts of Blount and Sevier Counties (Fig. 1).

Most of the terrain in the study area is mountainous and accessible only by foot trails. Elevations range from 271 m at the junction of Abrams Creek and the Little Tennessee River to 2025 m at Clingman's Dome. More than 90 percent of the surface area has a slope of greater than 10 percent (Message from the President 1902).

The Great Smoky Mountains represent a high altitude island with respect to soil, vegetation and climate in the Southeast. With the exception of the Cades Cove pastureland, soil types in the study area are broadly categorized in the

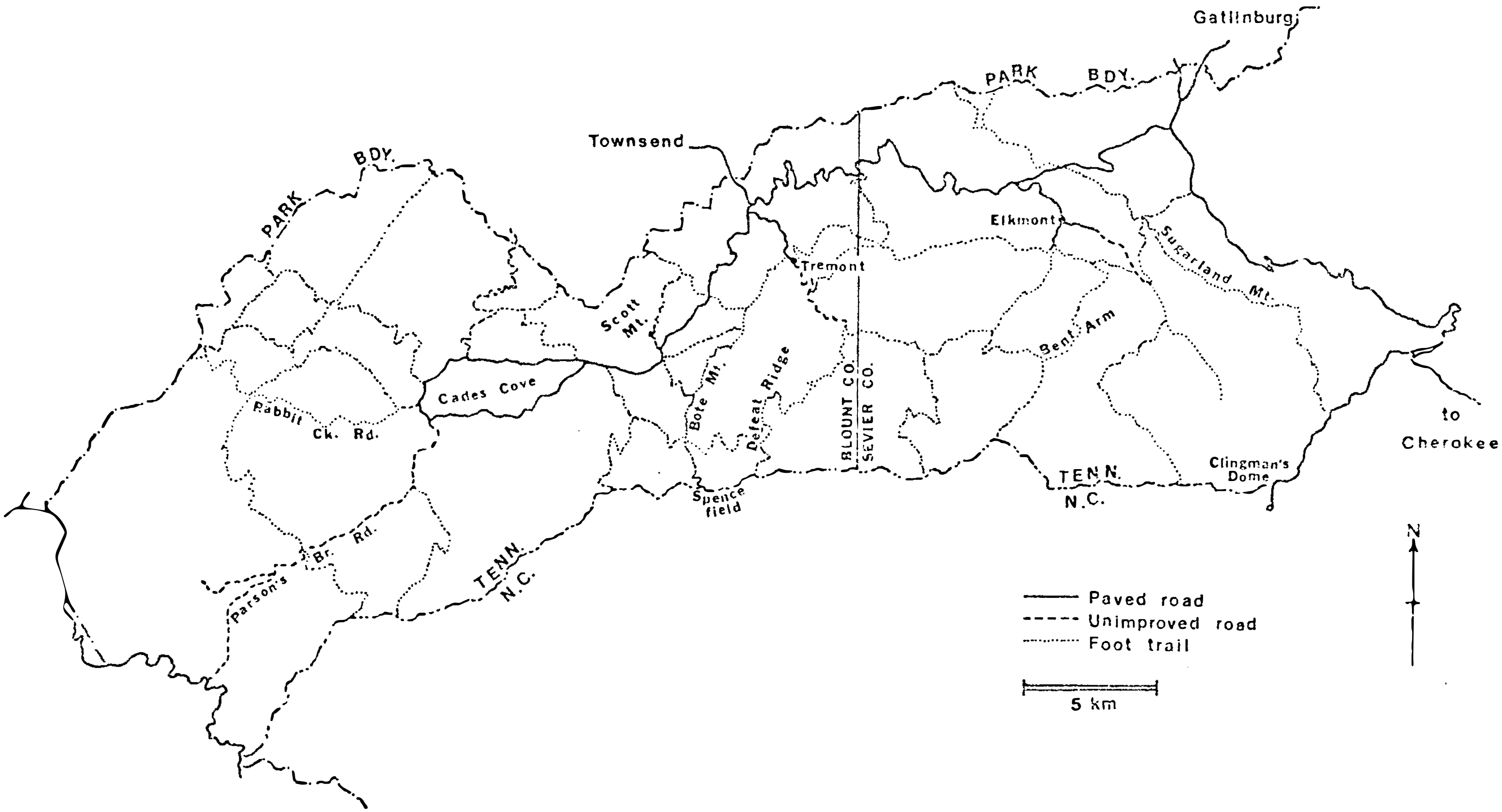

Fig. 1. Study area within the GSMNP.

Ramsey association with most mountain slope soils in the Ramsey series and some lower slope soils in the Jefferson series. These soils are characterized by low water storage capacity, medium to high acidity and moderate natural fertility (Soil Survey 1945, 1953). They are derived from a parent rock of feldspathic sandstone, siltsone and conglomerate from the Ocoee series of the late Precambrian (King et al. 1968).

The vegetation in the Park is dense and highly diverse with considerable interspersion of forest types. It includes over 1300 species of flowering plants of which 131 represent native trees. Various botanical studies have identified 32 different ferns, approximately 350 mosses and liverworts, 230 lichens and over 2000 species of fungi (King and Stupka 1950, Stupka 1960). Major forest types have been categorized by Cain (1935), Shanks (1954a), Whittaker (1956) and Golden (1974). A comparison of these types is shown in Table A-1 in the Appendix. Singer et al. (1978) described 10 vegetational associations for the upper elevations of the central part of this study area, with cove hardwoods and hemlock hardwoods dominating. Much of the understory in this area is over 75 percent rhododenron (*Rhododendron maxima*) and mountain laurel (*Kalmia latifolia*).

The climate in the Great Smoky Mountains varies considerably with elevation. Using the system of Thornthwaite

(1948), most areas can be categorized as mesothermal perhumid (warm-temperate rain forest). Average annual temperature ranges from about 14 C at lower elevations (below 450 m) to only 8 C at higher elevations (above 1900 m), with monthly means usually reaching a high in July and a low in February. Precipitation averages about 140 cm a year at low elevations to well over 200 cm at the highest elevations. Maximum precipitation usually occurs in July while the minimum is in September or October. Precipitation exceeds evapotranspiration for all seasons except in rare drought years (Climatography of the U.S. 1972, Shanks 1954b, Tanner 1963).

CHAPTER III

METHODS AND MATERIALS

Bears were captured in Aldrich, spring-activated, foot snares and immobilized with intramuscular injections of M-99 (Etorphine) or Sernylan (Phencyclidine hydrochloride). The trapping procedures used are described in detail by Eubanks (1976) and Eagar (1977). From June 1967-September 1977 112 captures were made on trap lines in 6 different sections of the study area. Twenty-four selected individuals, with at least 1 representative from each of the 6 sections, were instrumented with radio-collars in the frequency range of 150.8-151.2 (Wildlife Materials, Inc., Carbondale, Ill.). Five other individuals instrumented in 1975 for a previous telemetry study had transmitters which were still functioning at the beginning of this study. Fig. 2 depicts the capture locations for these bears as well as a composite of their respective home ranges. Further information concerning sex, age, reproductive status, capture location, period of time tracked and transmitter frequency is presented in Table A-2 in the Appendix. The focus of this project was in the central part of the study area in the watersheds of the West Prong of the Little River and Laurel Creek (Fig. 3), where 2 previous telemetry studies were conducted

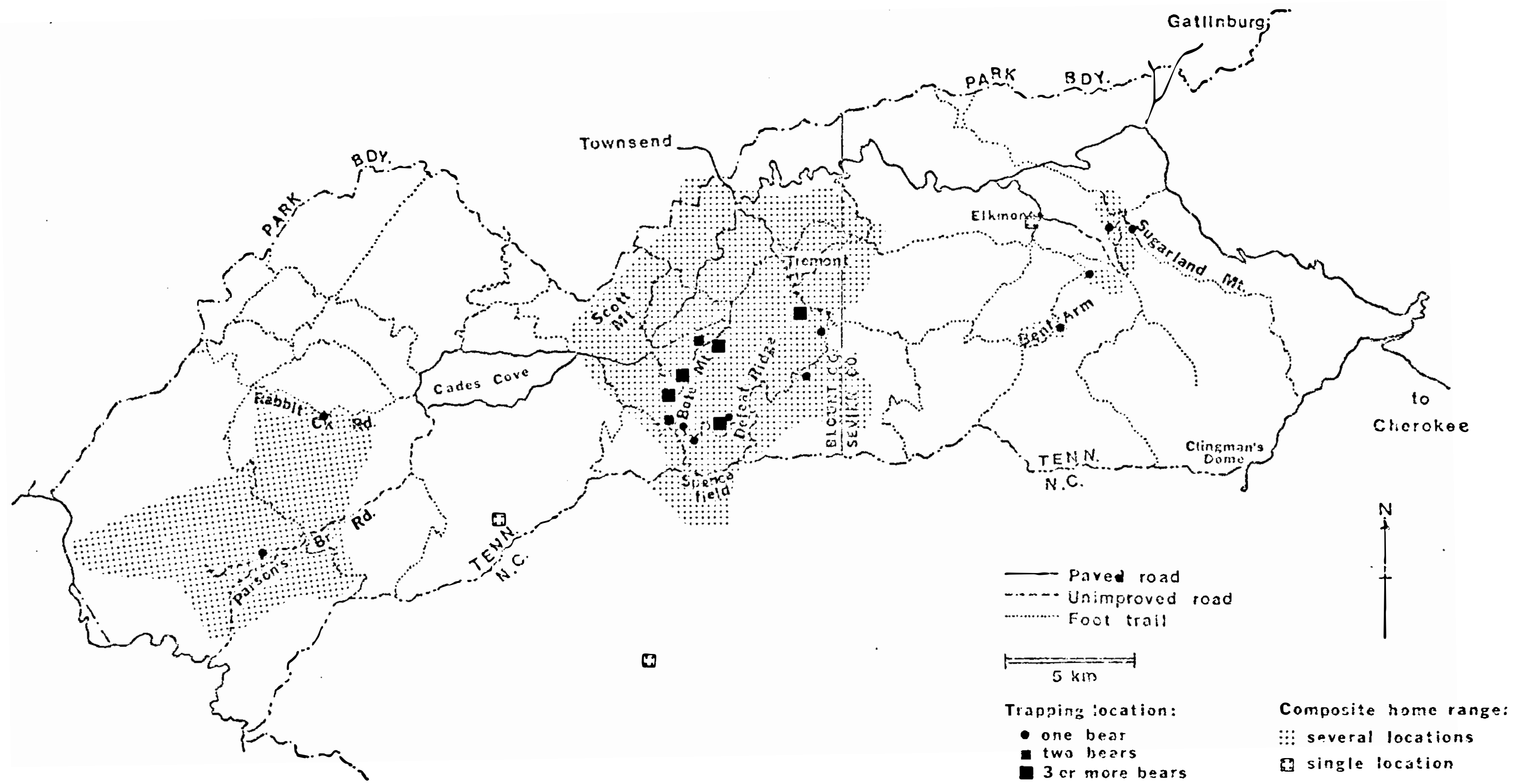

Fig. 2. Trapping locations and composite of home ranges of the radio-collared bears in the GSMNP during 1976 and 1977.

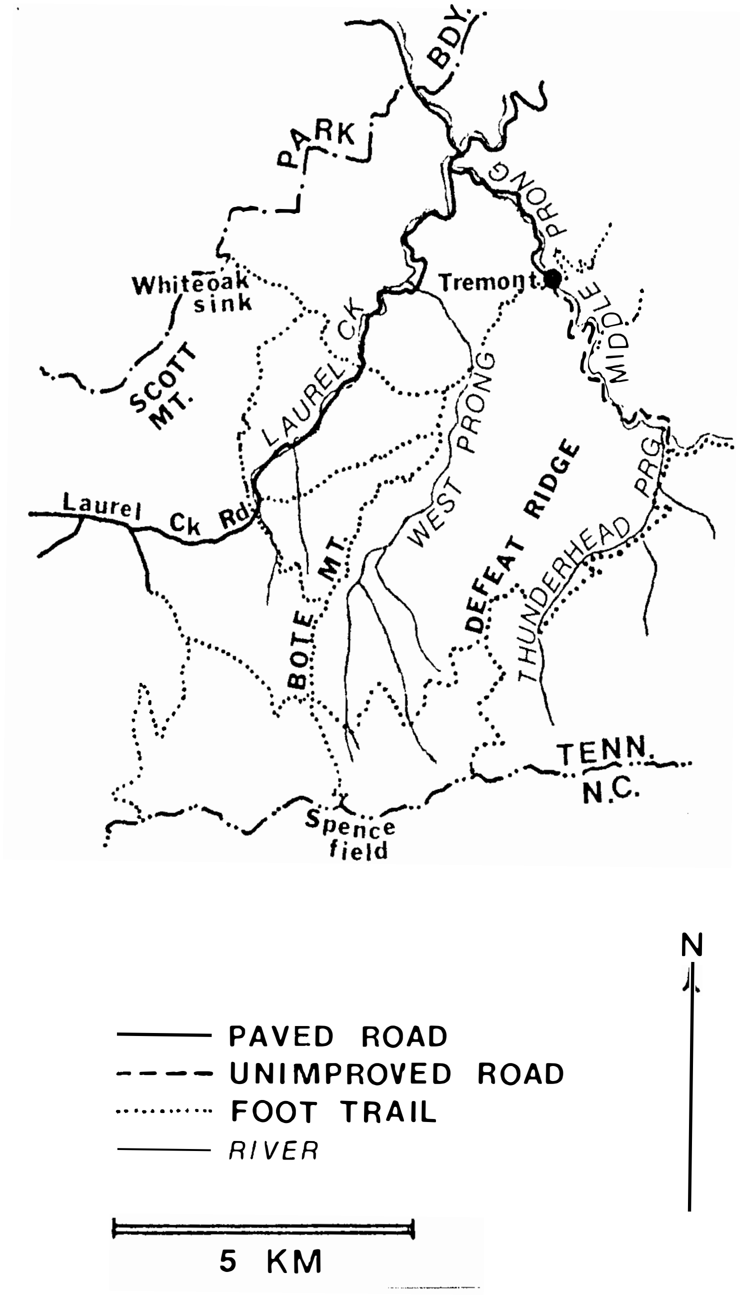

Fig. 3. Map of central portion of study area within the GSMNP.

(Beeman 1975, Eubanks 1976). Most of the radio-tracking data were collected from 5, 8-element mast antennas that were erected along Bote Mountain, the ridge separating these 2 watersheds. Two other mast antennas were erected on Defeat Ridge for bears crossing over into the watershed of the Thunderhead Prong, and 1 on Spence Field for bears moving into North Carolina. These mast antennas exhibited superior accuracy in direction finding over 3 and 4 element, hand held antennas which were used exclusively in other areas of the Park. By orienting a fixed compass-rose at the base of the mast, a tracking station was established that could be easily operated both day and night. Walkie-talkies were used to communicate between stations to obtain approximately simultaneous hourly readings for periods of up to 48 hr. As many as 15 animals have been monitored from any 1 station during the course of an hourly tracking sequence. During most of the study, however, lack of manpower and dispersion of the bears prevented the extensive use of continuous tracking from fixed stations. An attempt was made to locate all bears at least once a week and bears from the Bote Mountain region at least twice a week. Locations were established by the intersection of at least 2 bearings from widely separated points. In most cases 3-4 bearings were taken to minimize the amount of error. Locations were plotted on U.S. Geological Survey 7.5 min quadrangles as circles drawn around the polygon formed by the intersection of all bearings. Those readings which deviated considerably from the location established by the others were excluded. Such readings may have been caused by refraction of the radio signal in the mountainous terrain, poor reception due to interference, or movement by the animal. Because the tracking procedure involved moving from 1 point to another by foot, this last factor was often a considerable influence; nonetheless, most intersection polygons could be inscribed by a circle with a diameter representing 300 m or less. Heezen and Tester (1967) considered error polygons with a length of 240 m acceptable with an automatic tracking system. Locations obtained by aerial tracking were less accurate but were necessary in view of the fact that some animals were extremely difficult to locate from the ground. Aerial searches were conducted approximately once a month when the Tennessee Wildlife Resources Agency pilot and aircraft were available and weather conditions permitted.

The density of the vegetation prohibited verification of radio-locations by direct observation. Only 2 individuals with functioning transmitters were observed in a nondenning situation during the course of this study. However, "dummy" transmitters at known points helped test the accuracy of the equipment and the technique. These dummy transmitters were also used occasionally to pinpoint the position of the observer on an unfamiliar ridge by using a back-azimuth.

All location data were coded to the nearest 100 m of the Universal Transverse Mercator Grid System and recorded on computer cards. Annual and seasonal home ranges were then calculated using the Fortran IV program described by Koeppl et al. (1975). Assuming that an animal utilizes each point in its habitat with a frequency that can be expressed by a bivariate normal distribution, this method defines a home range as the area of the smallest region which can account for a given percentage of this utilization. However, since the utilization distribution is a function of time, the bias involved by varying the time interval between sequential locations from 1 hr to greater than a week had to be minimized. Using diel movement data, it was determined that although a bear is capable of moving from any given point in its seasonal range to any other point in the course of a day, most animals restricted their movements to a smaller subsection of this range by moving in a zig-zag or circular path (this study p. 67 and Beeman 1975). Using this information and the calculated average rate of travel, it was determined that a bear could usually move between any 2 points in its daily range in a period of about 6 hr. (Annual average daily range length divided by annual mean active hourly rate of travel equals 6.5 hr.) Therefore, locations taken 6 or more hours apart were considered to represent a fair sampling of a bear's utilization of its habitat. Locations recorded less than 6 hr apart (460 of the 1660 total locations recorded in this study) were disregarded in the analysis of elliptical confidence areas.

The areas of the convex polygons established by connecting the outermost location points for each seasonal and annual range were also calculated. Using these polygons, measurements were determined for range length, as defined by the greatest distance between any 2 points, and range width, defined as the greatest distance perpendicular to the axis used for length. Also, using the respective set of confidence ellipse areas as a comparative, a confidence value could be expressed for the area of each polygon.

Range confidence values were also assessed by determining percentage tracking success. Tracking success was measured as the amount of time a bear was known or assumed to be within the borders of its plotted range as compared to the total time interval covered in the occupation of that range. A bear was assumed to be within its home range whenever a radio-location was obtained (since radio-locations were the only means of delineating the range) or whenever the 1 or more bearings taken on an animal were directed into the area of the known range even though they did not result in a usable radio-location. A bear was not assumed to be within its home range if its signal could not be received from the usual tracking positions surrounding its range, or if the 1 or more bearings taken on the animal indicated that it had taken a brief excursion or sally outside what were considered to be the range boundaries (Burt 1943). Only 1 such excursion, lasting 3-6 days, occurred in this study.

Annual ranges were divided into seasonal ranges by tracing the movement of activity centers (Hayne 1949) calculated for overlapping 30 day periods beginning every 15 days. Where a significant distance separated 2 clusterings of activity centers, a seasonal division was inferred. Home ranges were then categorized by magnitude of seasonal separation. To determine the factors influencing this separation, sampling transects were directed along the longitudinal axis of various seasonal ranges. Trees were sampled every 100 m using a prism-angle gauge. Seasonal shifts in elevation were determined by observing changes in the elevation of seasonal activity centers.

Diel movements were analyzed with respect to daily range length (maximum distance between radio-locations in a 24 hr period) and its relationship to seasonal range length, mean and maximum hourly rates of travel (means calculated for periods of 12 or more continuous hours), mean and maximum total daily movement (summing distances between successive hourly locations), average net movement in a 24 hr period (distance between beginning and end point) and circuity of the travel route. Circuity was calculated by dividing net movement over a period of 12 or more hours by the total distance traveled in that period. A value of 1 indicates straight line movement while a value of 0 indicates that the animal has returned to the original location. Relatively stationary animals were deleted from the analysis of circuity.

Diel movements were also used to help determine daily activity patterns. However, as discussed in the Introduction, there are several drawbacks to this technique. For this reason, motion sensitive radio-transmitters were used on 26 of the 29 collared bears in this study. These specialized transmitters have 2 transmission modes, 1 slow pulsing and 1 fast pulsing. A small mercury switch activates 1 of the 2 modes depending on the spatial position of the collar. If a bear is active, the transmitted signal will change repeatedly from a slow to a fast pulse. If the animal is shifting position or moving its head, the signal may also change pulse rate 1 or more times during the listening period. To distinguish this type of motion from true body activity (e.g., traveling, foraging, climbing), a cutoff point was established by observing radio-collared bears recovering from an immobilizing drug (especially during the slow recovery from Phencyclidine hydrochloride) while listening to the response of the transmitted signal. If the pulse rate changed at least 2 times during each minute over a period of 3 or more minutes, or at least 4 times during any 1 min period, the animal was considered to be active. If changes in pulse rate occurred but were less frequent, the bear was assumed to be inactive and a note was made of the probable head movement.

An activity reading and weather conditions were recorded each time a bear was radio-tracked. Over 5000 readings were cataloged and put on computer cards. Activity was coded either 1 (active) or 0 (inactive). Temperature was grouped in 3 C increments, cloud cover divided into classes of 20 percent and precipitation categorized as rain, drizzle or snow. Precipitation within the previous 24 hr was also recorded. The effects of weather, time of year, time of day, sex, age and presence of cubs on the activity behavior were analyzed using a least squares analysis of variance procedure. The validity of the significance tests associated with this procedure when the dependent variable is coded simply as a "success" or "failure" (1 or 0) is supported by Harvey (1964) and Li (1964).

Aside from this analysis in Chapter V, the t-test was used to determine statistical significance in all comparisons except where specifically noted otherwise.

CHAPTER IV

RESULTS AND DISCUSSION: MOVEMENT ECOLOGY

Home Range Dynamics

Many bears in this study displayed home ranges with distinct seasonal changes. These changes were inferred from the movement of activity centers as described in the previous chapter. In order to facilitate comparisons of bears in different parts of the park, of different sex and age groups, and in different years, annual home ranges were categorized by their magnitude of seasonal changes. Bears exhibited home ranges which were divided into the following categories:

Type I: Random movement of 30 day activity centers throughout the range with no evidence of seasonal clusterings (Fig. 4).

Type II: Continuous directional movement of activity centers through the range with no evidence of seasonal clusterings (Fig. 5).

Type III: Separation of 2 distinct clusters of activity centers occurring sometime in the fall (postbreeding).

a. An activity center shift occurs without a definite shift in the range boundary. The overlap area of the 2 seasonal ranges (convex polygons) contains at least 50 percent of each range (Fig. 6).

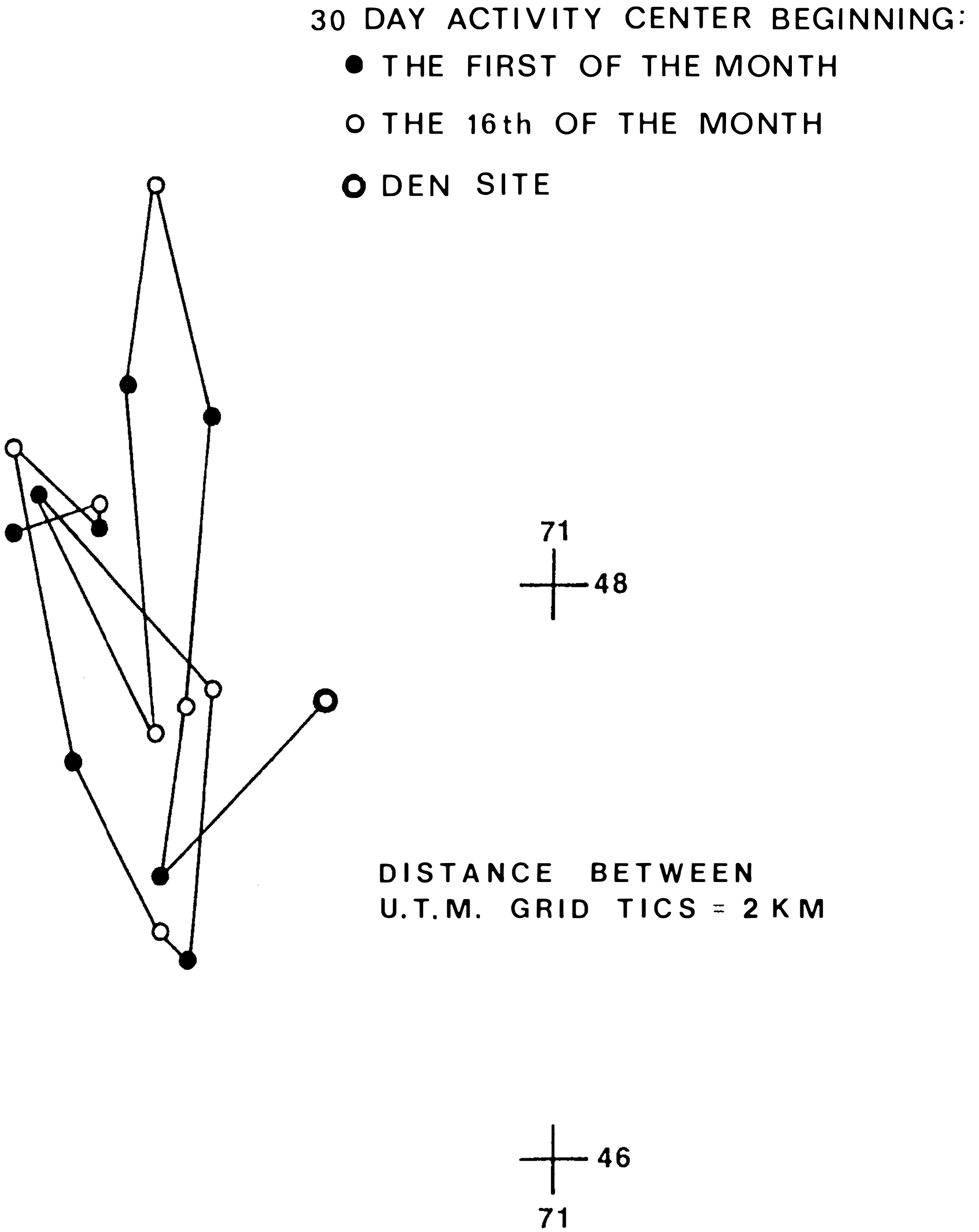

Fig. 4. Movement of activity centers in a type I home range (bear F5).

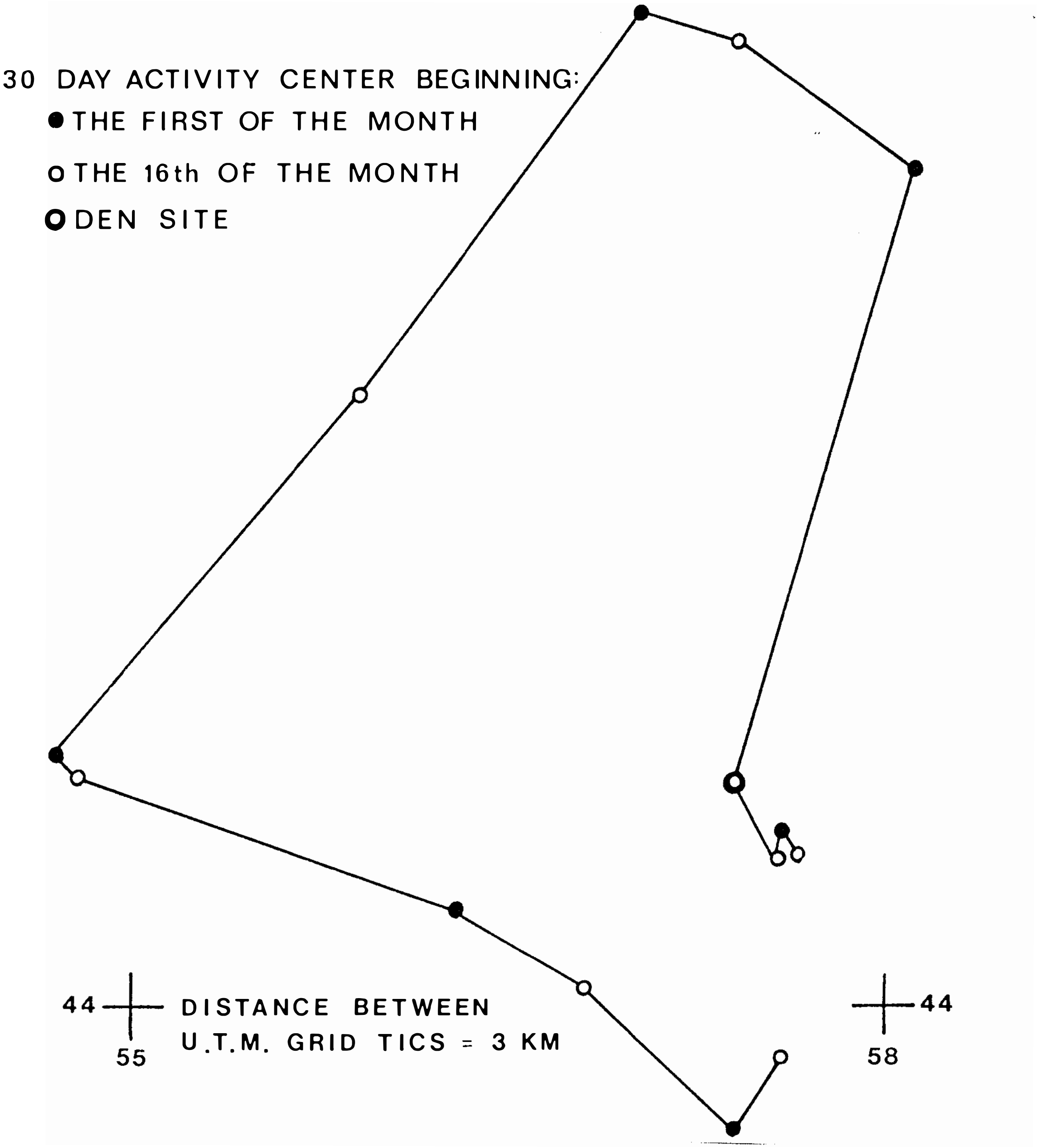

Fig. 5. Movement of activity centers in a type II home range (bear 89).

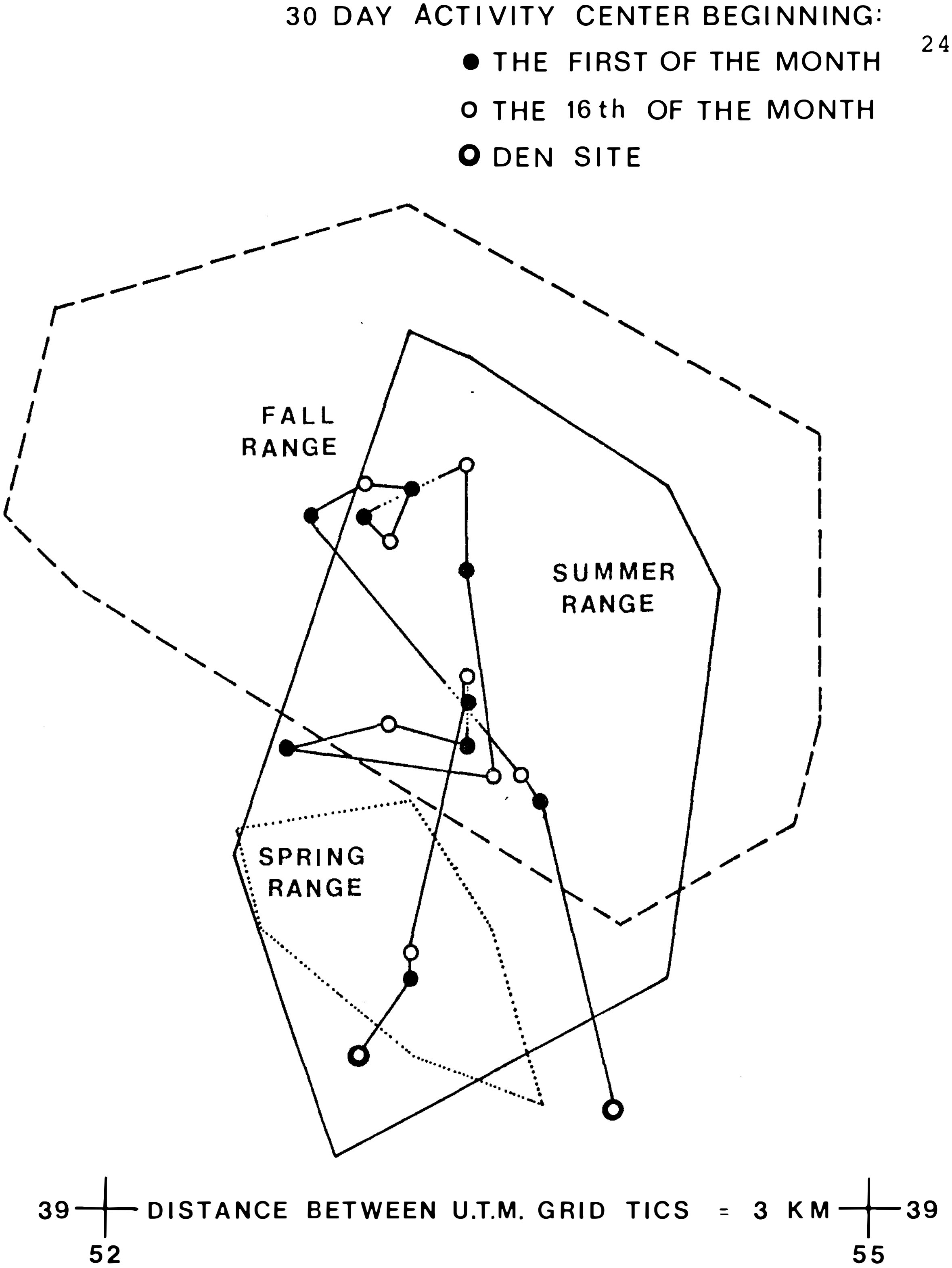

Fig. 6. Movement of activity centers and range boundary shifts in a type III-a/type IV home range (bear A28).

b. There is a definite shift in the range boundary. The 2 seasonal ranges may slightly overlap (area of overlap less than 50 percent of at least 1 of the ranges) (Fig. 7) or not overlap at all. If there is no apparent overlap of range polygons, the animal is nonetheless suspected of being familiar with the intervening space (95 percent confidence ellipses overlap).

c. Completely distinct fall range connected to spring/summer range by only a corridor of very brief travel. There is an area between the 2 ranges which is utilized by the animal less than 5 percent of the time (95 percent confidence ellipses do not overlap) (Fig. 8).

Type IV: Separation of 2 distinct clusters of activity centers occurring sometime other than in the fall (Figs. 6 and 8).

Shifts of activity centers and range boundary shifts are distinguished from dispersal movements by the animal's return to a "home" area for denning. Table A-3 in the Appendix lists each bear and the respective categorization of its home range. Of the 11 observed annual home ranges, 27 percent (3) exhibited a distinct spring-summer range separation (type IV), and of the 29 ranges observed for at least half a year, 79 percent (23) exhibited a distinct summer-fall range separation (type III-b or III-c). One

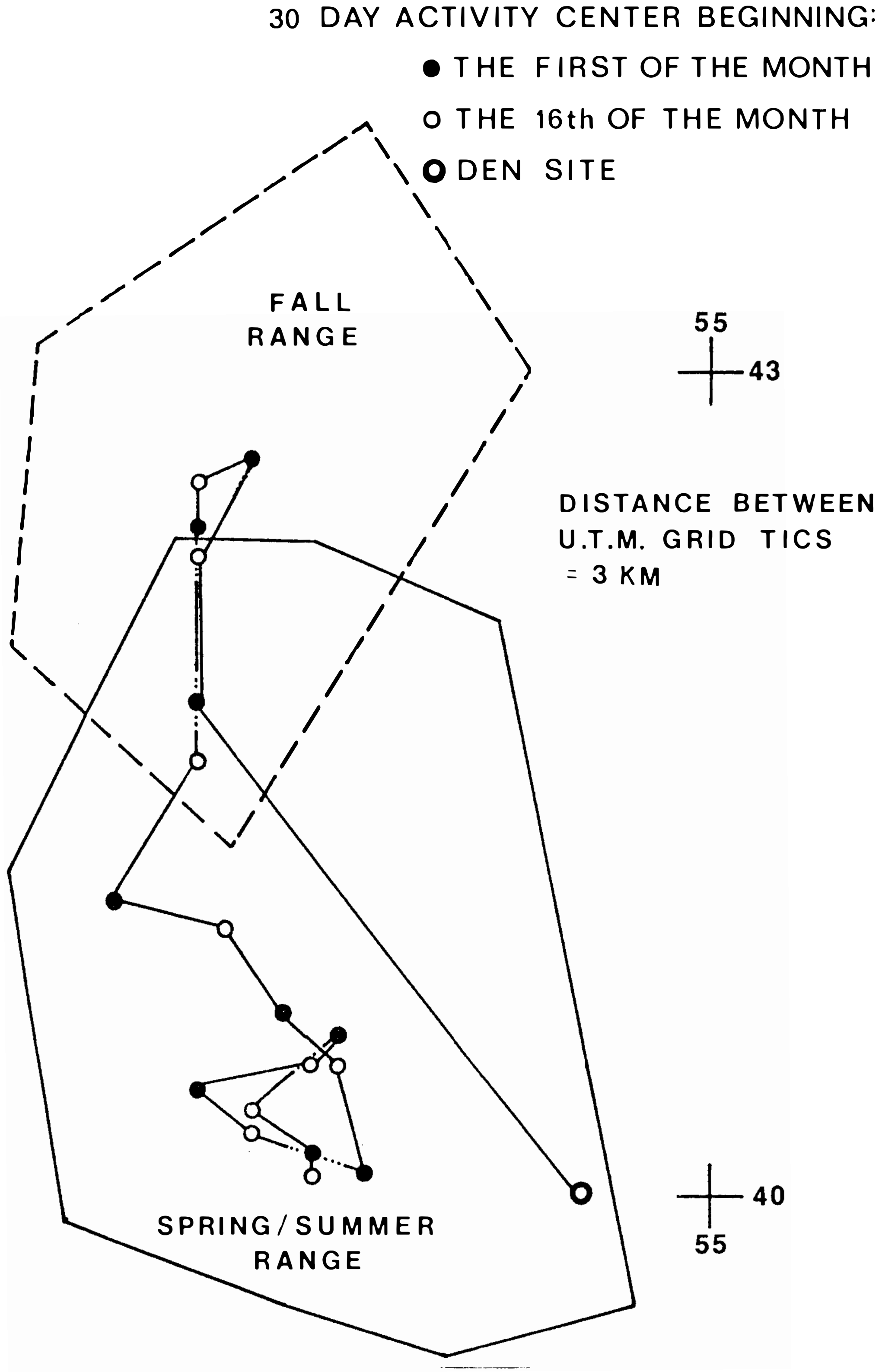

Fig. 7. Movement of activity centers and range boundary shifts in a type III-b home range (bear A9).

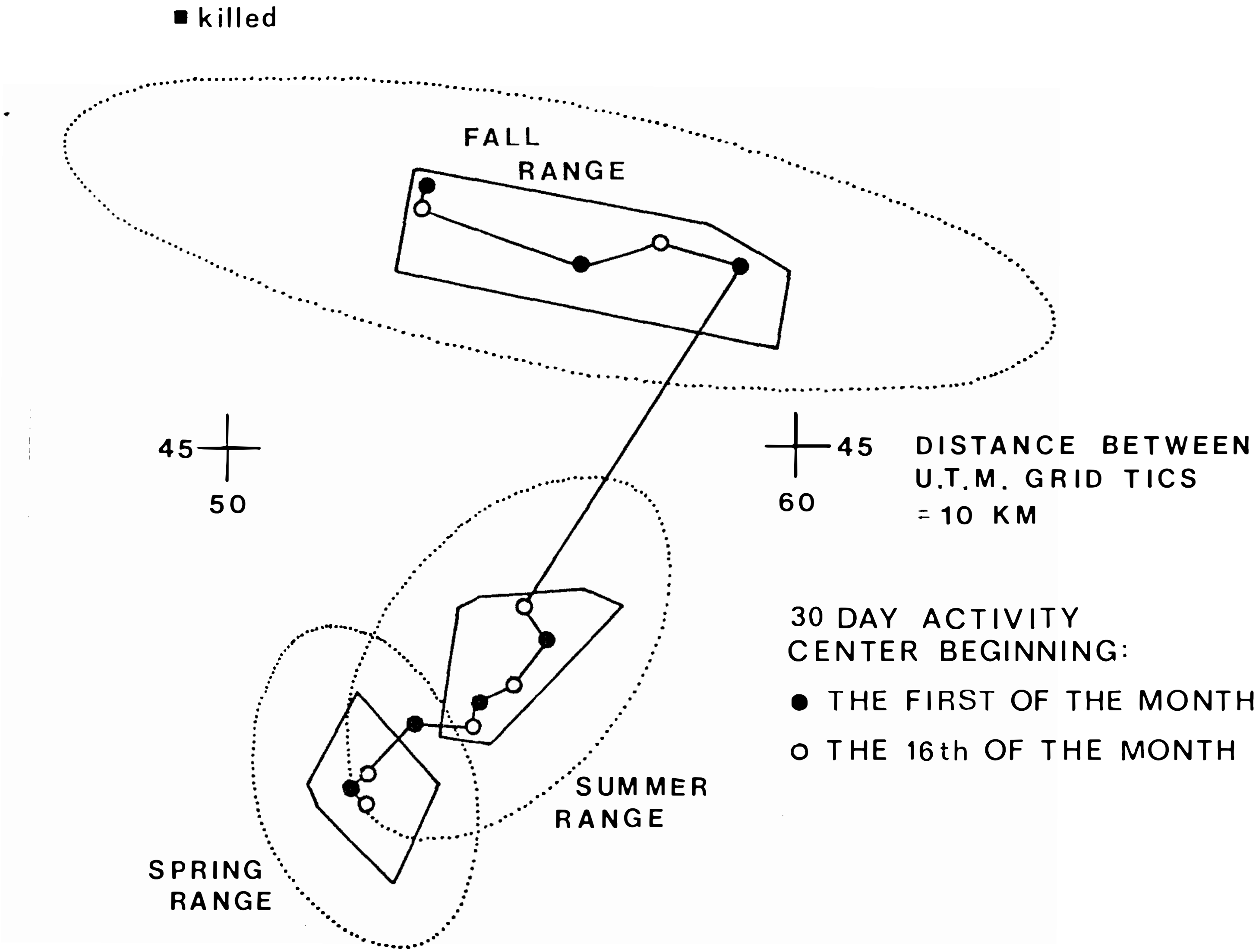

Fig. 8. Movement of activity centers, range boundary shifts and relationship of 95 percent confidence ellipses in a type III-c/type IV home range (bear A30).

female (D2) entered the central study area (West Prong watershed) in late August from an outlying area where she had been trapped during 3 separate summers from 1973 to 1976. Since she returned to her spring/summer range to den, this movement represented a fall range shift (type III-c). However, this particular individual was noteworthy because upon establishing a fall range in an area which coincided with the summer ranges of resident bears, she made a secondary fall range shift (type III-b). This secondary shift matched the fall shifts of resident female bears as far as direction of travel, time of year (mid-October) and displacement distance of the activity center. Another female from the same outlying area (D16) was trapped the next summer (1977) and also located in the central study area in late August. Unfortunately, a premature failure of the radio-collar (or poaching) precluded further observation of this animal.

Similarities in range dynamics were also noted among bears from other sections of the study area. Of the 4 bears trapped within the drainage of the Middle Prong of the Little River (near Tremont), 2 adult females (B10 and 89) had type II home ranges (Fig. 5, page 23) with constant counterclockwise movement of the activity center beginning sometime during the breeding season. These were the only 2 animals in this study with such ranges (Table A-3 in the

Appendix). One adult male from this area (B12) showed a similar pattern until the beginning of November when his range shifted enough to be categorized as a type III-c. One yearling bear from this area (B18) did not exhibit directional movements of the activity center like the other 3 bears, but did make a distinct (type III-c) fall shift into an area utilized by her mother (89) during the fall of the previous year when the 2 were together. In fact, the maximum distance between the November activity centers for these 4 bears was only 2.5 km; these bears were closer to each other than to any other radio-collared bear. This is surprising since bears from other areas occupied fall ranges in the immediate proximity.

Bears from the area of Bote Mountain also demonstrated consistency in the fall range shift. This was particularly true for males. During the fall of 1976 and 1977, all resident subadult and adult males from the Bote Mountain area with radio-collars established a fall range in a relatively small area on the east slope of Scott Mountain in the Laurel Creek Watershed. One subadult male from another part of the Park as well as 1 adult male without a radio-collar were also observed in this area. Beeman (1975) found 3 males in this same area in the fall of 1973 and 1 male was located there in the fall of 1975 (Al Kinlaw, University of Tennessee pers. comm.). To date, only 1 radio-collared female has been located in this area (p. 64).

Similar movement patterns among bears of a particular section of the study area may be explained by characteristics of the habitat and learning. A bear may simply move in response to phenological development of the surrounding area (Amstrup and Beechum 1976). Bears from the same section of the study area respond to the same habitat changes and therefore exhibit similar movement patterns. However, in view of the magnitude of many of the fall movements, it is unlikely that all movement patterns develop in this manner. As previously mentioned, 1 yearling female (B18) established a fall range in the exact area she utilized the year before when she was with her mother (89). Rogers (1977) also noted similar movement patterns for members of a given family year after year. If bears of a particular watershed are all closely related, as suggested by Manlove et al. (1977) for bears in the GSMNP and Rogers (1977) in a study of black bears in northeastern Minnesota, then the similar movement patterns exhibited by these bears may merely be a function of information passed along from 1 generation to the next during the year or more that a female is traveling with her offspring. Such movement patterns may be modified by year to year differences in food availability, population density, social structure and behavioral characteristics of particular individuals or sex-age groups. Table 1,

Table 1. Sex, age, regional and year to year influences on seasonal range shifts of black bears in the GSMNP. Values represent the percentage of bears having the type of range indicated.

		Range type				
Category of comparison	(n)	I or III-a	II	III-b	III-c	III-b or III-c
Females	(19)	21	11	37	32	68
Males	(11)	0	0	64	36	100
difference		ns	ns	ns	ns	*
Adults	(20)	20	10	50	20	70
Subadult/yrl.	(10)	0	0	40	60	100
difference		ns	ns	ns	*	ns
Bote Mt. area	(20)	10	0	65	25	90
Other areas	(10)	20	20	10	50	60
difference		ns	*	*	ns	ns
1976	(10)	0	10	50	40	90
1977	(20)	20	5	45	30	75
difference		ns	ns	ns	ns	ns
1976 + 1977	(30)	13	7	47	33	80
1973[a]	(8)	?	?	?	75	?
difference					*	

[a] Adapted from Beeman (1975), including only back-country bears.

*χ^2 test, $p < 0.05$.

derived from Table A-3 in the Appendix, highlights the affects of some of these influences in this study. The seemingly inherent tendency for young male bears to travel more widely in the fall (i.e., type III-c range shifts) than animals of any other sex-age group may have led to the disparity between male and female movement patterns in the Bote Mountain area, a situation which could not have occurred if yearling males merely retraced the fall movements of their mothers.

Sex, age, regional and social factors were also evident in the timing of fall range shifts (Fig. 9 and Table A-4 in the Appendix). All Bote Mountain area bears with type III-b or III-c home ranges established their fall ranges in September or October, while in other areas of the Park fall movements were noted in August and November. This may be explained by differences in habitat within the Park (pp. 36-38). Males, in general, initiated range shifts earlier than females with two-thirds of the males and only one-third of the females having left their summer ranges by the end of September. Males also stayed in their fall ranges later in the year. Only 1 male left the fall range before 15 Dec, while this was observed for 10 of the 12 females. Yearling bears of both sexes returned to their respective spring/summer ranges earlier than older bears of the same sex. This behavior allows these inexperienced bears more time

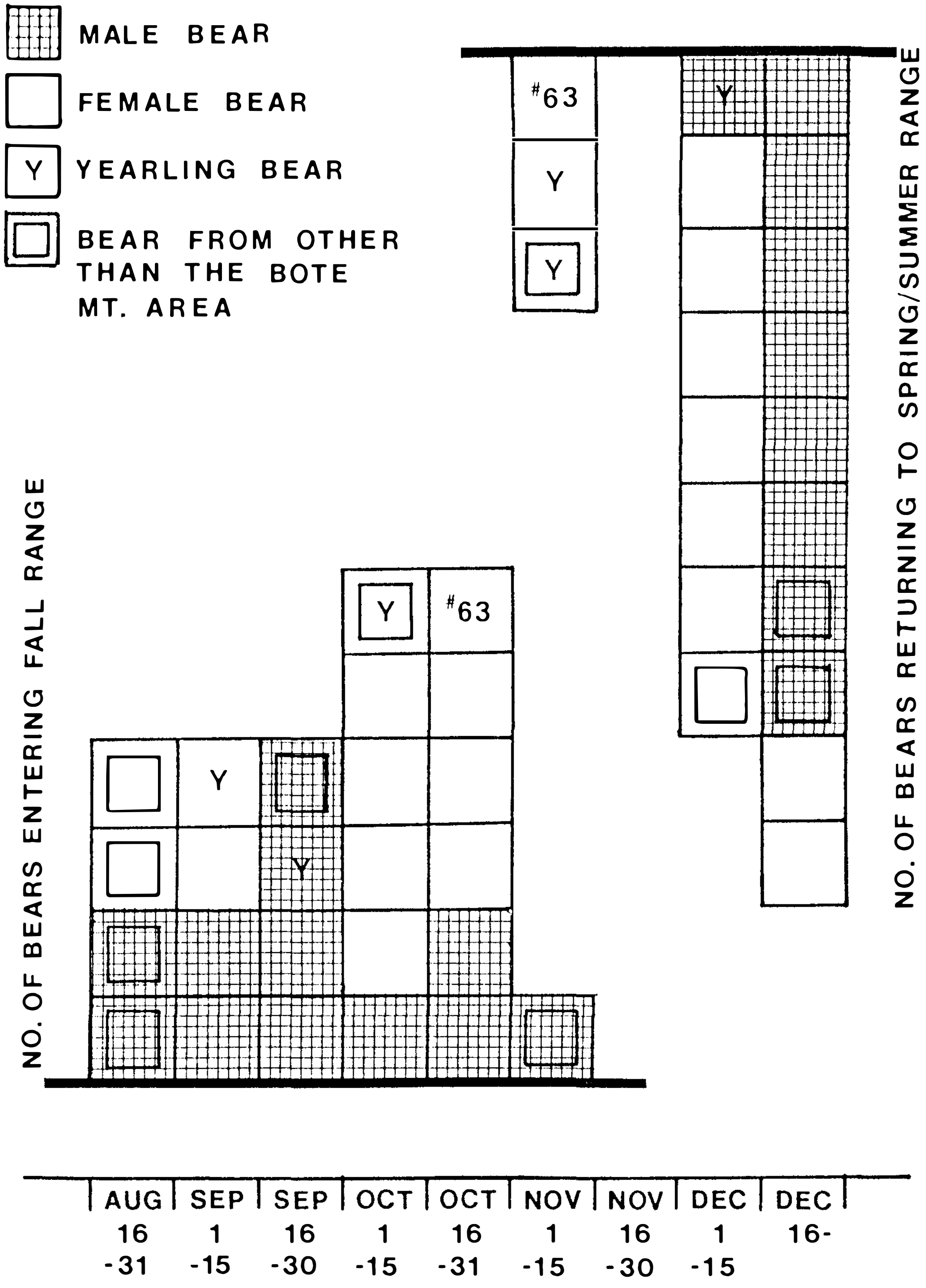

Fig. 9. Timing of the fall range shift, emphasizing the early arrival and late departure of males from the fall range, early return of yearling bears to the spring/summer range and the short duration of occupancy of the fall range by adult female #63 (discussed on p. 64). Regional influences on the timing of the fall range shift are also evident.

to locate an acceptable den. Such a trend would be strongly favored evolutionarily. Social factors are implicated in the early return of adult female 63 (p. 64).

Of 4 bears observed in distinct fall ranges during both years of this study (A9, A29, A30, C14), 3 left their summer ranges during the same week in both 1976 and 1977. Only 1 of these 4 bears was observed returning to its spring/summer range during both years (2 of the other 3 were killed and one's transmitter ceased functioning), and again the movement occurred during the same week in both 1976 and 1977. However, the fall range established was not consistent from year to year. In 1 case (A30), the activity center of the fall range in 1976 was almost 25 km from the activity center of the 1977 fall range. In another instance, a bear (A28) made a considerable fall shift in 1976 (categorized as a type III-c although it could not be located in 5 aerial searches until it returned to den) and virtually little movement the next (type III-a). Such year to year differences in individual movement patterns may be influenced by such factors as social pressures and sexual development. The presence or absence of a family group did not affect the movements of females in this study, nor did it affect the late summer excursions of the bears studied by Rogers (1977) in Minnesota.

More drastic year to year changes are probably due to food availability. Beeman (1975) noted 6 of 8 back-country bears and 1 of 3 panhandler bears making extensive fall movements (in fact they could not be located) in 1973 when the acorn crop was rated fair (Wildlife Research Report 1977-78). Bears made less extensive movements (type III-b instead of type III-c, Table 1, p. 31) in 1976 and 1977 when the acorns, especially in the red oak group, were much more abundant. Of 2 individuals common to both studies, 1 adult female (A44 = Y52) and 1 adult male (A26 = R26), the female exhibited much more extensive fall movement in 1973, while the range shifts for the male were not appreciably different between the 2 studies. Another female tracked by Beeman (Y70) was also believed to make extensive movements out of the central study area, yet 1 of her cubs which was tracked in this study (A43), was consistently found within the mother's 1973 summer home range throughout the fall of 1977. This situation may have been confounded, however, by the death of the female in the early part of September 1977, leaving the collared cub and its 2 siblings to forage without maternal guidance.

The fall movement patterns were not significantly different between the 2 years of this study (Table 1, p. 31), although there appeared to be a tendency, on both an individual and group basis, for bears to travel further in 1976. This again likely reflects acorn production which was rated higher in 1977 (Wildlife Research Report 1977-78).

The above results indicate that food abundance is an important factor initiating and regulating seasonal range shifts of black bears in the GSMNP. Results of the vegetational sampling carried out in this study strongly support this conjecture. Measuring abundance by basal area, percentage composition and percentage frequency, it was determined that fall ranges had significantly more oaks of all sampled species than did spring/summer ranges (Fig. 10). Beeman and Pelton (1977) found acorns to be the staple food item of black bears in the GSMNP during the late fall (16 Oct-Dec). This fits well with Strickland's (1972) findings that peak production for acorns in East Tennessee occurs during the middle part of October, with acorn fall beginning near the end of August and ceasing at the end of November. This pattern also corresponds with the timing of fall range shifts shown in Fig. 9, p. 33. In the early fall (1 Sep-15 Oct) black cherries are the most important food item in the diet (Beeman and Pelton 1977). Cherry trees (*Prunus serotina* and *P. pennsylvanica*) were significantly more abundant in spring/summer ranges as shown in Fig. 10. A preference for cherries may have been reponsible for holding bears in their summer range until finally compelled to move when the cherries became scarce in October. This may account for the abruptness of the fall shift. Bears from areas of the Park where cherries are not

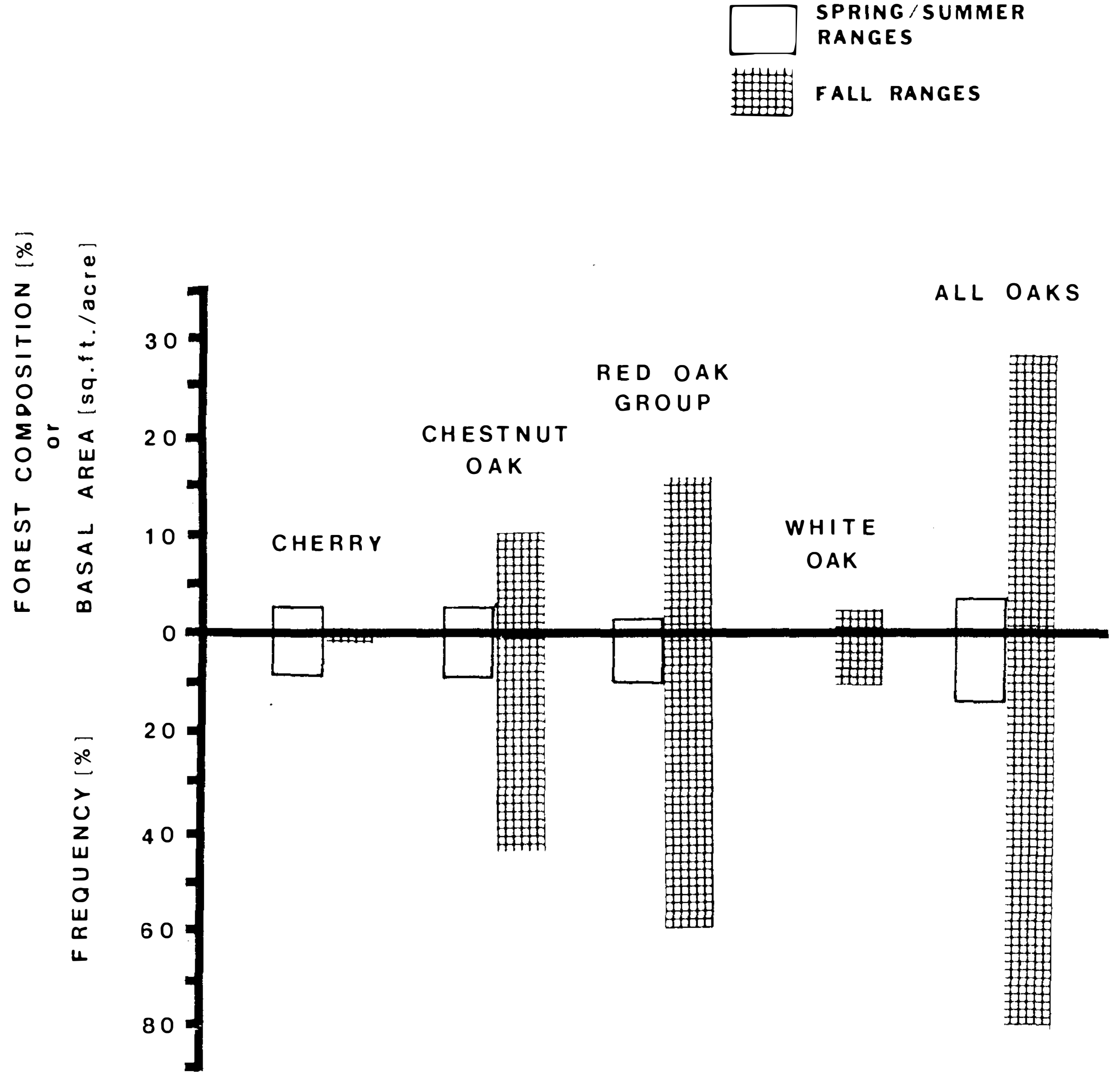

Fig. 10. Comparison of oak and cherry abundance in spring/summer and fall home ranges in 1976 and 1977. Total basal area for all tree species averaged 100 ft^2/acre. Basal area was therefore equal in value to percentage composition for each observed species. All comparisons were significantly different ($p < 0.05$).

abundant should, according to this notion, begin fall movements earlier in the year; some evidence exists to support this. Bears D2, D16, and C14 occupied summer ranges in areas where cherries (especially black cherry) are less abundant than in the central study area. These bears were observed to leave their summer ranges comparatively early (Table A-4 in the Appendix). This is not to say that cherries, by themselves, regulate the timing of the fall range shift, but rather that the availability of both soft and hard mast may substantially affect the timing from year to year in any given area of the Park.

The fact that most male bears initiate fall range shifts earlier than females is probably not due to a food scarcity in the male summer ranges (since male summer ranges overlapped those of females), but rather to the severe competition among bears that apparently exists for prime oak areas. As previously mentioned (p. 29), many of the fall ranges of males were clustered in an area which was virtually devoid of females. All oak species except chestnut oak (*Quercus prinus*) were more abundant in the male ranges (Fig. 11) and dominant (heavier) males had a proportionately greater abundance of these species than did subordinate males (Fig. 12). These factors indicate a preference for fall ranges with abundant white oak (*Q. alba*) and red oaks (*Q. rubra*, *Q. coccinea*, *Q. velutina*). White oak appears to be

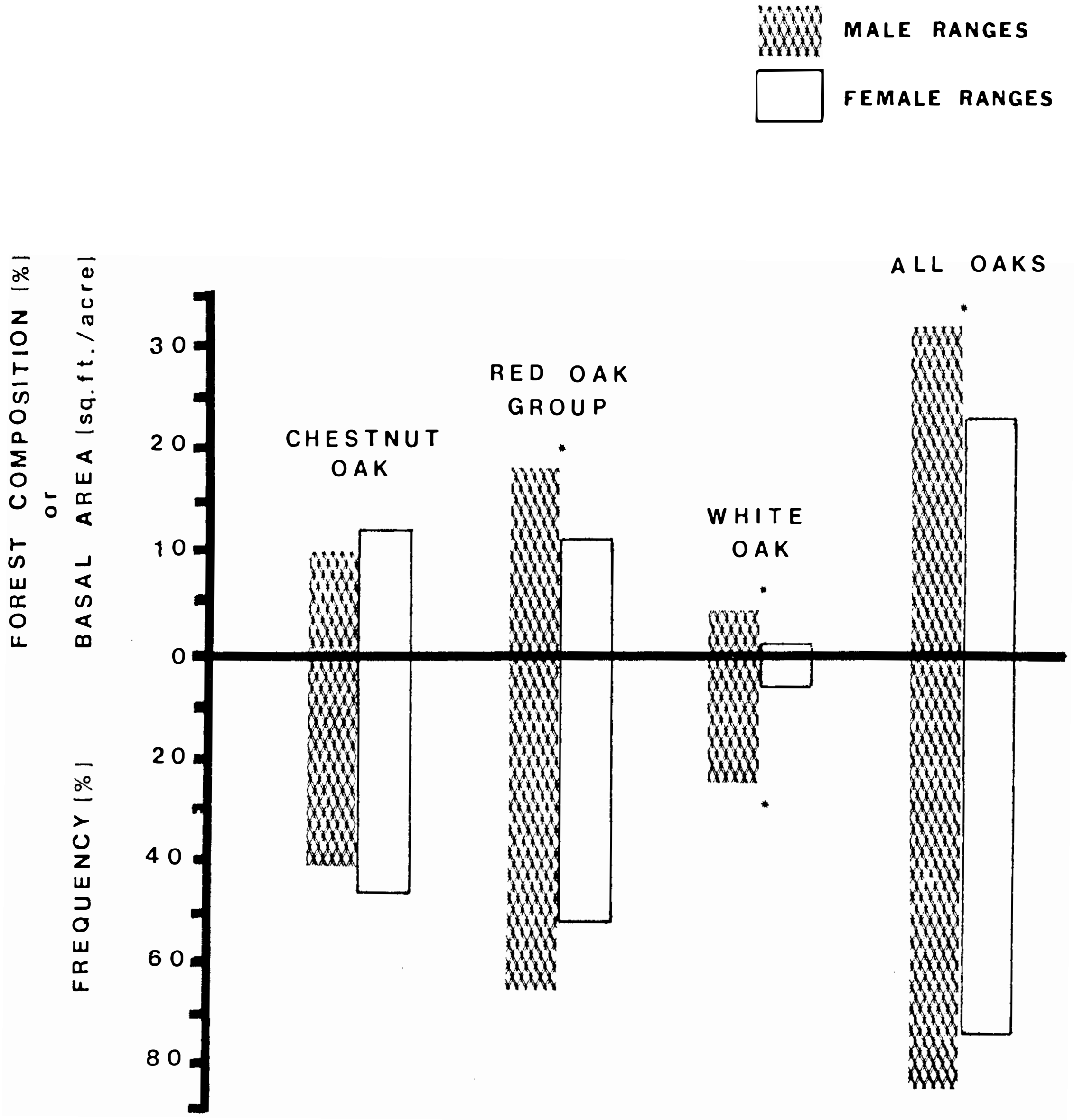

Fig. 11. Comparison of oak abundance in male and female fall ranges in 1976 and 1977. Total basal area for all tree species averaged 100 ft^2/acre. Basal area was therefore equal in value to percentage composition for each observed species. Starred comparisons are significantly different ($p < 0.05$).

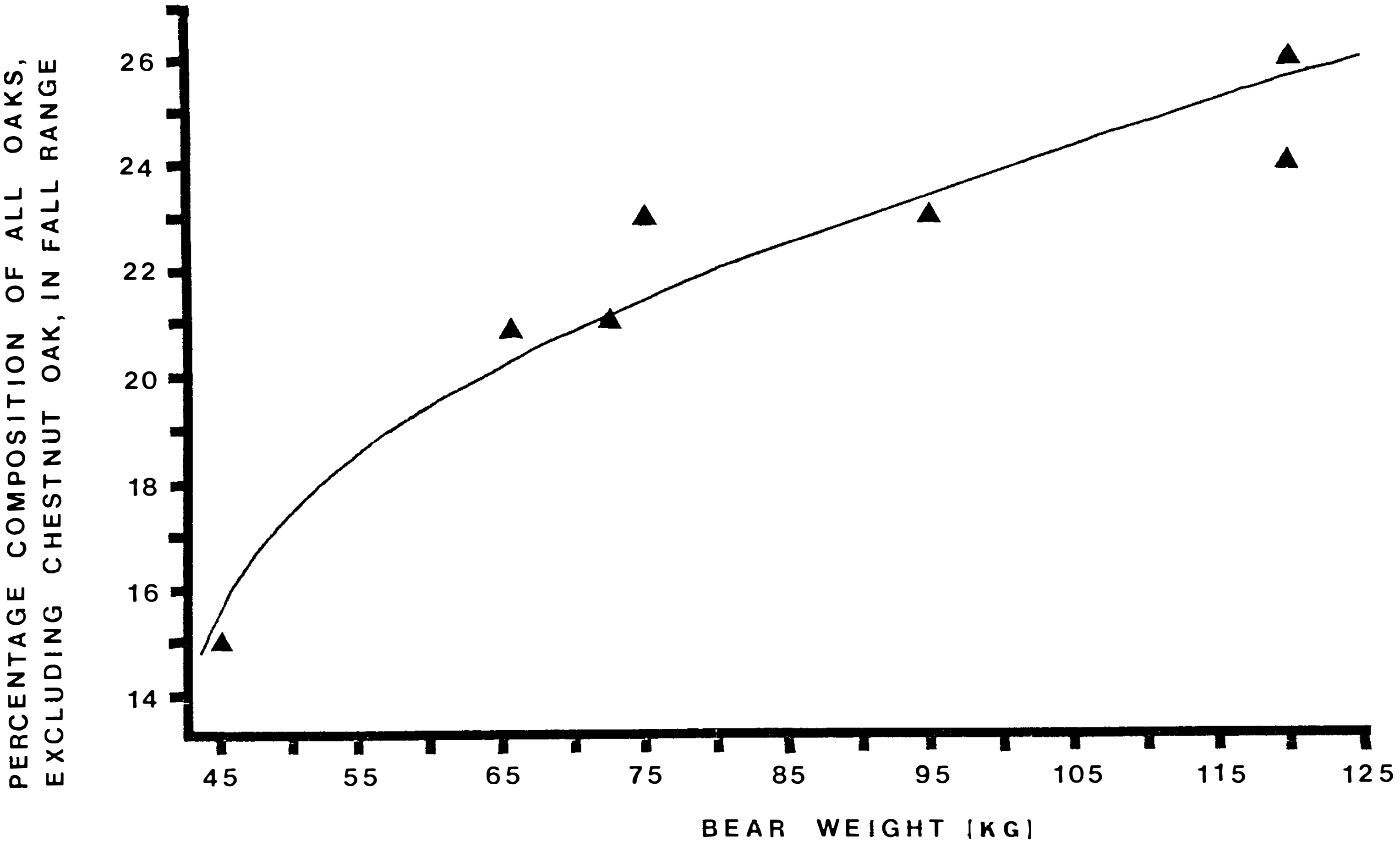

Fig. 12. The relationship between weight of male bears occupying highly overlapping fall ranges, and the abundance of preferred oak in each range. Curve generated by regression ($r^2 = 0.85$, $p < 0.05$).

the most preferred, as it is with many other wildlife species (Van Dersal 1953, Wildlife Habitat Management Handbook 1971). Three male fall ranges overlapped an area known as Whiteoak Sinks and each was located in the sink area at least once. Females apparently had to manage in less prime habitats during the fall, with individuals that were willing to stray further from their summer range faring better than those that were not (Fig. 13). Two females that did not exhibit a fall range shift were observed to have an adequate supply of chestnut oaks in their summer range, while the more preferred mast producing species were lacking.

Elevational shifts of home ranges reflected the movement of bears into areas of abundant oaks (low elevations). Fig. 14 depicts the elevational decline of activity centers from spring to summer to fall. All bears tracked with type III or type IV home ranges exhibited this trend (Table A-5 in the Appendix). Males were at a significantly lower elevation than females during the fall, again substantiating their occupancy of prime feeding areas, while there was little elevational difference between the sexes during the spring and summer. Beeman (1975) concluded that no abrupt seasonal shifts in elevation were evident for black bears in the GSMNP, however extensive blocks of missing data during the fall of his study may have precluded an accurate evaluation of this effect.

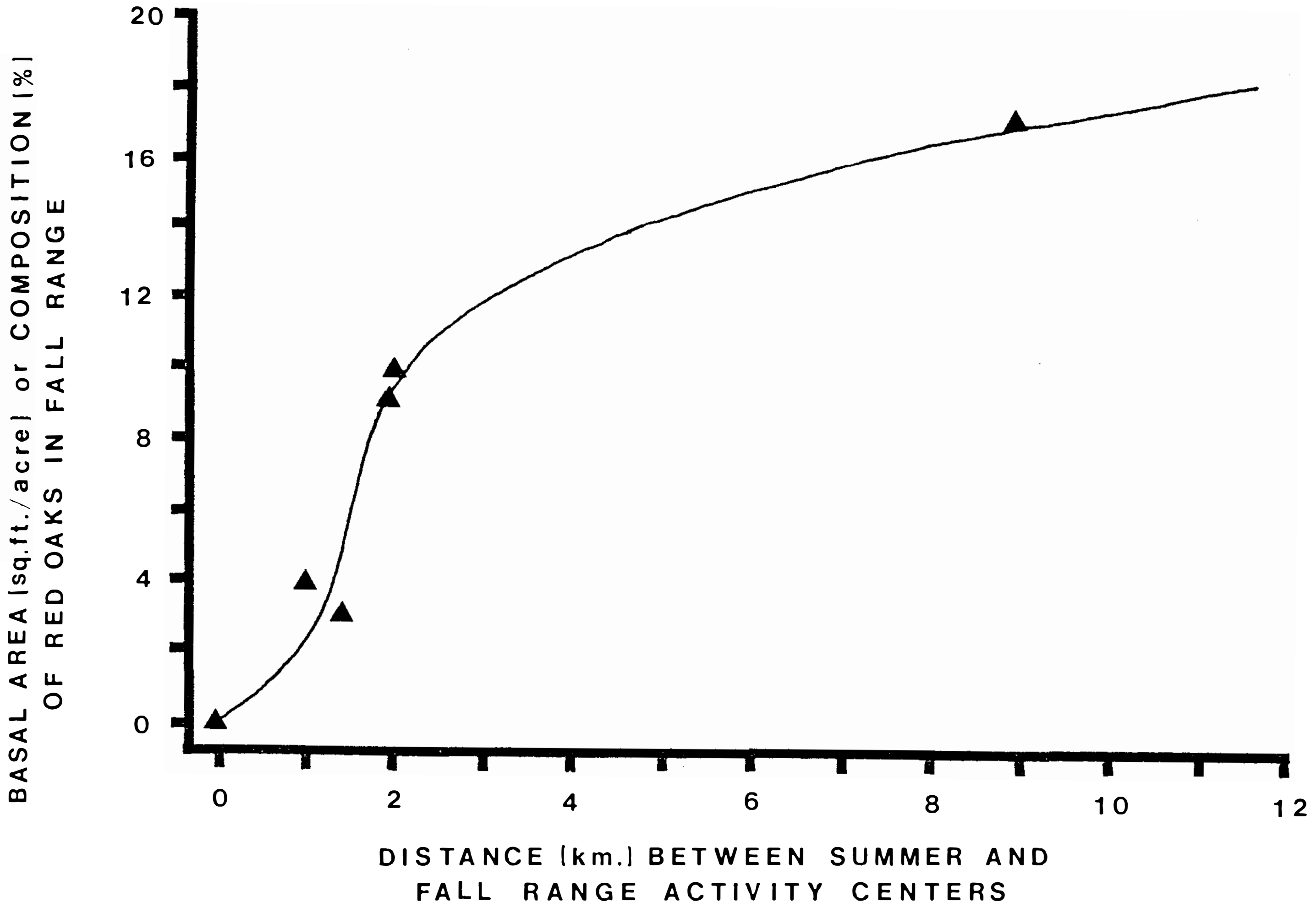

Fig. 13. The relationship between the displacement of the fall range for 6 female black bears from the Bote Mountain area, and the abundance of preferred oak in each range. Curve generated by regression ($r^2 > 0.99$, $p < 0.01$).

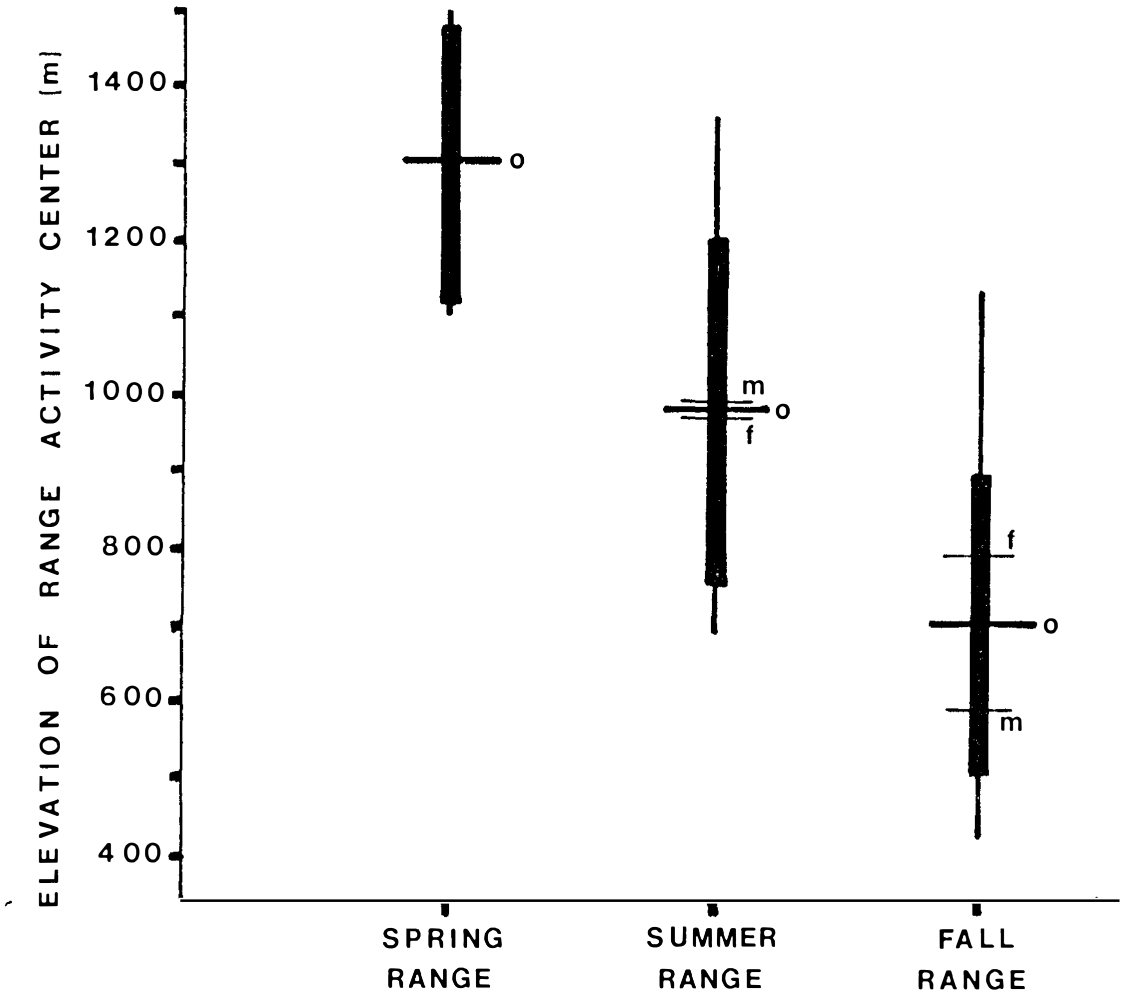

Fig. 14. Overall mean (o), ± SD and range of elevations of seasonal activity centers for radio-collared black bears from the Bote Mountain area in 1976 and 1977. Differences are significant between seasons ($p < 0.05$) and between sexes (m, f) during the fall ($p < 0.05$).

Home Range Size and Shape

As discussed in Chapter III, 2 techniques were used to define home range size. A 95 percent confidence ellipse was used to allow an equitable comparison between bears in this study and other studies, as well as among the bears within this study itself. Although the area obtained by this method is not believed to represent the actual area "traversed by the individual in its normal activities of food gathering, mating and caring for young" (definition of home range, Burt 1943:351), it does represent a valid index (which in order to avoid confusion, probably should be left unitless) free of the biases inherent in other techniques (pp. 2-3). Convex polygons were used primarily to determine geographical home range boundaries, home range shape and range overlap, although area estimates were also computed. These estimates were generally equivalent to areas substantially less than 95 percent confidence regions. Approximately half were greater than and half were less than the 75 percent confidence level, although tracking success rate indicated a higher degree of confidence for the area estimates (Table 2).

Tables 2 and 3 list the annual and seasonal home range sizes for the animals in this study calculated by both techniques. Annual area estimates for type III-c ranges were derived as the sum of the areas of the spring/summer

Table 2. Size (km^2) and confidence limits of annual and seasonal home ranges of black bears in the GSMNP. Range size is defined as the area of the convex polygon connecting the outermost locations. Confidence limits for these polygons correspond to the percentage value for an equal area confidence ellipse (%CE) and to percentage tracking success (%S).

Bear	Spring range			Spring/summer range			Fall range			Annual range		
no.(yr)	Area	%CE	%S	Area	%CE	%S	Area	%CE	%S	Area	%CE	%S
Females												
A9(76)				3.9	50-75	86	5.1	<50	88	9.0	a	87
A9(77)		-------		5.1	75-90	99	2.8	75-90	100	7.8	75-90	100
A28(76)				5.5	50-75	98						
A28(77)	0.8	50-75	100	4.1	75-90	100	5.9	75-90	96	8.5	90	98
A29(76)							11.8	75-90	97	15.8	90-95	94
A29(77)		-------		1.9	75-90	99						
A40				1.7	50-75	100	1.2	75	100	3.6	90	100
A44							3.5	75	99	5.9	75-90	99
A45					-------			-------		1.5	75-90	99
B10					-------			-------		15.8	50-75	84
B18		-------		0.4	90	100	1.0	<50	58	1.4	a	95
D2							2.8[b]	50-75	100			
E7					-------			-------		4.6	50-75	89
F5		-------			-------			-------		3.2	75	88
H1				4.1	50-75	100	3.8	50-75	100	8.6	75-90	100
63				4.2	50-75	83	1.3	50-75	100	9.5	50-75	86
64				6.5	50-75	80						
89	0.3	75	100		-------			-------		23.0	75-90	99
subavg.	0.5			3.7			3.9			8.4		
(SD)	--			(1.9)			(3.2)			(6.2)		
Sol.cub												
A43							1.3	50-75	100			

Table 2 (Continued)

Bear no. (yr)	Spring range Area	Spring range %CE	Spring range %S	Spring/summer range Area	Spring/summer range %CE	Spring/summer range %S	Fall range Area	Fall range %CE	Fall range %S	Annual range Area	Annual range %CE	Annual range %S
Males												
A26(76)							3.8	75	80	24.5	75-90	79
A26(77)	5.5	50-75	81									
A30(76)				4.5	50	100	23.8	<50	a	28.3	a	a
A30(77)	4.1	50-75	86	13.4	50-75	83	12.6	50-75	65	26.0	a	76
A42				9.0	75	96	12.7	75-90	100	22.9	75-90	98
A47				17.1	50-75	94	11.5	75-90	95	25.7	75-90	95
A50				4.8	50-75	69	7.8	75-90	100	14.7	75-90	90
A52							12.2	75	95	20.3	75	96
A53							18.3	75-90	99			
B12				10.9	50-75	85	2.5	50	85	13.4	a	86
C14		-------		1.4	75	93	7.5	50-75	84	12.8	75-90	89
65				5.8	50-75	51	10.3	75-90	79	23.4	75-90	70
subavg.	4.8			8.4			11.2			21.2		
(SD)	--			(5.2)			(6.1)			(5.6)		
totavg.	2.7			5.8			7.4			13.8		91

[a] Value could not be calculated due to methodology.

[b] Area of secondary fall range only.

---- Indiscrete range.

Table 3. Annual and seasonal home range size (km^2) for black bears in the GSMNP. Range size is defined as the area of the 95 percent confidence ellipse.

Bear no. (yr)	Spring range area	Spr/sum range area	Fall range area	Annual range area	Total sample size[a]
Females					
A9(76)		14.3	(69.4)	(83.7)	35
A9(77)	----	8.0	5.1	12.5	185
A28(76)		14.9			28
A28(77)	2.8	8.6	9.9	11.6	159
A29(76)			24.5	19.6	66
A29(77)	----	3.5			
A40		6.3	3.0	5.3	68
A44			7.7	9.5	83
A45		----	----	2.6	36
B10		----	----	44.6	50
B18	----	0.6	(13.5)	(14.1)	71
D2			7.9[b]		45
E7		----	----	10.5	21
F5	----	----	----	5.2	34
H1		12.5	9.7	13.3	70
63		12.2	7.4	18.4	29
64		24.2			16
89	0.8	----	----	29.5	61
subavg.	1.8	10.5	9.4	15.2	
(SD)	--	(6.7)	(6.5)	(11.8)	
Sol.cub					
A43			3.8		23
Males					
A26(76)			8.8	47.2	63
A26(77)	14.3				
A30(76)		27.5	(391.9)	(419.4)	13
A30(77)	17.8	36.8	(66.1)	(102.9)	42
A42		21.4	27.9	34.6	76
A47		(90.4)	21.9	44.5	58
A50		20.4	14.6	25.9	72
A52			28.6	46.0	48
A53			34.9		80
B12		43.7	16.5	60.2	26
C14	----	3.5	38.1	28.0	35
65		33.5	19.4	42.8	46
subavg.	16.1	27.6	23.4	41.1	
(SD)		(13.2)	(9.7)	(11.2)	
totavg.	8.9	17.2	16.1	25.6	

[a] The number of locations actually used in this analysis was often less than the value indicated (pp. 16-17).

[b] Area of secondary fall range only.

() Area estimate not averaged due to possible bias (p. 48).

---- Indiscrete range.

and fall ranges excluding the travel routes between them. Type III-b annual range sizes were calculated by considering the entire scatter of points to be a single group. Estimates computed by the 2 methods for both annual and seasonal ranges compared favorably by regression ($r = 0.50$, $N = 64$, $p < 0.001$) especially when type III-c fall ranges were eliminated from the analysis ($R = 0.82$, $N = 59$, $p < 0.001$). These ranges were often highly inaccessible (low success rate), which resulted in small sample sizes for radio-locations thereby inflating the 95 percent confidence region. This inflation caused type III-c annual and fall ranges to appear much larger ($p < 0.05$) than other range types when confidence ellipse estimates were used. No appreciable difference was noted using the polygon. Because of this confusion, the following comparisons involving annual and fall ranges were made independent of bears with type III-c ranges. All conclusions were confirmed by both area estimates.

Males had larger ($p < 0.05$) spring/summer, fall and annual ranges than females, averaging 2.3-3.3 times more area (depending on the season and method of estimate). Mean annual range size was 42 km^2 for adult males and 15 km^2 for adult females. These estimates are considerably lower than those reported by Alt et al. (1976) and Lindzey et al. (1976) who used the same method of analysis. No difference was evident between females with offspring and solitary females, nor between bears of the same sex from different sections of the Park. Spring/summer and fall range sizes were also not significantly different for either sex. Exactly half the bears of each sex had larger spring/summer ranges, and half had larger fall ranges. The 4 discrete spring ranges observed appeared more restricted than other seasonal ranges (Fig. 6, p. 24) although no statistical significance could be attributed due to the small sample size. Annual ranges are, by definition, larger than the seasonal ranges (although some instances may be noted on Table 3, p. 47, where the increased sample size of the annual range actually functioned to shrink the area estimate below that obtained for 1 of the seasonal ranges). Of the 6 male and 6 female type III-b ranges where estimates were made for a spring/summer, fall and annual range, annual ranges averaged 1.5 times the area of the seasonal ranges. Type III-c annual ranges are exactly twice the average of the 2 seasonal ranges and may often exceed the area of any 1 seasonal range by 500 percent or more. These points stress the need for year round tracking in order to obtain useful estimates of home range size.

One full year of radio-tracking apparently gives more accurate home range estimates than even several years of seasonal tracking, at least for the bears in the GSMNP. Year to year shifts of the summer range are considerably less than the shifts that may occur seasonally in 1 year ($p < 0.01$). Displacement of the activity center from summer to fall averaged 2.8 km and 10.0 km for type III-b and type III-c ranges respectively (Table 4), while year to year displacement of the summer activity center averaged only 1.1 km (Table 5). Amstrup and Beechum (1976) and Alt et al. (1977) also noted geographic stability of the home range activity center from year to year.

In this study, the boundaries of the spring/summer range also appeared relatively fixed from year to year. Many ranges bordered on the same ridge systems, often those dividing watersheds. The shape of the watershed, then, has an important impact on the shape of the home range, especially for those animals that restrict their range to 1 watershed. Although most male ranges are longer and wider than female ranges, the length:width ratio averages about 2:1 for both sexes and for annual (excluding type III-c) as well as seasonal ranges (Table 6). The ratio of the eigenvalues in the confidence ellipse analysis can also be used to describe the linearity of the home range. These values are presented in Table 6 for those ranges where the assumptions discussed by Koeppl et al. (1975) have been met. Average linearity was determined to be 3.6:1. The increase in linearity using this method is due to the stretched appearance of the confidence ellipse with respect to the

Table 4. Displacement of seasonal ranges of black bears in the GSMNP measured as the distance (km) between seasonal activity centers.

Bear no. (yr)	Spring to summer range	Spring/summer to fall range	
		type III-b	type III-c
Females			
A9(76)			8.9
A9(77)		1.9	
A28(77)	1.1	(1.0)	
A29(76)		1.8	
A29(77)			8.6
A40		1.4	
B18			3.5
D2		3.0[a]	12.6
D16			18.2
H1		2.0	
63		2.7	
subavg.		2.1	10.4
(SD)		(0.6)	(5.4)
Males			
A26	b	5.1	
A30(76)			17.6
A30(77)	3.5		9.0
A42		2.3	
A47		2.7	
A50		2.9	
A53			6.1
B12			5.3
C14		4.3	
65		3.1	
subavg.		3.4	9.5
(SD)		(1.1)	(5.6)
totavg.	2.3	2.8	10.0

[a] Secondary fall range shift.

[b] Could not be determined due to failure of the radio-collar.

() Type III-a fall shift shown for comparative purposes only.

Table 5. Year to year displacement of the summer activity centers of black bears in the GSMNP.

Bear no.	Years	Displacement distance (km)
A9	1976-1977	0.8
A28	1976-1977	0.8
A30	1976-1977	1.6
63	1975-1976[a]	1.4
64	1975-1976[a]	1.3
A45	1975-1977[a]	0.8
avg.		1.1
(SD)		(0.4)

[a] Activity center calculated from data presented by Eubanks (1976).

Table 6. Indices of home range shape tabulated for annual and seasonal ranges of black bears in the GSMNP. L: length (km), W; width (km), λ_x/λ_y: ratio of eigenvalues.

Bear no. (yr)	Spring range				Spring/summer range				Fall range				Annual range			
	L	W	L/W	λ_x/λ_y	L	W	L/W	λ_x/λ_y	L	W	L/W	λ_x/λ_y	L	W	L/W	λ_x/λ_y
Females																
A9(76)					4.1	1.8	2.3	--	4.2	2.4	1.8	--	(11.5)			
A9(77)					3.1	2.0	1.6	2.8	2.6	1.6	1.6	2.1	4.5	2.1	2.1	4.9
A28(76)					3.7	2.1	1.8	3.1								
A28(77)	1.6	0.7	2.3	--	3.2	1.7	1.9	3.0	3.5	2.0	1.8	2.2	3.7	3.2	1.2	2.6
A29(76)									5.1	3.4	1.5	-- }	5.7	2.9	2.0	3.7
A29(77)					2.8	1.0	2.8	--								
A40					2.0	1.4	1.4	--	2.3	0.8	2.9	4.5	4.0	1.4	2.9	6.8
A44									3.5	1.7	2.1	2.9	4.6	1.9	2.4	--
A45													1.8	1.3	1.4	1.5
B10													5.4	4.9	1.1	--
B18					1.0	0.6	1.7	3.0	1.7	0.9	1.9	--	(4.8)			
D2									2.5	1.8	1.4	--				
E7													6.1	1.3	4.7	--
F5													3.3	1.5	2.2	6.9
H1					3.3	2.2	1.5	--	2.9	1.9	1.5	--	4.3	2.9	1.5	3.6
63					3.0	1.9	1.6	--	2.2	1.0	2.2	--	4.7	2.7	1.7	3.5
64					6.2	1.9	3.3	--								
89	0.7	0.7	1.0	--									6.8	5.4	1.3	--
subavg.	1.1	0.7	1.7		3.2	1.7	2.0		3.1	1.7	1.9		4.6	2.6	2.0	4.2
Sol.cub																
A43									1.9	1.1	1.7	1.9				

Table 6 (Continued)

Bear no. (yr)	Spring range L	Spring range W	Spring range L/W	Spring range λ_x/λ_y	Spring/summer range L	Spring/summer range W	Spring/summer range L/W	Spring/summer range λ_x/λ_y	Fall range L	Fall range W	Fall range L/W	Fall range λ_x/λ_y	Annual range L	Annual range W	Annual range L/W	Annual range λ_x/λ_y
Males																
A26(76)									3.0	1.7	1.8	3.5	8.6	4.1	2.1	--
A26(77)	4.9	1.8	2.7	8.3												
A30(76)					4.1	1.4	2.9	--	9.1	5.1	1.8	--	(23.4)			
A30(77)	3.5	2.0	1.8	--	6.4	2.8	2.3	6.2	7.1	2.1	3.4	--	(12.9)			
A42					4.5	3.2	1.4	--	5.7	3.0	1.9	--	8.6	4.0	2.2	--
A47					6.2	3.8	1.6	--	4.8	4.2	1.1	1.4	7.0	5.6	1.3	--
A50					3.8	1.7	2.2	--	4.7	2.8	1.7	2.3	6.8	3.3	2.1	5.2
A52									5.8	3.3	1.8	--	7.1	4.6	1.5	1.9
A53									6.8	3.3	2.1	--				
B12					6.5	2.4	2.7	--	2.3	2.1	1.1	--	(9.0)			
C14					1.8	1.1	1.6	--	4.6	2.4	1.9	--	7.1	2.4	3.0	--
65					6.0	1.6	3.8	--	6.9	2.7	2.6	--	9.7	5.7	1.7	--
subavg.	4.2	1.9	2.3		4.9	2.3	2.3		5.5	3.0	1.9		7.8	4.2	2.0	
totavg.			2.0				2.1				1.9				2.0	4.1

--Scatter of location points either too highly skewed or kurtotic, or sample size too small (<20) for this value to be meaningful.

()Distance between most widely separated location points of a type III-c home range; value not included in average.

polygon. This says, in a sense, that the boundaries of the range width are more certain than those of the range length. This is exactly what would be expected of bears occupying deep narrow watersheds.

Social Interactions

Since bears could not be directly observed in this study, social interactions were inferred from home range overlap, distance between activity centers, proximity of simultaneous radio-locations and dispersal patterns.

Range overlap was measured whenever 2 or more animals appeared to occupy the same general area for an extensive period of time. The spring/summer ranges of 2 females in the West Prong watershed overlapped considerably in both 1976 and 1977 (Fig. 15). The area of overlap contained 90 percent of the range of A28 and 73 percent of the range of A9. Considering the ages of these 2 bears (10 and 3 years respectively), the possibility exists that A9 is the daughter of A28 as suggested by the results of studies by Jonkel and Cowan (1971) and Rogers (1977). Although the activity centers of these 2 ranges were only 100 m apart, the average distance between simultaneous radio-locations was 1 km, possibly indicating mutual avoidance. Only once were the 2 bears located within 100 m of each other.

For a known mother-daughter pair tracked in this study, avoidance was noted after the family breakup in the spring

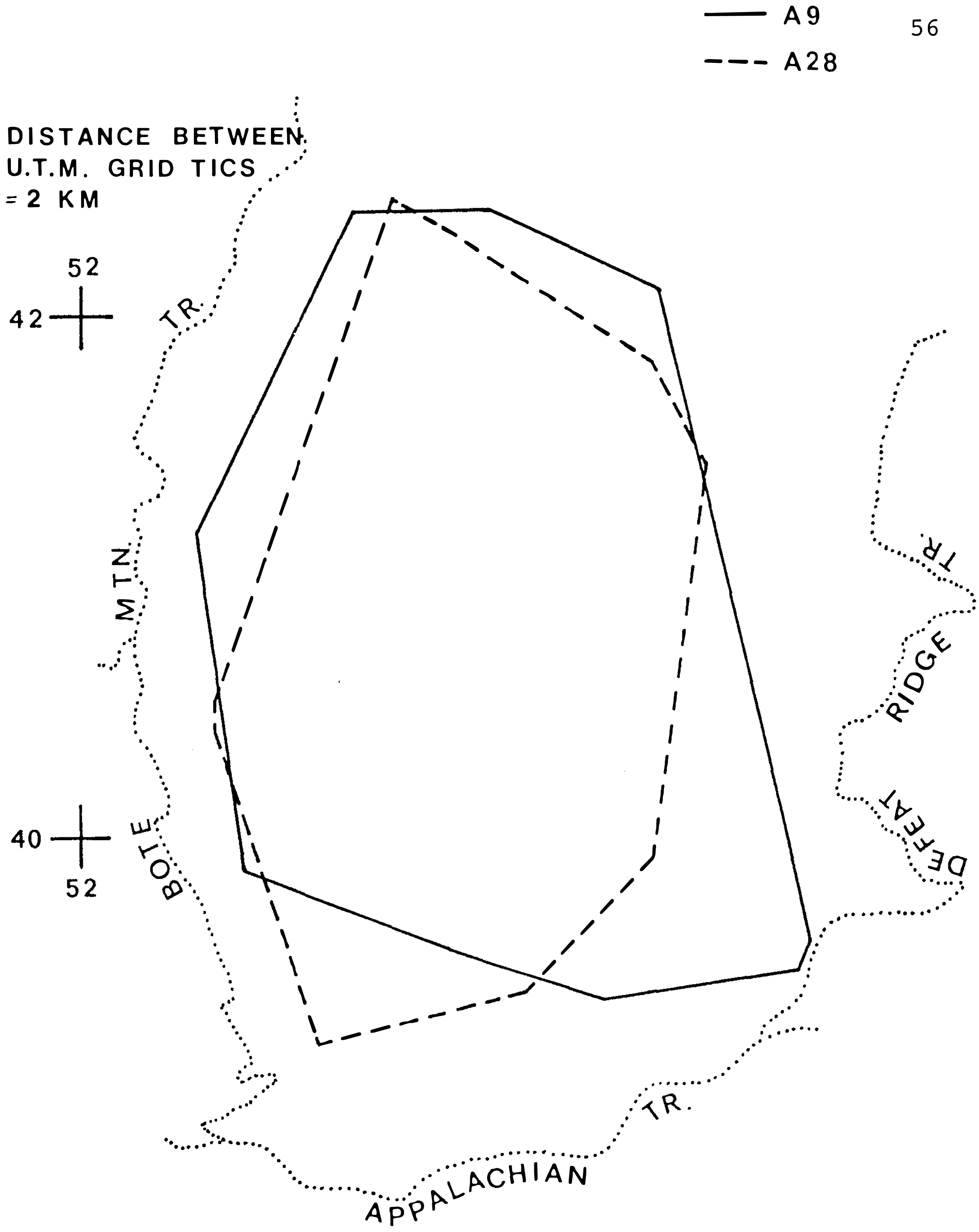

Fig. 15. Extensive spring/summer range overlap for an adult female (A28) and subadult female (A9) in the Bote Mountain area in 1977.

of the daughter's second year. Although both bears occupied virtually the same small spring range (< 1000 m at the widest point), activity centers were 170 m apart and the 2 were frequently separated by 300 m or more (Fig. 16). Two observations were made where the bears had apparently rejoined. On 1 of these occasions, they remained together for at least 5 days. However, the results of this study may have been biased since the breakup occurred prematurely, due to human disturbance at the den site. Reynolds and Beechum (1977) noted intermittent reassociation after the initial family breakup, while Rogers (1977) found this to be rare.

The actual extent of range overlap for both related and unrelated individuals could not be determined because even in the central study area, only a small percentage of the bears were radio-collared. If no overlap occurred, the West Prong watershed would be able to support only about 6 individuals (using the mean spring/summer range area from Table 2, p. 45), however Eagar (1977) estimated that there were 35 residents there in the summer of 1974, and 52 in the summer of 1975. It is therefore evident that spring/summer ranges for bears in the GSMNP overlap considerably. This was also recognized by Beeman (1975) and Eubanks (1976). Studies in other areas have also indicated extensive range overlap (Spencer 1955, Sauer et al. 1969, Amstrup and

Fig. 16. Distance between a mother (89) and her yearling offspring (B18) throughout the spring of 1977. The radio-collar on bear 89 ceased functioning after 13 May.

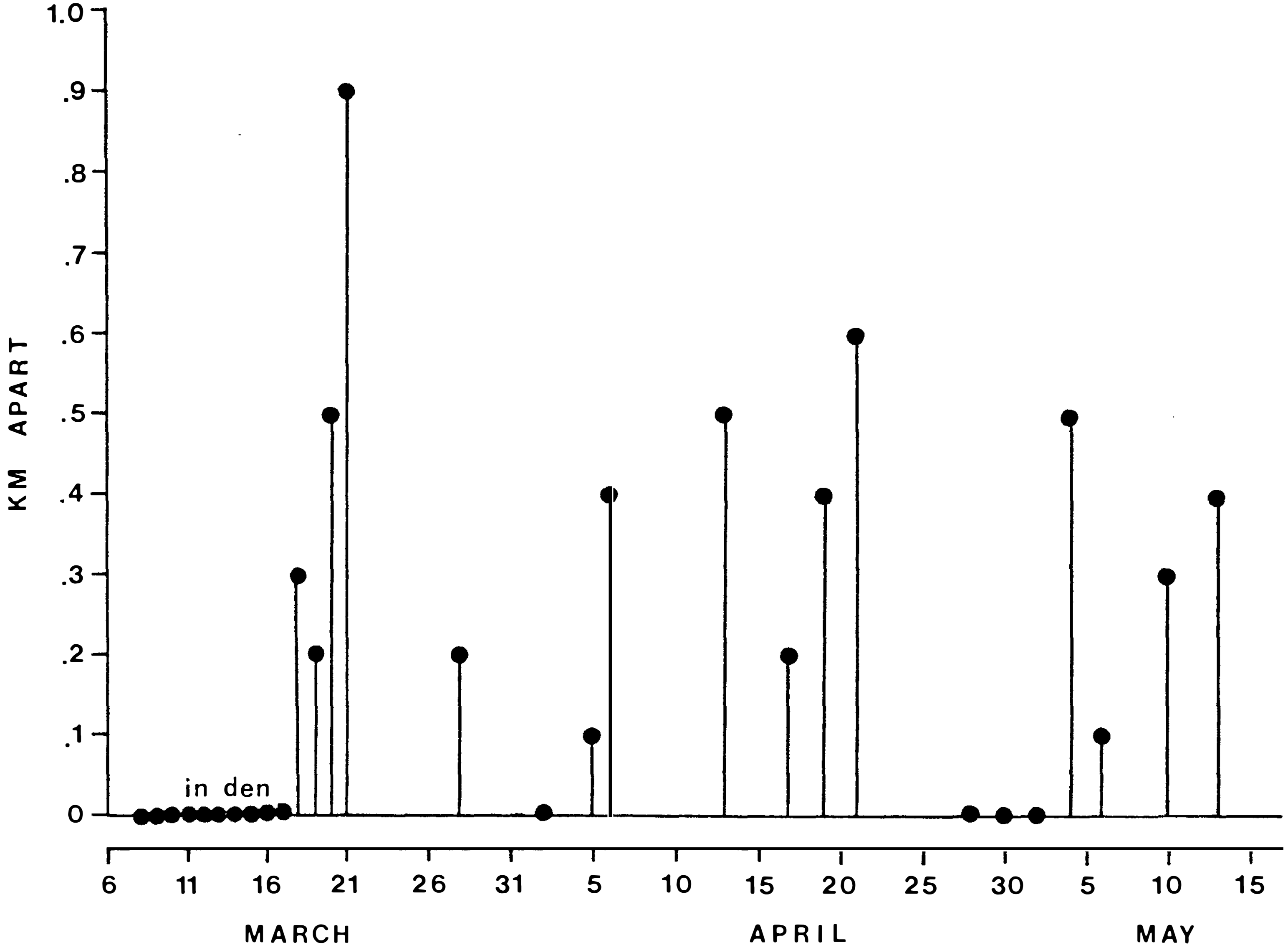
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
KM APART
in den
6
11
16
21
26
31
5
10
15
20
25
30
5
10
15
MARCH
APRIL
MAY

Fig. 16

Beechum 1976, Reynolds and Beechum 1977, LeCount 1977, Lindzey and Meslow 1977), although some authors indicate that only minimal overlap occurs between individuals of the same sex (Jonkel and Cowan 1971, Poelker and Hartwell 1973).

Substantial range overlap was also observed during the fall. The fall range of 1 female with cubs completely overlapped that of another family group (Fig. 17). Temporal separation again indicated a mutual avoidance. The seasonal activity centers were only 200 m apart while monthly activity centers were separated by as much as 1 km. The average distance between the 2 families at any given time was 700 m (range 100-1600 m).

As previously mentioned (p. 29), many male fall ranges were clumped and overlap was extensive. Fig. 18 depicts the fall ranges of 5 male bears in 1977. If virtually all subadult and adult males from the Bote Mountain area as well as some males from other areas utilize this region in the fall, then the density likely exceeds 1 bear per km^2. This high density is supported by an abundance of preferred species of oak (p. 38). During poor mast years, however, increased competition may lead to social intolerance and many bears may be driven out of their traditional fall feeding grounds. Because fall ranges of females are more dispersed, they may be less radically affected by a mast

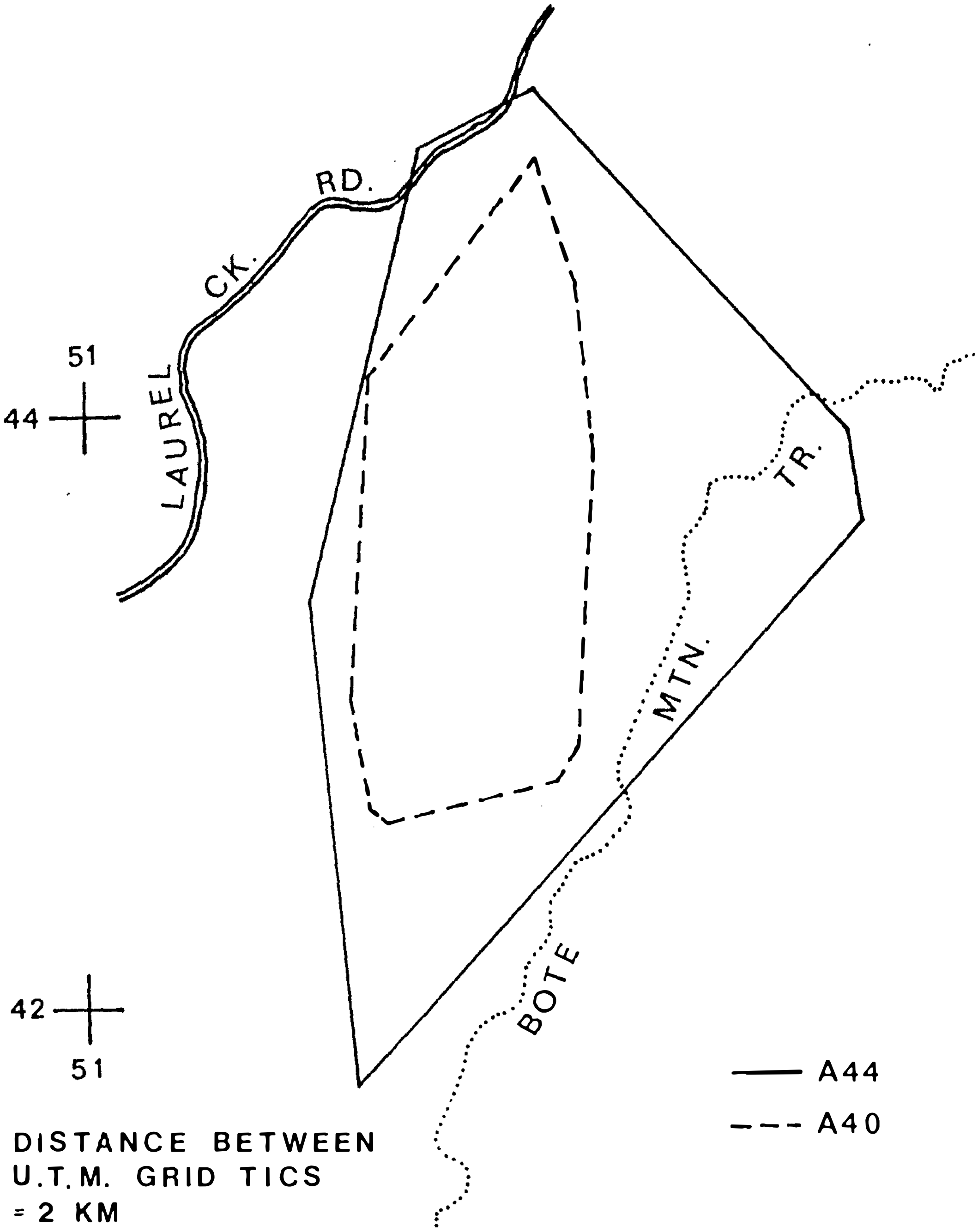

Fig. 17. Fall range overlap between 2 family groups in the Bote Mountain area in 1977.

Fig. 18. Extensive fall range overlap among 5 males in the Laurel Creek watershed in 1977. Percentage overlap ranges from 56 percent for A53 to 100 percent for A42.

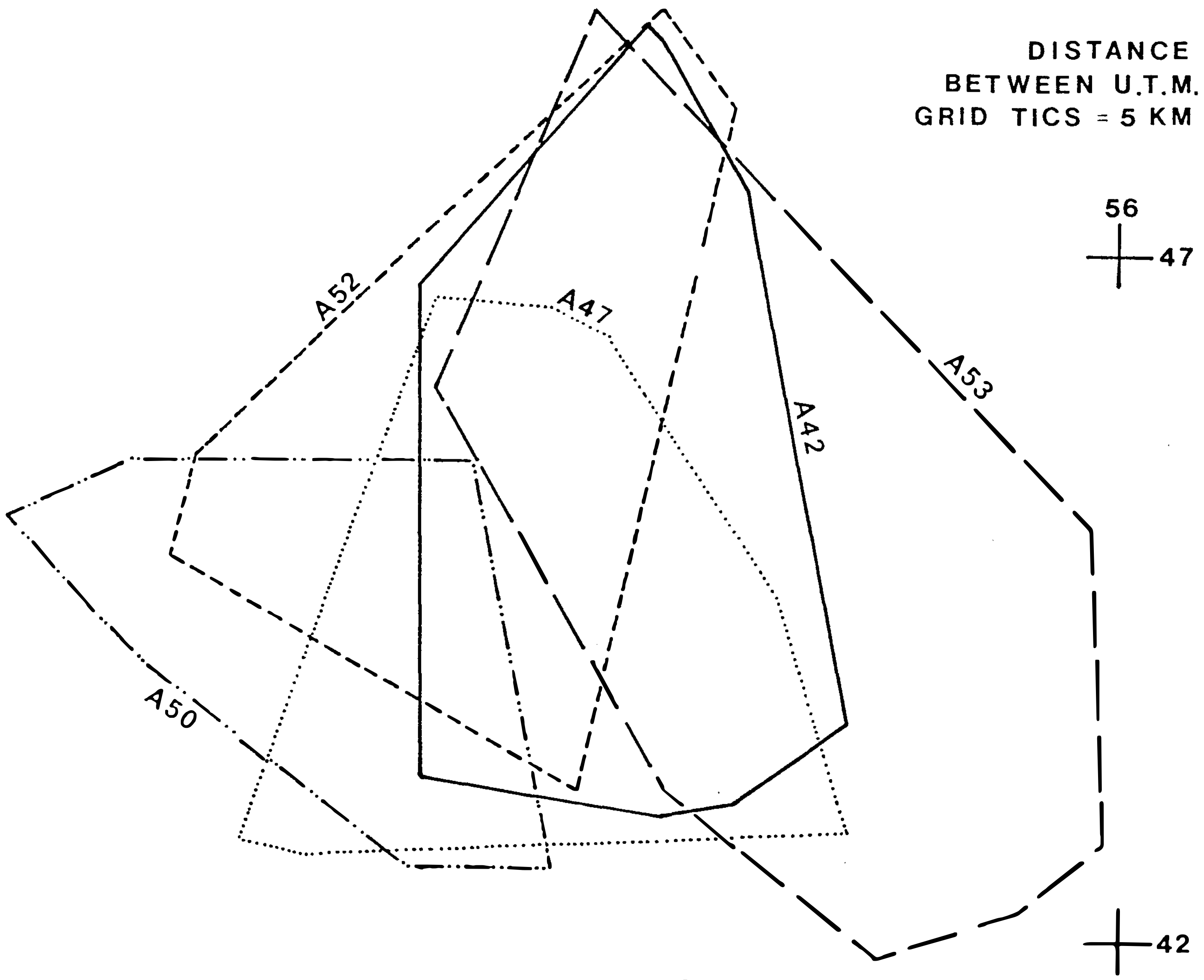
DISTANCE
BETWEEN U.T.M.
GRID TICS = 5 KM
56
47
42
56
A52
A47
A42
A53
A50

Fig. 18

shortage. Beeman and Pelton (1977) noted a sharp increase in the kill of subadult males outside the Park during 2 mast crop failures. In this study, 2 radio-collared males (A11 and A30) and 1 radio-collared female (A29) were killed outside the Park boundaries during the fall. One cub (A40) was poached from within the central study area.

The only natural death observed may have also been a function of social interactions during fall foraging. The individual involved was an 11 year old female (#63). Her summer range in 1975 (Eubanks 1976) and 1976 was in an area used heavily by other females in the fall. In view of her old age, it may be speculated that she was forced from her summer range by the advance of other females and enticed by the abundance of oak in the area used exclusively by the males. Here she maintained a fall range for only 20 days, considerably less time than any other bear in this study (Fig. 9, p. 33, and Table A-4 in the Appendix). She returned to her summer range and died about 2 weeks later, possibly of injuries resulting from social interactions with the males. Rogers (1977) observed considerable aggression directed towards female black bears attempting to feed at a dump utilized exclusively by males in the fall. One instance of a black bear mortality resulting from wounds incurred in an aggressive interaction has been reported in the GSMNP. Mutual avoidance serves to reduce such agonistic encounters; only twice were 2 males in the fall range located within 100 m of each other.

Diel Movements

Hourly movements were monitored on a periodic basis from May through December although considerably more data were collected in the fall than in the spring and summer. Because of similarities in home range structures, as previously discussed, and apparent similarities in the daily activity patterns (pp. 79-81), spring and summer (May-August) diel movement data were grouped together for this analysis. Some comparisons were hampered by the fact that only 1 male was tracked for a complete 24 hr period during the spring and summer, while sample sizes in the fall were relatively equal for the 2 sexes.

Mean total daily movement for males was greater than that for females ($p < 0.05$) considering the whole year or just the fall season (a valid spring/summer sex comparison could not be made) (Table 7). Net daily movement, however, was not significantly different because males appeared to travel in a more circuitous fashion. Examples of extremes in circuity and linearity of the daily travel routes are illustrated in Fig. 19. In general, fall movements were more circuitous ($p < 0.05$) than spring/summer movements; thus, although total daily movement increased from summer

Table 7. Daily movement parameters of black bears in the GSMNP (distance in km).

Category (n)	Total daily movement mean	Total daily movement (SD)	Total daily movement max.	Net daily movement mean	Net daily movement (SD)	Circuity[a] mean	Circuity[a] (SD)	Daily range length mean	Daily range length (SD)	Daily range length range	Daily ÷ seasonal range length[b] mean	Daily ÷ seasonal range length[b] (SD)
Spr/summer												
Females (6)	3.2	(1.2)	4.2	1.3	(1.0)	0.4	(0.2)	1.6	(0.9)	0.6-3.1	0.6	(0.1)
Males (1)	1.7	---		1.0	---	0.6	---	1.0	---		0.2	---
Total (7)	3.0	(1.2)		1.3	(1.0)	0.5	(0.2)	1.5	(0.8)		0.5	(0.2)
Fall												
Females (23)	4.9	(2.2)	7.1	0.8	(0.6)	0.3	(0.2)	1.5	(0.7)	0.4-2.7	0.5	(0.2)
Males (17)	6.7	(2.7)	10.1	1.6	(1.3)	0.2	(0.2)	2.1	(1.1)	0.6-4.3	0.4	(0.2)
Total (40)	5.7	(2.6)		1.2	(1.0)	0.3	(0.2)	1.8	(0.9)		0.5	(0.2)
Annual												
Females (29)	4.6	(2.2)		1.0	(0.8)	0.3	(0.2)	1.5	(0.7)		0.5	(0.2)
Males (18)	6.4	(2.9)		1.5	(1.2)	0.2	(0.2)	2.1	(1.1)		0.4	(0.2)
Total (47)	5.3	(2.6)		1.2	(0.9)	0.3	(0.2)	1.7	(0.9)		0.5	(0.2)

[a] Where 1 = straight line movement and 0 = return to the original location.

[b] Calculated on a per individual bear basis.

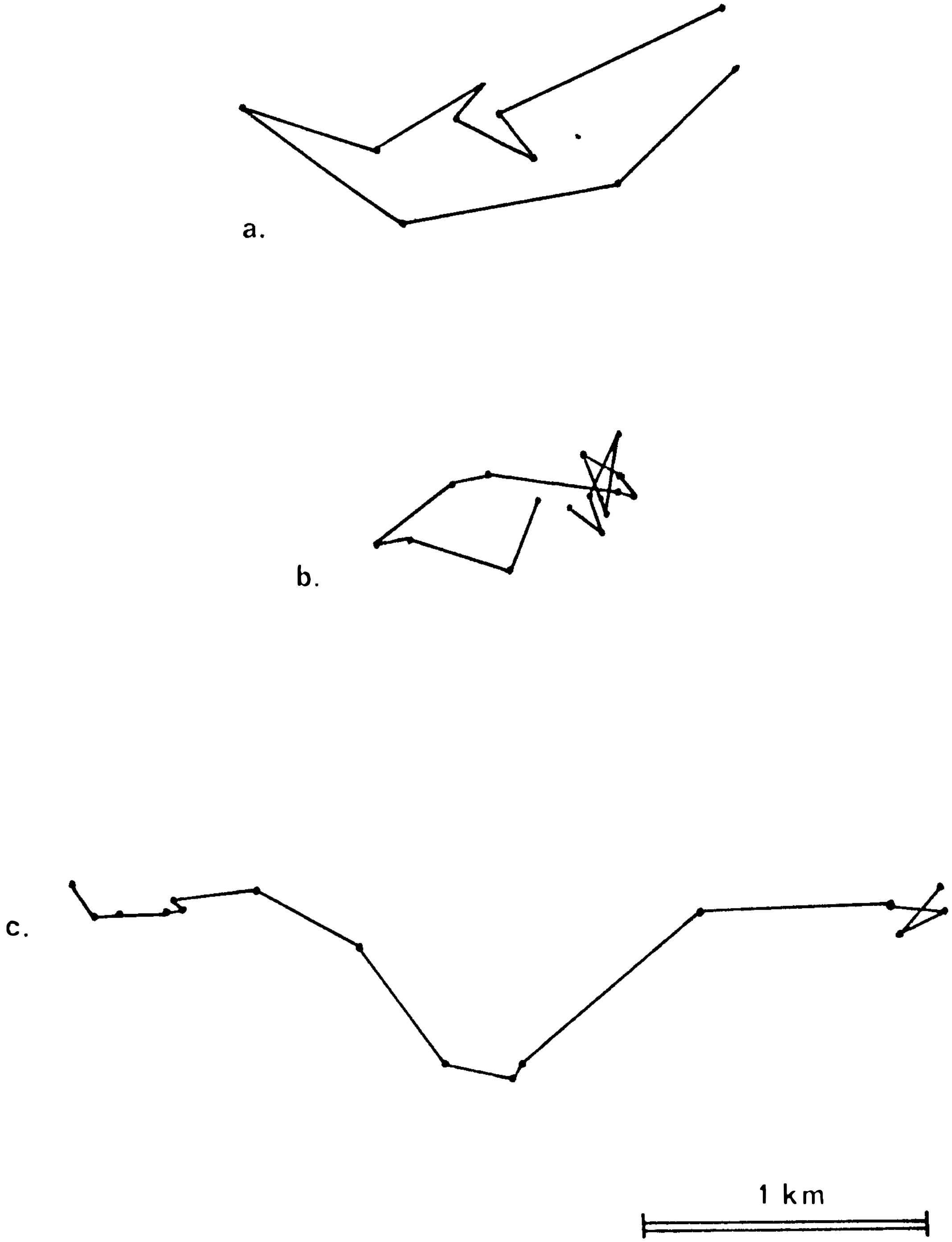

Fig. 19. Maximum and minimum circuity of diel travel routes. (a) Circular travel route of a subadult male (A42) during the fall of 1977, circuity = 0.05; (b) zig-zag travel route of an adult female (H1) during the fall of 1977, circuity = 0.04; (c) linear travel route spanning entire length of home range of a subadult female (A9) during the spring of 1977, circuity = 0.74.

to fall ($p < 0.05$), avoidance behavior (pp. 64-65) have functioned to restrict net movement and the daily range length especially where density levels were particularly high. Mean net daily movement and mean daily range length were not significantly different between seasons. Net daily movement averaged 1.2 km which compares favorably with the findings of Amstrup and Beechum (1976) of 1.3 km for black bears in Idaho. Alt (1977) noted that translocated bears made considerably greater net movements per day than those traveling within their home ranges. It is not known whether total daily movement is also increased in this situation.

During the fall, mean daily range length for males exceeded that of females ($p < 0.05$). A slight tendency existed for the long axis of the daily range to be aligned with that of the seasonal range. Daily range lengths were usually one-third to two-thirds the distance across the seasonal range (calculated on a per individual bear basis). This is consistent with the findings of Beeman (1975). Some daily range lengths were less than 10 percent of the seasonal length, while in 1 case a daily travel route spanned the entire length of the home range (Fig. 19).

During the fall, males moved further per hour than females ($p < 0.05$) (Table 8). Overall hourly travel rates appeared greater during the fall than during the spring/summer, however this was due to the lack of nocturnal

Table 8. Hourly movement parameters of black bears in the GSMNP (km/hr).

Category (n)	All day avg. rate of travel		Mean "active" (0600-2200) rate of travel	Mean "nocturnal" (2300-0500) rate of travel	Maximum hourly rate
	mean	(SD)			
Spr/summer					
Females (6)	0.13	(0.05)	0.21	0.0	1.1
Males (1)	0.07	--	0.15	0.0	0.6
Total (7)	0.12	(0.05)	0.20	0.0	
Fall					
Females (23)	0.21	(0.09)	0.23	0.16	1.4
Males (17)	0.28	(0.11)	0.31	0.22	1.6
Total (40)	0.24	(0.11)	0.27	0.17	
Annual					
Females (29)	0.19	(0.09)	0.22		
Males (18)	0.27	(0.12)	0.29		
Total (47)	0.22	(0.11)	0.26		

activity in the spring and summer (pp. 79-81). Average travel rates between the hours 0600-2200 were virtually constant (200-300 m/hr) with respect to the time of the year. The maximum hourly movement recorded in this study was 1.6 km. Rogers (1977) observed travel rates of 1.6-2.7 km/hr for bears not involved in foraging.

CHAPTER V

RESULTS AND DISCUSSION: ACTIVITY BEHAVIOR

Assessment of Equipment

Activity interpreted by the motion sensitive radio-collars used in this study correlated with activity measured by the distance between successive hourly locations during early and middle fall (2 Oct-4 Dec, 1976 and 1977) (Fig. 20). A similar analysis for spring/summer data also indicated a high correlation, especially when 2 unusually long, hourly movements of greater than 800 m were disregarded due to the small sample size ($r = 0.88$, $N = 24$, $p < 0.001$). The above relationship exists despite the countering influence of such factors as individual behavioral peculiarities among the bears (a particular animal may be very active but restrict its movements, p. 94), recognizable differences in the sensitivity of the activity monitor in each collar (tested prior to being put in the field) and variables affecting the daily activity rhythm of the population as a whole (weather and time of day may greatly affect the distance moved during any period of activity, pp. 83-86. Too few observations were made on bears without activity sensing radio-collars to warrant a similar comparison between changes in signal integrity and distance moved, but on many occasions it was noted that signal quality fluctuated on collars having

Fig. 20. Comparison of 2 measures of activity for 13 black bears radio-tracked during early and middle fall (2 Oct-4 Dec, 1976 and 1977). Upper curve represents average distance moved per hour (mean sample size for each point = 27). Lower curve represents corresponding percentage activity as determined by the activity monitor (since activity was usually sampled twice an hour, mean sample size for each point = 52). Regression indicated that the 2 measures were highly correlated ($r = 0.69$, $N = 24$, $p < 0.001$).

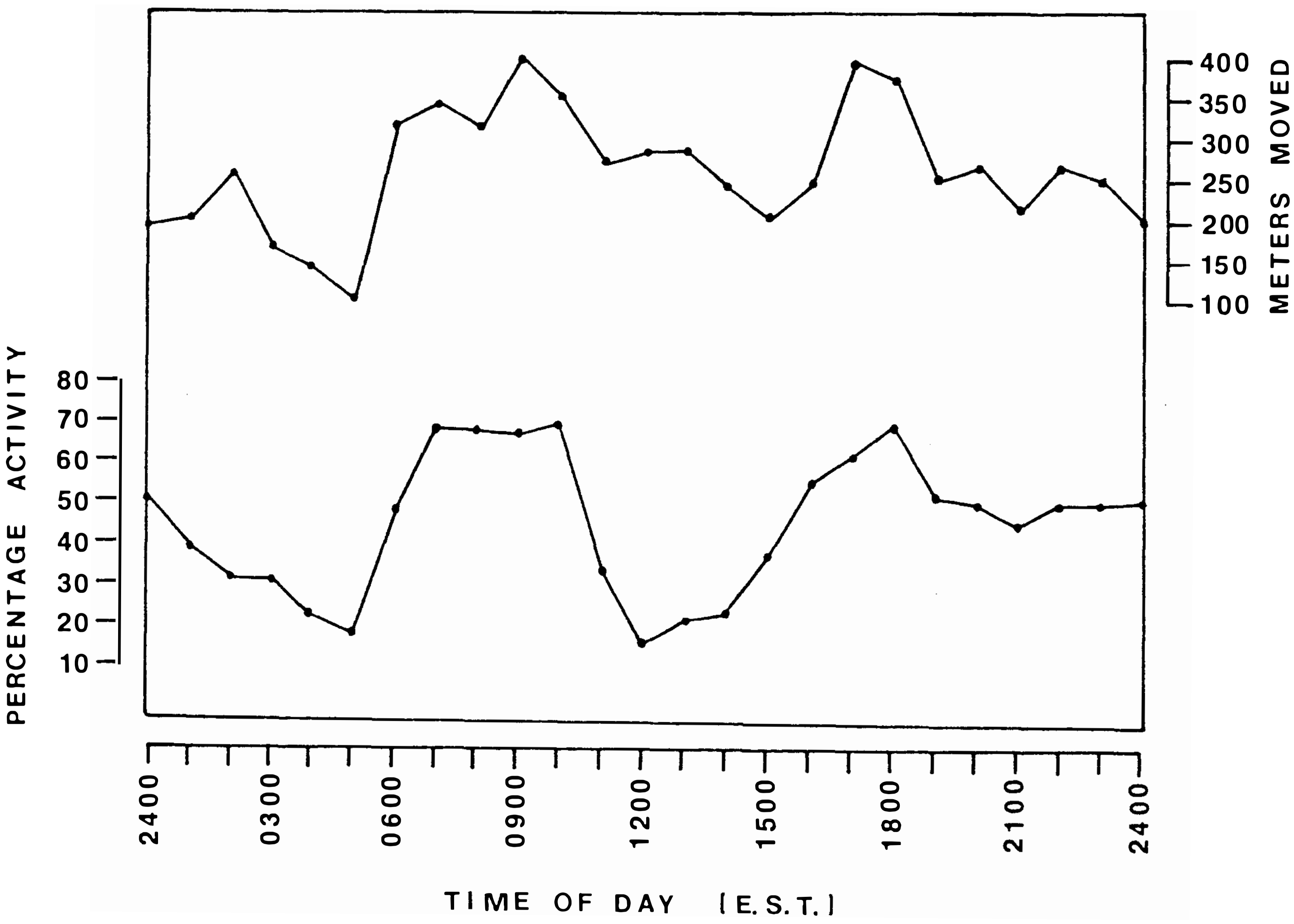
PERCENTAGE ACTIVITY
80
70
60
50
40
30
20
10
400
350
300
250
200
150
100
METERS MOVED
2400
0300
0600
0900
1200
1500
1800
2100
2400
TIME OF DAY (E.S.T.)

Fig. 20

the sensor, while the pulse rate remained constant (indicating inactivity). The above supports Lindzey and Meslow's (1977) observation that activity as determined by modulations in signal strength and/or frequency is exaggerated, possibly by radio-interference, temperature fluctuations and very slight movements by bears. In contrast, interference and temperature fluctuations did not affect the workings of the activity monitor, and slight movements of the head could be distinguished from true activity (pp. 19-20). Such head movements were considered to represent general inactivity in this study. To verify this assumption, data were reviewed in which 2 independent observations were made within a 10-min period on the same bear. When a head movement was noted by only 1 observer, inactivity was noted by the other observer 64 percent of the time, which proved to be a significant association between what was called head movement and inactivity (sign test, $N = 39$, $p = 0.05$). Head movements were recorded by both observers in only 4 instances indicating that the motion was very brief and therefore should not be considered true activity.

Factors Affecting Activity

Time of year (Month) and time of day (Hour) greatly affect the activity behavior of black bears in the GSMNP (Table 9). Individual differences among bears (Bear) were

Table 9. Analysis of variation in activity behavior of black bears in the GSMNP with respect to time of year, time of day and differences among bears.

Source of Variation	df	SS	MS	F
Total	5213	1303.4568		
Bear	24	59.4521[a]	2.4772	10.05*[b]
Month	9	59.4461[a]	6.6051	26.71*[b]
Season	2	2.5281[a]	1.2641	5.11*[b]
Hour	23	60.6441[a]	2.6367	10.66*[b]
Month × Hour	140	69.5163[a]	0.4965	2.01*[b]
Season × Hour	46	40.9660[a]	0.8906	3.60*[b]
Other interactions involving bear	3329	823.1184	0.2473	1.91*[c]
Variation of observations within bear-month-hour	1688	218.3333	0.1293	

[a] Partial sum of squares.

[b] Tested against other interactions involving bear.

[c] Tested against variation of observations within bear-month-hour.

*$p < 0.01$.

also found to significantly affect the level of activity, as did the differing response of some individuals to the time of year and time of day (Other interactions involving bear). The apparent inconsistency of activity behavior among bears may reflect differences in sex, age and family associations (p. 89). Weather factors also appear to influence activity patterns (Table 10). Of the 3 elements of weather that were recorded in this study (temperature, cloud cover and precipitation), only temperature and precipitation had a reasonably clear effect. However, interactions among the various elements of weather, and among these elements and other environmental and biological conditions (day length, food supply, biological clock, reproductive condition, etc.) tended to complicate the observance of direct cause-effect relationships with activity (p. 86).

Seasonal and Hourly Effects

During the first month following den emergence, most bears were predominantly inactive (Fig. 21). The level of activity then increased rapidly, and almost linearly, until June when a peak was reached. Bears of both sexes remained highly active throughout the June-July breeding season. Subsequently, activity gradually diminished until denning. A similar pattern of annual activity has been reported for bears in Pennsylvania (Alt et al. 1976), Washington (Lindzey and Meslow 1976) and Idaho (Amstrup and Beechum 1976).

Table 10. Analysis of variation in activity behavior of black bears in the GSMNP with respect to time of year, time of day, differences among bears and weather factors.

Source of variation	df	SS	MS	F
Total	3850	956.7899		
Bear	24	59.4832	2.4785	12.25*
Month	9	81.4166	9.0463	44.70*
Hour	16	35.1950	2.1997	10.87*
Weather	30	52.8114	1.7604	8.70*
Temperature	14	7.4606[a]	0.5329	2.63*
Cloud cover	4	1.1832[a]	0.2958	1.46 ns
Precipitation	12	4.7854[a]	0.3988	1.97*
Residual	3771	763.0788	0.2024	

[a] Partial sum of squares.

*$p < 0.05$.

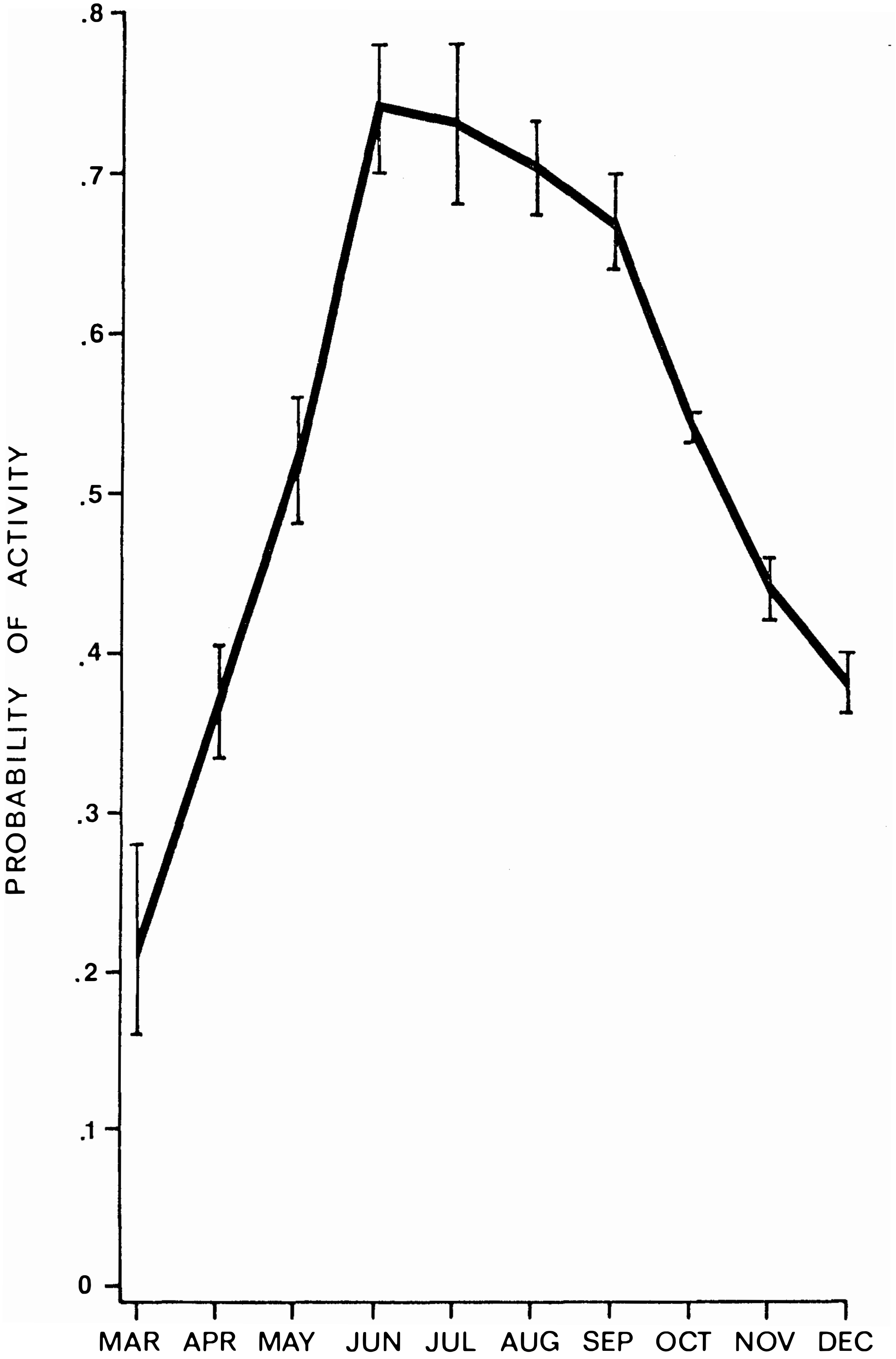

Fig. 21. Relationship between time of year and activity of black bears in the GSMNP.

The daily activity pattern showed 2 peaks, 1 at 0800 and 1 at 1800. This indicates that the bears in the GSMNP are generally crepuscular. However, time of year had a significant effect on hourly activity (Month × Hour, Table 9, p. 75). To observe this effect more clearly, months were grouped into seasons and least squares means calculated for each hour of each season rather than for each hour of each month. Seasonal divisions were made independent of the activity data, but were based on factors believed to affect activity, namely phenological development of food sources (Beeman and Pelton 1977), seasonal range shifts (Chapter IV) and breeding behavior. Spring was considered to last from March until the end of May, summer ranged from June through September and fall included October, November and December.

The most distinct crepuscular rhythm was exhibited during the spring (Fig. 22). Most bears became active about 30 min before sunrise (0500 EST) and remained active for 3-4 hr. Activity then sharply declined and remained at a comparatively low level throughout most of the day. At approximately 1700, activity again began to increase. It reached a daily maximum between 1800-2000, and then rapidly diminished within 30 min after sunset. With the exception of occasional slight head movements, total inactivity was observed throughout the night.

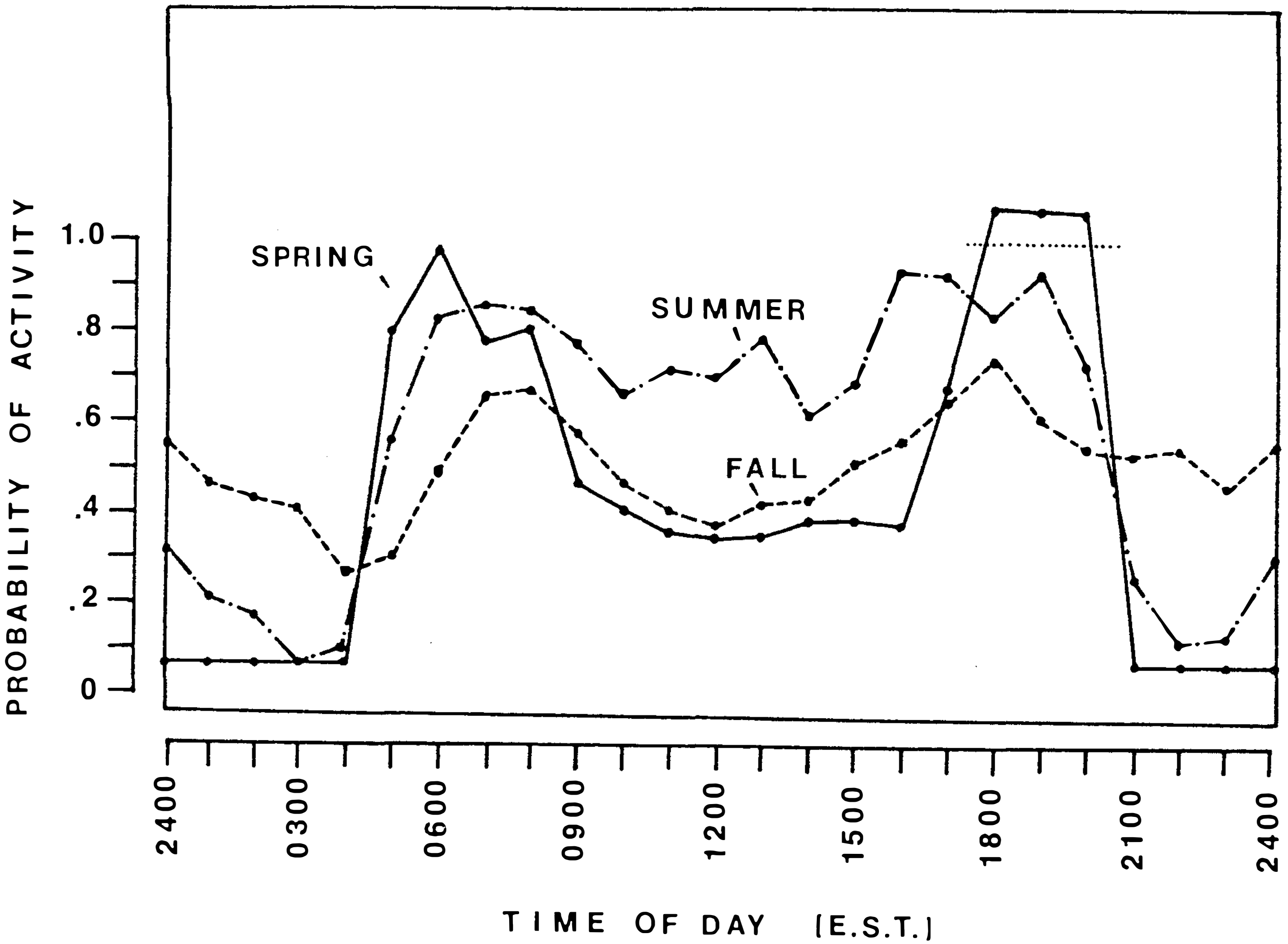

Fig. 22. Seasonal differences in the daily activity pattern. Least squares means above 1.0, as exhibited during the spring from 1800-2000, are mathematically possible although unrealistic. Such values represent an extremely high probability of activity.

During the summer, the early morning and early evening peaks in activity were less pronounced although still discernible. Nocturnal activity remained very limited, but the extent of activity in the middle of the day was more than twice that observed in the spring. The summer activity peaks, however, appeared slightly below the level achieved in the spring; the morning peak also occurred approximately an hour later and the evening peak approximately an hour earlier. This is surprising since the sun rises earlier and sets later during the summer months.

In the fall, black bears in the GSMNP exhibited a trend in circadian activity which was further modified from the simple crepuscular pattern of the spring. Two activity peaks persisted, but the degree of activity during these peak periods was only two-thirds that observed during April and May. The level of activity during the middle of the day (1000-1500), however, was virtually equivalent to the activity during the midday slump in the spring. The major difference between the daily activity pattern in the fall and that of the other 2 seasons was in the extent of nocturnal activity. In the fall, bears of both sexes were as active during the middle of the night as they were during the middle of the day. In fact, a slight activity peak was noticed at 2400 possibly indicating the tendency towards a trimodal activity rhythm. Minimum activity occurred at 0400, but during this hour 25 percent of the bears were still observed to be active on any given night. Amstrup and Beechum (1976) also observed increased nocturnal activity of black bears in Idaho during the fall. Black bears in Alaska (Erickson 1965) and Minnesota (Rogers 1970) are principally nocturnal throughout the year, while in Washington black bears are chiefly diurnal (Poelker and Hartwell 1973, Lindzey and Meslow 1977).

Seasonal and regional differences in the circadian rhythm may be influenced by the physiological condition of the bears, the abundance and nature of the food supply and seasonal or regional weather patterns. During the spring, bears are in a state of perpetual weight loss (Beeman 1975). It is not known whether this condition is caused by a lack of availability of nutritious foods or the inability to efficiently digest the available foods due to the physiological condition of the gastrointestinal tract after the long period of dormancy (Beeman and Pelton 1977). The diet during this period consists of 90 percent grasses and other herbaceous material (Beeman and Pelton 1977). It is probable that the crepuscular activity pattern exhibited in the spring represents an optimal foraging strategy for bears on a low energy budget.

During the summer months, berries and other nutritious fruits are abundant and bears can afford to expend more energy during the middle part of the day. Much of this energy may be utilized in mating activities and in expansion of home range (p. 49). During this period, bears need only to maintain their body weight after surviving the "negative foraging period" (Poelker and Hartwell 1973:116) in the spring.

In contrast, during the fall bears must increase their body weight in preparation for the winter. For this reason, foraging must continue through the night. Unlike the summer, the staple food item in the fall (acorns) is rather evenly dispersed throughout the range rather than concentrated in patches. Bears in the summer may find a full day's nutritional requirements in 1 berry patch, while in the fall they must continually move from place to place looking for enough food to satisfy their needs. It was shown in the previous chapter (Table 8, p. 69) that increased nocturnal activity in the fall is associated with actual movement and not merely restlessness. Whether bears can efficiently feed during these nocturnal ramblings is unknown, but since their rate of travel is in the same proportion to their hourly activity throughout the night and most of the day (Fig. 23), it is suspected that they are occupied with the same mode of activity, namely foraging. The only part of the day which may not be involved exclusively with foraging is during the hours 1200-1400. The level of

Fig. 23. Average hourly rate of travel of black bears with respect to the level of activity for each hour of the day during early and middle fall (2 Oct-4 Dec, 1976 and 1977). Values on the y-axis correspond directly to expected distance moved for an activity level of 100 percent.

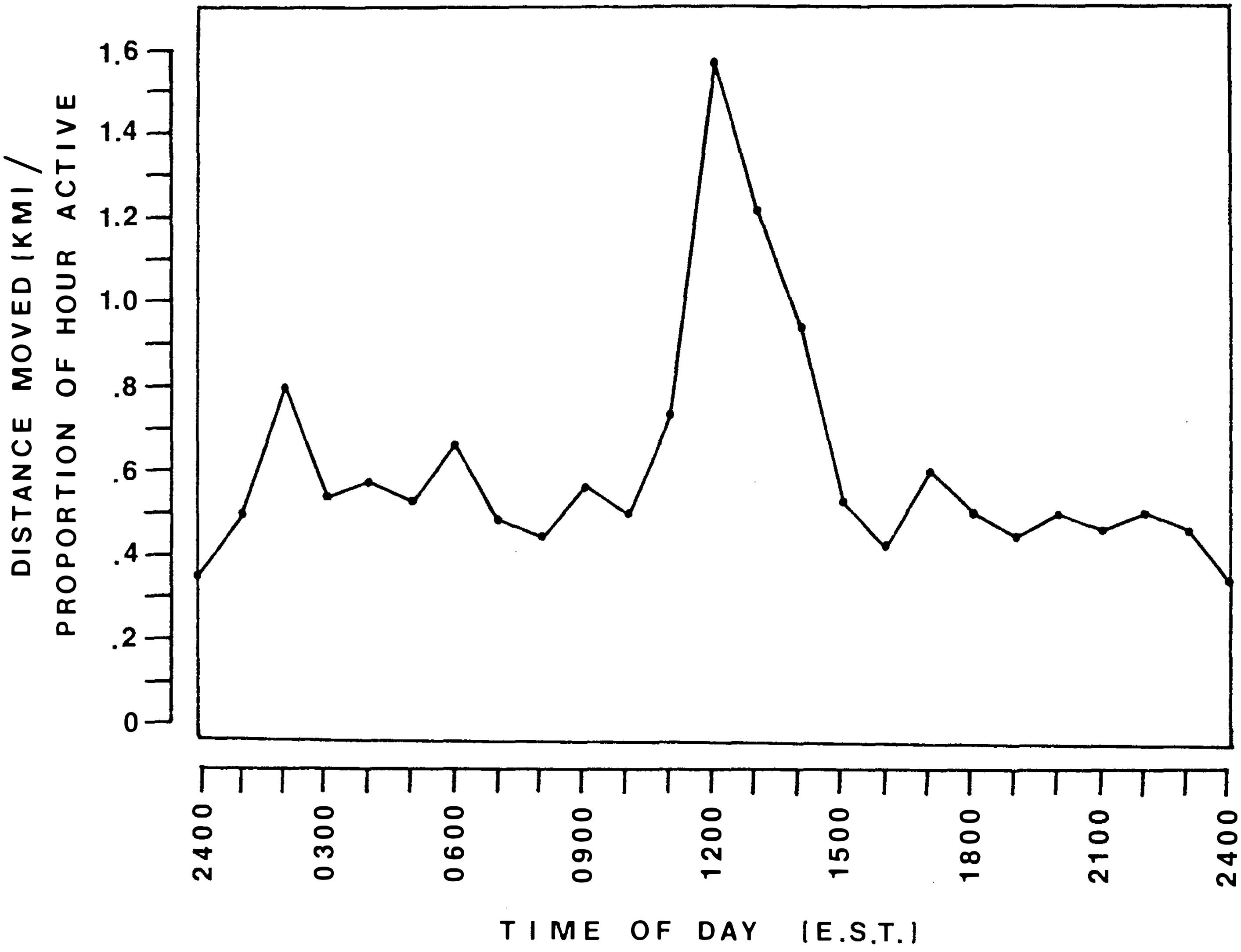
DISTANCE MOVED (KM) /
PROPORTION OF HOUR ACTIVE
1.6
1.4
1.2
1.0
.8
.6
.4
.2
0
2400
0300
0600
0900
1200
1500
1800
2100
2400
TIME OF DAY (E.S.T.)

Fig. 23

activity is generally very low during this period (Fig. 20, p. 72, and Fig. 22, p. 80), but those bears that are active are apparently concerned more with traveling than with foraging (Fig. 23). If, for example, a bear was active for the entire 1200 hr (1130-1230), it would be expected to move about 1.6 km. This is exactly the maximum travel rate observed for bears in the GSMNP (Table 8, p. 69). However, a bear which is active for a full hour during any other part of the day would be expected to move only about 0.5 km.

The above pattern of behavior was observed only in the fall. During the summer, expected movement for a full hour of activity averaged less than 0.25 km and was relatively consistent throughout the active part of the day (range 0.10-0.37 km). Although bears were more active during the daylight hours of the summer than they were during the fall, they traveled less ($p < 0.01$) per period of activity. This explains why the observed hourly rates of travel were similar for the summer and fall seasons (Table 8, p. 69).

Effects of Weather

In the spring, bears generally responded to increased temperatures with an increase in activity (Fig. 24). This trend continued up to 20 C where the level of activity

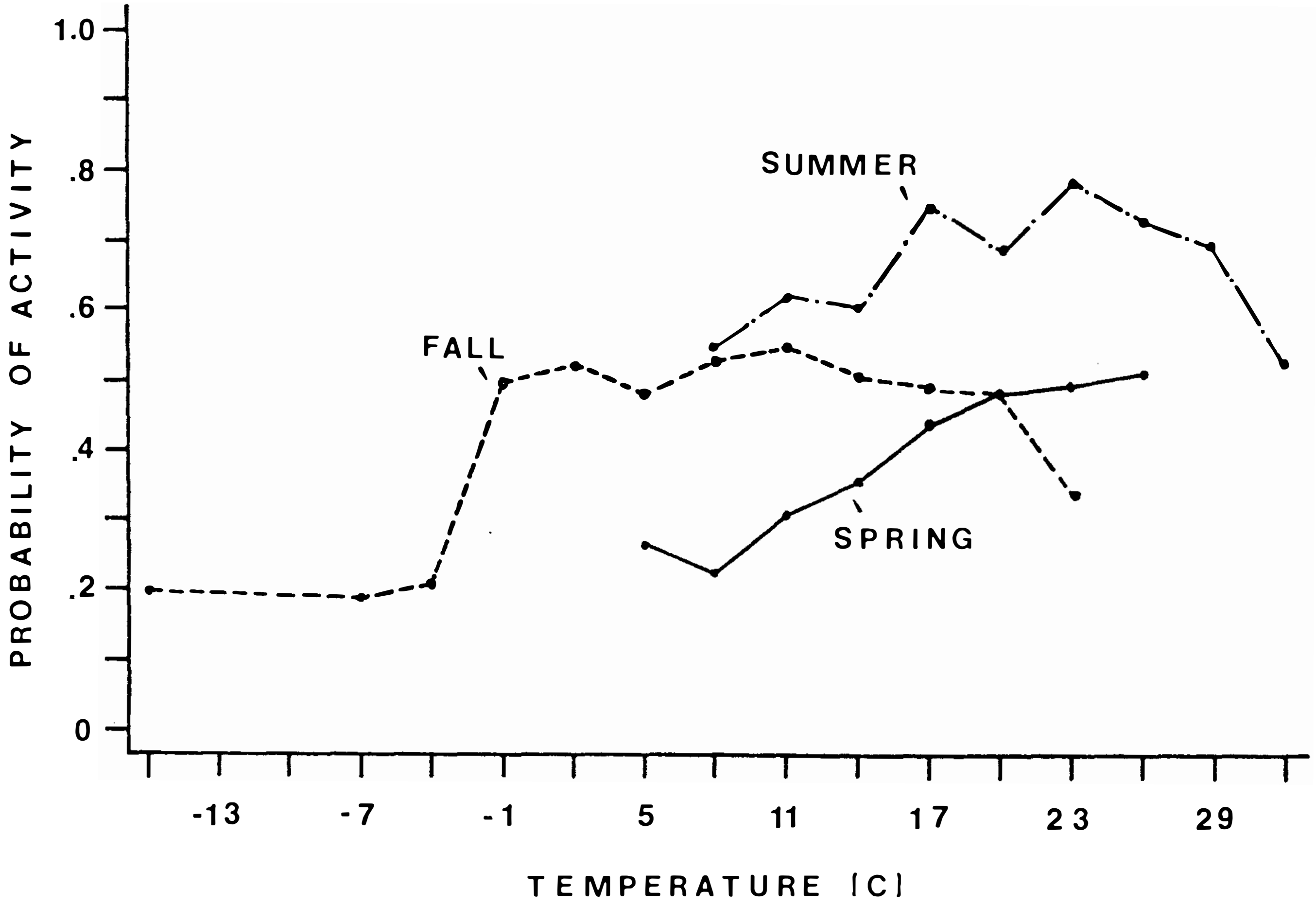

Fig. 24. Seasonal effects of temperature on the activity behavior of black bears in the GSMNP.

appeared to stabilize. A direct relationship between temperature and activity was also observed in the summer. However, as temperatures climbed above 23 C (approximately room temperature), activity tapered off. Higher temperatures may also cause decreased activity in the spring, although this could not be determined because the temperature rarely exceeded 26 C.

In the fall, diminished levels of activity were observed at temperatures above 20 C and below freezing. Between this range, temperature had little affect on activity. The apparent preoccupation with foraging during this season may suppress preferences for temperature much as it appears to eliminate the concern for time of day (p.81). It must be noted that time of day effects were adjusted-for in this analysis so any disparity between seasonal responses to temperature are due to factors other than mere differences in the circadian rhythm.

Cloud cover alone had little effect on activity behavior (Table 10, p. 77). Because of the high density of vegetation in the study area, bears are seldom exposed to direct sunlight. Other elements of the weather, which are strongly associated with cloud cover, such as humidity, barometric pressure and precipitation, therefore have a greater influence on activity.

The relationship between activity and precipitation is somewhat obscured by the interaction of other factors such as temperature. Bears were less active than normal while it was raining ($p < 0.05$), but more active than usual within 3 hr after the rain stopped (difference not significant at $\alpha = 0.05$) (Fig. 25). No longer term effects (3-24 hr) were observed from the rain.

Snow had a depressing influence on activity, although accumulation of snow apparently affects activity more than does the actual precipitation. Bears were least active when there was over 2 cm of snow on the ground, regardless of whether or not it was snowing. It may be that the subfreezing temperatures had more to do with this inactivity than did either the snowfall or accumulation of snow. Temperature was found to affect activity during the rain. Bears were more active during the rain at temperatures above 25 C than at more moderate temperatures, while rain at temperatures below 7 C had a severe depressing effect on activity.

Sex, Age and Family Effects

Planned sets of linear contrasts were used to test differences in activity patterns among different sex and age groups and between females with and without cubs. In general, adult males were more active ($p < 0.05$) than

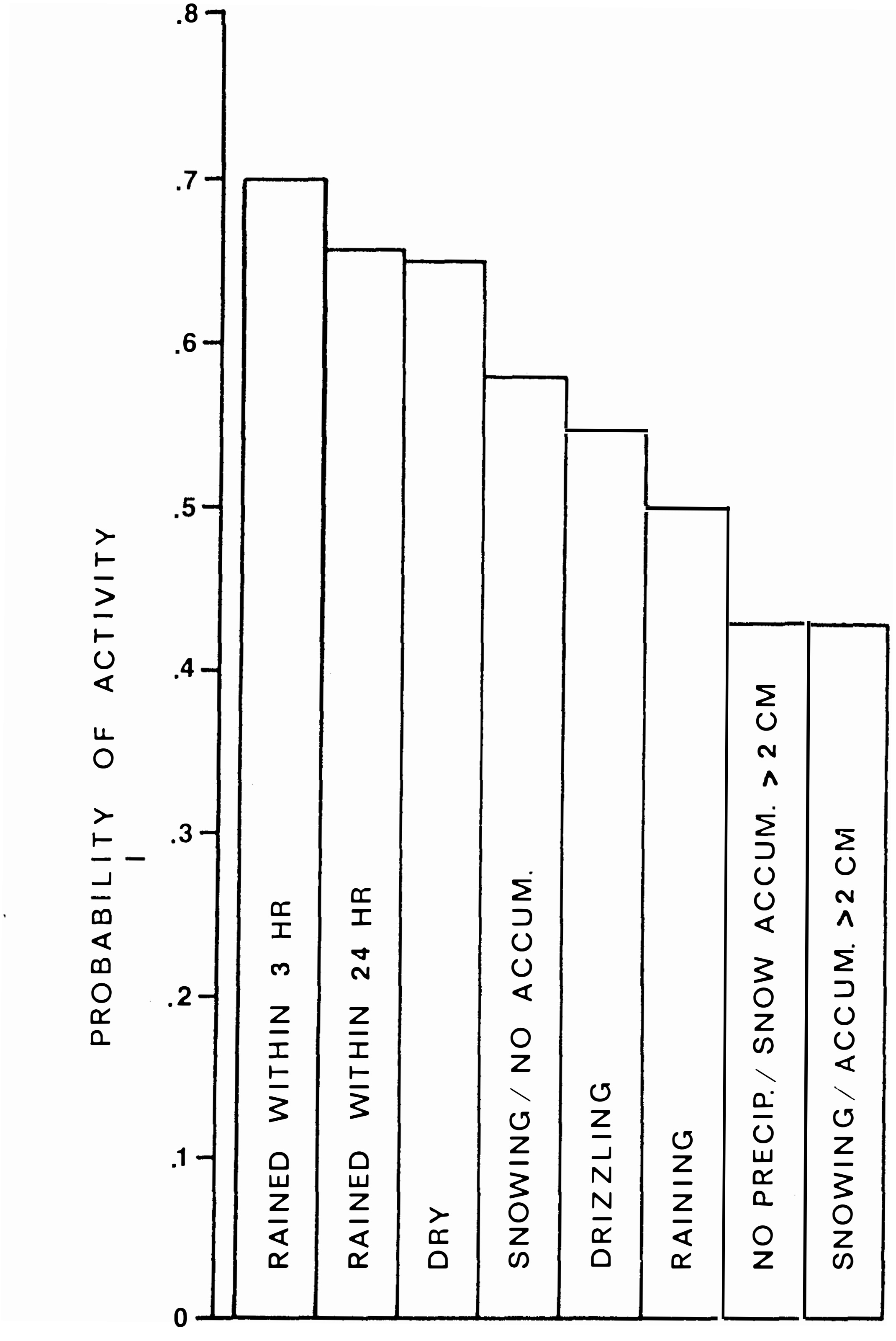

Fig. 25. Effects of precipitation on activity of black bears in the GSMNP.

solitary adult females. Subadult and yearling bears of both sexes were more active ($p < 0.01$) than solitary adults of their respective sex. Females with cubs were also considerably more active than solitary adults of both sexes ($p < 0.01$), and appeared to be more active than most subadults and yearlings (although this contrast could not be tested). Using this criteria, many of the adult females with unknown reproductive histories could be classified as solitary or as having cubs depending on the pattern of activity they exhibited. Bear D2, for example, is strongly suspected of having had cubs with her during the period of time she was radio-tracked since her overall level of activity was greater than that of any other bear in this study with the exception of 1 adult female (F5) known to have cubs. Similarly, the activity behavior of bear A28 suggests that she had cubs with her during the fall of 1976. Her activity during this period was almost twice the level she exhibited during the fall of the following year ($p < 0.0001$). When she was captured in September 1976, her teats were enlarged although no milk could be expressed. A sighting of a bear, believed to be this individual, with 3 cubs in the spring of 1978 lends support to the assumption that she also had cubs 2 years previously. In contrast, the activity observed for bear 63, the 11 year old female which died during the course of this study (p. 64), indicates that she was most likely solitary. While certain bears in the population may not follow the patterns established by their respective sex or age class, few of the individuals observed in this study appeared to deviate radically from their class "norm." The 3 most active bears included 2 females with cubs (as discussed above) and 1 subadult male (A30), while the 3 most inactive bears were 2 dominant males (A26 and A52) and 1 solitary female (B10). The 2 cubs tracked in this study were, as a group, slightly less active than adult females with cubs; however, the death of the mother of 1 of these cubs (A43) may have had a depressing effect on its activity. During the fall, this cub had a particularly small home range (Table 3, p. 47) at a relatively high elevation (Table A-5 in the Appendix) where oaks were not abundant. The fact that it removed its radio-collar in November, after having worn it for almost 3 months, may indicate that it was losing weight.

When viewed on a seasonal basis, some of the overall relationships between the activity behavior of different sex, age and family classes were somewhat altered (Fig. 26). In the spring, adult males were less active than any other group. Amstrup and Beechum (1976) also noted this for black bears in Idaho. Since most adult females were traveling with cubs or yearlings during this period, their level of activity was relatively high. Nursing and play

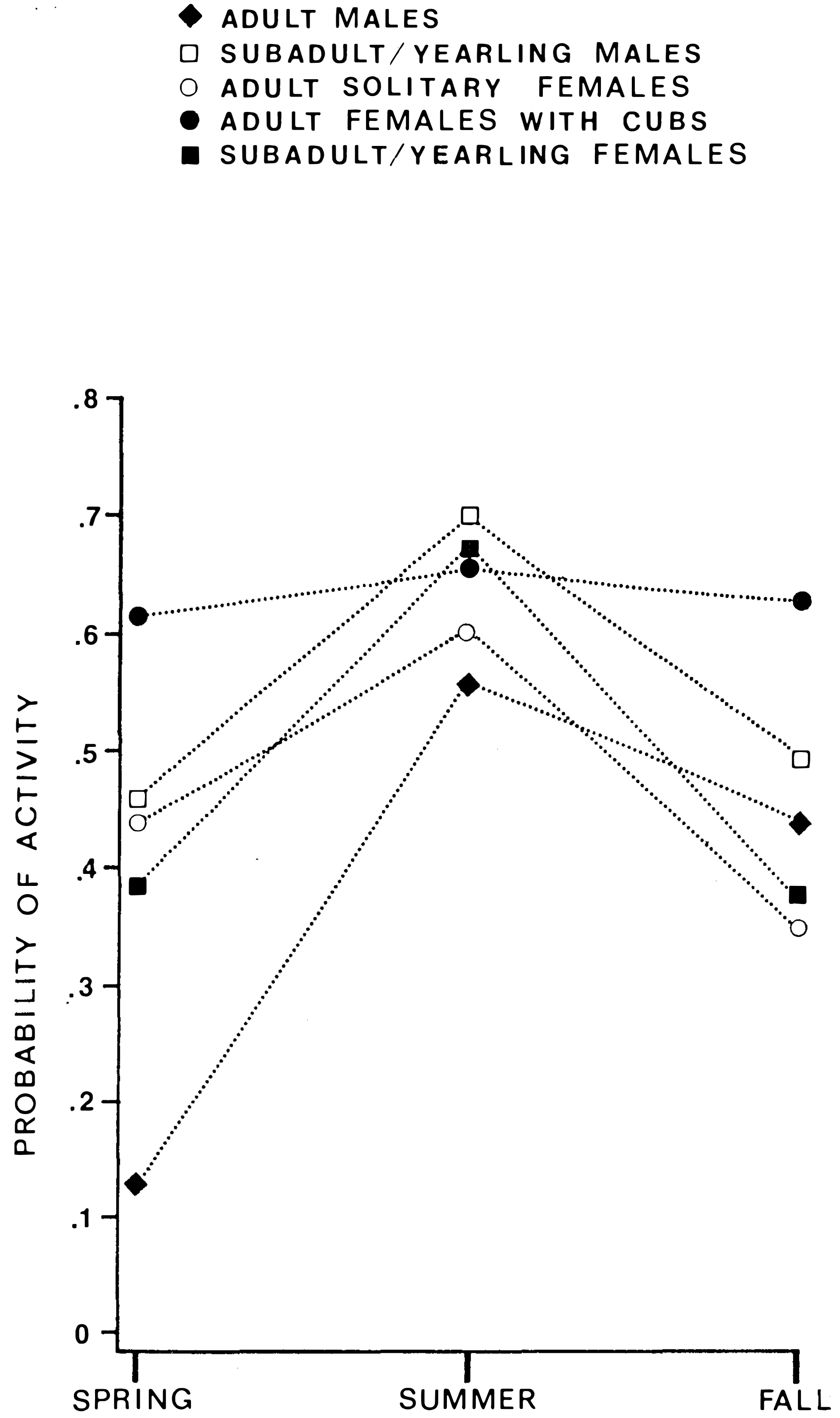

Fig. 26. Seasonal differences in activity behavior among different sex and age groups, and between females with and without cubs. Most females that were solitary in the summer and fall probably had yearlings with them during the spring.

behavior by these young bears evidently stimulates activity, although not necessarily actual movement, by the mother. Alt et al. (1976) and Rogers (1977) noted very limited movement by females with cubs throughout the spring. In the GSMNP, all classes of bears showed a high degree of activity in the summer, while activity diminished in the fall for all groups except females with cubs.

CHAPTER VI

CONCLUSIONS

Many black bears radio-tracked in the GSMNP from 1976-1977 displayed home ranges with abrupt seasonal changes. Home ranges were categorized by their magnitude of seasonal change. Movement of 30 day activity centers, overlap of range boundaries and relationship of 95 percent confidence regions around the seasonal range were used to define 4 basic types of ranges.

Similarities in range dynamics were observed among bears trapped within the same section of the study area. This may be explained by characteristics of the habitat within each section, low genetic variability among bears of a particular section and transmission of information from a female to her offspring. One young bear was observed to utilize the same seasonal ranges while with its mother and when solitary.

Twenty-three of 29 observed home ranges exhibited a distinct summer-fall separation. This separation was more prevalent for males than females, and more extensive for subadults and yearlings than adults. The timing of the fall range shift was also influenced by sex and age. Males generally entered the fall range earlier and departed the fall range later than females. Yearling bears of each sex were the first to return to the spring/summer range, possibly enabling them sufficient time to find a den.

Year to year changes in the extent and timing of the fall range shift are probably due to food availability. Bears traveled more widely in the fall of 1973 when food was scarce than they did in 1976 and 1977 when acorns were abundant. This, coupled with the observance of significantly more oaks in the fall ranges than in the spring or summer ranges indicate that fall movements are in response to oak mast. Bears preferred white oak over red oaks, and red oaks over chestnut oak. Fall ranges of males contained more white oaks and red oaks than those of females, while females that traveled extensively in the fall secured ranges with more red oaks, than did more sedentary females. An elevational decline in the range activity centers from summer to fall reflects the movement of bears into areas of abundant oaks.

Competition for prime oak areas may be severe. One prime area was believed to be occupied almost exclusively by males. A female that attempted to establish a range in this area quickly returned to her spring/summer range and died 2 weeks later, possibly of injuries resulting from aggressive interactions. Overlap of male ranges in this area was considerable, but strong mutual avoidance was noted. Dominant males occupied ranges within this area that contained a higher proportion of white and red oaks than were found in the ranges of subordinate males. Social pressures during poor mast years may drive many subordinate males outside the boundaries of the Park in search for food. Because the fall ranges of females are more dispersed, they may be less radically affected by a mast shortage.

Home range size was calculated as the area of the smallest region which can account for at least 95 percent of a bear's utilization of its habitat. Although this area may be larger than that actually used by the animal, it represents a more valid index by which range sizes can be compared than does the area of the minimum or convex polygon. Males were found to have larger spring/summer, fall and annual ranges than females. Mean annual range size was 42 km^2 for adult males and 15 km^2 for adult females. Range size did not differ from season to season for either sex, with the possible exception of discrete spring ranges which appeared more restricted. Summer ranges were geographically stable from year to year; displacement of the summer activity center over 2 or more years was considerably less than the displacement that occurred seasonally in 1 year. This stresses the need for year-round tracking in order to obtain useful estimates of home range size.

Diel movements were monitored on a periodic basis from 2 fixed 8-element mast antennas. Males traveled over a larger area during a day than did females, however their travel routes were usually more circuitous especially in the fall when social pressures may have hampered their movements. Seasonally, the average hourly rate of travel between the hours 0600-2200 remained virtually constant for each sex. However, nocturnal movements were much more prevalent in the fall. This trend towards nocturnal activity during the fall was also noted through the analysis of activity data derived from the interpretation of the radio signal. Specialized motion-sensitive transmitters were used on 26 of the 29 bears radio-collared in this study. Activity determined by this technique proved to be more sensitive to extremely localized movement than activity measured by the distance between successive hourly locations.

Bears in the GSMNP exhibited a tendency towards crepuscular activity behavior, although mating activity and changes in the abundance and nature of the food supply modified this pattern seasonally. The most distinct crepuscular rhythm was observed in the spring when expendable energy was limited by a lack of nutritious food. Bears were found more active and more diurnal during the summer when berries were abundant. The level of activity reached a peak during the June-July breeding season. Nocturnal activity during the fall is probably associated with increased foraging in preparation for denning. Females with cubs were equally active throughout the year and were more active than any other sex-age group. Subadult and yearling bears were more active than solitary adults of their respective sex.

Weather factors also affected activity. Temperatures above 25 C and below freezing apparently depressed the level of activity. Rainfall also decreased activity, but bears appeared more active than normal just after the rain stopped. Temperature and precipitation together may have the greatest weather related influence on activity. Subfreezing temperatures with accumulated snow reduced activity considerably, and may indeed be a stimulus to den.

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APPENDIX

Table A-1. Forest types in the GSMNP.[a]

Classified by Golden (1974)	Classified by Cain (1935)	Classified by Whittaker (1956)	Classified by Shanks (1954a)
Yellow poplar	Yellow poplar-Old field		
Sugar maple	Sugar maple-Silverbell		
Buckeye	Buckeye-Basswood		
Basswood			
Hemlock-Buckeye	Mixed cove hardwoods	Cove hardwoods	Cove hardwoods
	Hemlock-Yellow poplar		
Silverbell-Hemlock			
	Hemlock-Beech		
Hemlock	Hemlock ridge	Hemlock	Hemlock
Yellow birch-Hemlock	Yellow birch-Rhododendron		
Spruce-Yellow birch	Red spruce	Red spruce	

Table A-1 (Continued)

Classified by Golden (1974)	Classified by Cain (1935)	Classified by Whittaker (1956)	Classified by Shanks (1954a)
Beech	Beech	Gray Beech	Northern hardwood
Red oak	Oak ridge	Red oak-Chestnut	
Red maple-Red oak	Oak-Chestnut		
Red maple-Sweet birch			
	Chestnut oak-Yellow poplar		
Chestnut oak	Chestnut oak	Chestnut oak-Chestnut	Closed oak
		Chestnut oak-Chestnut-Heath	
Oak-Pine	Oak-Pine		Open oak-Pine
Table mountain pine-Pitch Pine	Pine-Heath	Pitch pine-Heath	
Table mountain pine		Table mountain pine-Heath	

[a] Adapted from a table presented by Golden (1974).

Table A-2. Black bears radio-tracked in the GSMNP, 1976-1977.

Bear no.	Name	Sex	Age during tracking period	Reproductive status/family[a]	Capture location when radio-collared	Period of time tracked	Transmitter: frequency/ status[b]
A9	Wilma	F	2-3	immature	1.2 km east of Bee Cove Ck. on cross-over trail	12 Sep 76-	changed
					600 m above Sandy Gap on Bote Mt. Rd.	-23 Dec 77	150.961/ functional
A11		M	5	mature	1 km east of Bee Cove Ck. on C/O trail	never located	Killed in legal hunt
A26	Double red	M	7-8	dominant	Sandy Gap on BMR	20 Aug 76- 22 Sep 77	150.865/ unknown
A28	Judy	F	9-10	mature/ solitary after summer 1977, unknown before	1 km east of Bee Cove Ck. on C/O trail	6 Sep 76- 23 Dec 77	151.030/ functional
A29	Christine	F	1-2	immature	200 m east of BMR on C/O trail	9 Sep 76- 12 Nov 77	Killed in legal hunt
A30	Mugsy	M	1-2	immature	1.6 km east of BMR on C/O trail	12 Sep 76- 14 Dec 77	Poached outside Park
A40	Barney	M	cub	with mother	600 m above Sandy Gap on BMR	2 Sep 77- 27 Nov 77	Poached from within study area

Table A-2 (Continued)

Bear no.	Name	Sex	Age during tracking period	Reproductive status/family[a]	Capture location when radio-collared	Period of time tracked	Transmitter: frequency/ status[b]
A42	Newt	M	2	immature	2.7 km up BMR at 90° turn	2 Sep 77- 23 Dec 77	150.892/ functional
A43	Boo Boo	M	cub	with 2 siblings (mother died)	Cold Water Knob	2 Sep 77- 26 Nov 77	removed by bear
A44	Paula	F	10	mature/with cubs	Sandy Gap on BMR	4 Sep 77- 23 Dec 77	150.938/ functional
A45	Stumpy	F	8	mature/solitary (pregnant)	600 m above Sandy Gap on BMR	11 Sep 77- 23 Dec 77	151.147/ functional[c]
A47	Oscar	M	2	immature	4 km up BMR	21 Sep 77- 23 Dec 77	151.205/ functional
A50	Bruno	M	5	dominant	Cold Water Knob	22 Sep 77- 23 Dec 77	151.010/ functional
A52	Fred	M	7	dominant	Sandy Gap on BMR	23 Sep 77- 23 Dec 77	150.995/ functional
A53	Scoop	M	3	immature	2.7 km up BMR at 90° turn	27 Sep 77- 23 Dec 77	150.904/ functional
B10	Olivia	F	6	mature/ solitary	200 m W. of bridge above Tremont	21 Jul 77- 22 Dec 77	150.873/ functional

Table A-2 (Continued)

Bear no.	Name	Sex	Age during tracking period	Reproductive status/family[a]	Capture location when radio-collared	Period of time tracked	Transmitter: frequency/ status[b]
B12	Stitches	M	4	mature	100 m up Long Br. from Defeat Ridge trail	27 Jul 77- 22 Dec 77	150.986/ functional
B18	Muffet	F	1	immature/ daughter of bear 89	300 m W. of bridge above Tremont	18 Mar 77- 22 Jun 77	nonfunctional: changed
					200 m W. of bridge above Tremont	3 Aug 77- 22 Dec 77	150.960/ functional, activity monitor malfunctioned
C14	Jeckel	M	5-6	dominant	Andy McCully ridge on Rabbit Ck. Rd.	7 Sep 76- 22 Dec 77	150.914/ functional, activity monitor malfunctioned
D2		F	9	mature/ unknown	Ridgetop of Bent Arm	19 Aug 76- 17 Dec 76	150.953/ unknown
D16	Fannie	F	8	mature/ unknown	400 m up Bent Arm	5 Jul 77- 2 Sep 77	151.130/ unknown[c]
E7	Marianne	F	14	mature/solitary (pregnant)	400 m up Bunker Hill	4 Jul 77- 21 Dec 77	150.849/ functional[c]

Table A-2 (Continued)

Bear no.	Name	Sex	Age during tracking period	Reproductive status/family[a]	Capture location when radio-collared	Period of time tracked	Transmitter: frequency/ status[b]
F5	Hairlip	F	7-8	mature/solitary 1976, with cubs 1977	1.3 km above Husky Gap on Sugarland Mt.	23 Oct 76- 20 Dec 77	151.060/ functional
H1	Debby	F	8	mature/solitary (pregnant)	1 km east of Bee Cove Ck. on C/O trail	4 Sep 77- 23 Dec 77	151.125/ functional
61	Hyde	M	7	mature	BMR	21 Apr 77- 21 May 77	150.914/ unknown
63		F	11	mature/unknown	2.7 km up BMR	29 Jul 76- 24 Nov 76	Died of natural causes
64		F	16	mature/unknown	4 km up BMR	27 Jul 76- 24 Sep 76	150.964/ unknown
65		M	6	mature	Sandy Gap on BMR	27 Jul 76- 31 Dec 76	151.068/ unknown
89	Poco	F	13-14	mature/with cubs in 1976	Jct Green Camp Gap and DRT	23 Jul 76- 13 May 77	150.927/ unknown

[a] Male bears over 4 years old and greater than 80 kg were considered dominant.

[b] Status as of the termination of field work in December 1977.

[c] Transmitter without an activity monitor.

Table A-3. Categorization of home ranges for bears radio-tracked in the GSMNP, 1976-1977.

Bear No.	Yr.	Type I	Type II	Type III-a	Type III-b	Type III-c	Type IV
Females							
A9	76					X	0
A9	77				X		
A28	76					X	0
A28	77			X			X
A29	76				X		0
A29	77					X	
A40[a]	77				X		0
A44	77				X		0
A45	77	X					
B10	77		X				
B18	77					X	
D2	76				X	X	0
D16	77					X	0
E7	77	X					0
F5	77	X					
H1	77				X		0
63	76				X		0
89	76		X				
subtot/ tot. obs.		3/19	2/19	1/19	7/19	6/19	1/8
Males							
A26	76				X		0
A26	77			0	0	0	X
A30	76					X	0
A30	77					X	X
A42	77				X		0
A47	77				X		0
A50	77				X		0
A52	77				X		0
A53	77					X	0
B12	77					X	0
C14	77				X		
65	76				X		0
subtot/ tot. obs.		0/11	0/11	0/11	7/11	4/11	2/3
tot/ tot. obs.		3/30	2/30	1/30	14/30	10/30	3/11

X indicates type of home range, 0 indicates information unknown.

[a] Cub with its mother represents movements of an adult female.

NOTE: Portions of this table are inferred using radio-locations or trapping locations obtained previous to and/or subsequent to this study, assuming relative geographical stability of a spring/summer range (pp. 49-50).

Table A-4. Dates of seasonal range shifts for black bears in the GSMNP, 1976-1977.

Bear no. (yr)	Departure from spring range	Departure from summer range	Departure from fall range
A9 (76)		10-23 Oct	12-15 Dec
A9 (77)	------	10-14 Oct	9-16 Dec
A26 (76)		12-13 Sep	24-27 Dec
A26 (77)	13-20 Jun		
A28 (76)		12-17 Oct	4-8 Dec
A28 (77)	11-16 May	19-29 Aug	6 Nov-1 Dec
A29 (76)		before 8 Sep	5-10 Nov
A29 (77)	------	19-27 Oct	
A30 (76)		13-19 Sep	24 Nov-4 Dec
A30 (77)	10-13 Jun	11 Sep-22 Sep	
A40		30 Sep-4 Oct	
A42		15-21 Oct	about 23 Dec
A43		before 1 Sep	
A44		before 3 Sep	20-23 Dec
A47		4-14 Oct	11-16 Dec
A50		15-21 Oct	20-23 Dec
A52		before 30 Sep	after 23 Dec
A53		before 24 Sep	after 23 Dec
B12		27 Oct-6 Nov	after 22 Dec
B18	------	11-15 Oct	10-15 Nov
C14 (76)		before 24 Aug	
C14 (77)	------	11-22 Aug	
D2		before 19 Aug	9-12 Dec
		17-21 Oct[a]	4-8 Dec[a]
D16		before 19 Aug	
H1		30 Sep-4 Oct	1-3 Dec
63		12-21 Oct	10 Nov
65		13 Sep	24-27 Dec

[a] Secondary fall range shift.

------Indiscrete range.

Table A-5. Elevation of seasonal range activity centers (m) for bears radio-tracked in the GSMNP, 1976-1977.

Bear no. (yr)	Spring range	Summer range	Fall range
Bote Mt. area			
Females			
A9 (76)		940	740
A9 (77)		1130	760
A28 (76)		930	
A28 (77)	1200	960	870
A29 (76-77)		1350	1160
A40[a]		980	710
A43[a]			1130
A44			720
D2	1400	760	560
H1		1110	730
63		740	560
64		780	
subavg.		970	790
(SD)		(190)	(206)
Males			
A26 (76-77)	1100		690
A42		770	540
A47		780	550
A50		1060	570
A52			590
A30 (76)		1350	760
A30 (77)	1490	1280	430
65		690	620
subavg.		990	590
(SD)		(283)	(100)
Bote Mt. area avg.	1300	980	700
(SD)	(179)	(220)	(193)
Other areas			
A53			790
B12		1010	710
B18		620	590
89	690		
C14		880	610

[a] Cub representing an adult female; although the mother of A43 died in September, her movements until this time undoubtedly had a substantial influence on the cub's fall range.

VITA

David Lance Garshelis was born in New York City, New York, on January 16, 1953. He was raised in Clark, New Jersey, where he graduated from high school in 1971. He attended the United States Air Force Academy for two years before enrolling at the University of Vermont where he received a Bachelor of Arts degree in zoology in 1975. He did his graduate work in wildlife at Pennsylvania State University and at the University of Tennessee. He was awarded the Master of Science degree from the University of Tennessee in 1978. He will continue his graduate studies towards a doctoral degree at the University of Minnesota.

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