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BOBCAT BIOLOGY IN A MOJAVE DESERT COMMUNITY[1/]

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ABSTRACT

Eight adult bobcats (7 males, 1 female) were trapped in box-traps, radio-collared and released on Joshua Tree National Monument, Riverside County, California, during 2634 trap nights between 2 December 1978 and 1 April 1979. Minimum bobcat density is 0.1 bobcats/km^2 (0.25/mi^2). Home range size of 7 bobcats determined by 1310 radio-locations averaged 26.3 km^2 (10.2 mi^2). Male bobcat home ranges were overlapped as greatly as 66% by other male bobcats. The female bobcat home range was overlapped 75% by one male bobcat, A crepuscular bobcat activity pattern existed during the spring months. These bobcat activity patterns corresponded to the abundance of rodents and rabbits as determined by roadside census during the study.

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INTRODUCTION

Biopolitics

Declining populations and concomitant Federal and International restrictions on trade of spotted cat pelts has increased the demand for bobcat (*Felis rufus*) and lynx (*Felis lynx*) hides in domestic and foreign fur markets. Prices of bobcat pelts from California have tripled during the past five years. Presently, a prime bobcat pelt may have a value exceeding $400. The increased demand and high market values of bobcat pelts have resulted in a appreciable increase in trapping pressure.

Historically, the bobcat was an unprotected predator, but was reclassified as a nongame mammal in California in 1971. Subsequently, the California Fish and Game Commission established a no-limit season which restricted trapping of bobcats to the months from mid-November through February. Beginning with the 1979-80 trapping season, bobcats may be taken between mid-November and the end of January, or until 6000 bobcat pelts have been tagged for export.

Prompted by an apparent reduction of bobcat population levels in some areas of the nation and the increased market/trapping pressure imposed on the bobcat, the Defenders of Wildlife filed a petition on 20 January, 1977 with the Department of the Interior to place the bobcat on the United States list of Endangered and Threatened Wildlife. Pursuant to the Endangered Species Act of 1973, a review of the status of the bobcat was begun July 13, 1977 (Federal Register - July 1977). The bobcat was subsequently listed as an Appendix II species by the Convention of International Trade in Endangered Species of Wild Fauna and Flora and the Endangered Species Scientific Authority banned international export of bobcat pelts taken after August 29, 1977 (Endangered Species Technical Bulletin - August 1977). The Endangered Species Scientific Authority later allowed a quota of 6000 bobcat pelts to be exported from California during the 1977-1978 trapping season, providing each pelt was tagged to indicate the origin of the pelt (Endangered Species Technical Bulletin - August 1978). In October, 1978 the Endangered Species Scientific Authority approved export of bobcat pelts from 34 states, including California, with quotas set for only two states, New Mexico and Wyoming (Endangered Species Technical Bulletin - October 1978). The California Department of Fish and Game elected to continue its quota for bobcat pelts sold in fur markets despite the easing of restrictions.

Federal and state agencies initiated several research contracts in anticipation of the need for detailed data on the biology and status of the bobcat. This report documents the results of a study on bobcats at Joshua Tree National Monument in the Mojave Desert of California during the period from December 1978 to August 1979. The study was contracted by the Bureau of Land Management and jointly funded by the California Department of Fish and Game.

Literature

At least one of four subspecies of bobcat are present in most, if not all, counties of California (Grinnell, 1937). The northwestern bobcat (*F. r. fasciatus*) occupies the moist, coastal portions of northern California. The desert bobcat (*F. r. baileyi*) is found in arid, desert regions of southeastern California. The pallid bobcat (*F. r. pallescens*) is found on the western edge of the great basin habitat in extreme northeast California. The California bobcat (*F. r. californicus*) is found throughout the balance of the state with the exception of areas under extensive agriculture. All vegetation types or life zones are occupied by the bobcat in California.

Bobcats were historically distributed throughout the United States and most of Mexico and utilized a variety of habitat types. Habitat preference by bobcats in Minnesota was primarily thick cedar (Thuja occidentalis) or spruce (*Picea mariana*) swamps (Rollings, 1945). McCord (1974) found that bobcats preferred cliff areas, spruce plantations, (*P. abies*) and hemlock (*Tsuga canadensis*) -hardwood habitat in Massachusetts. Bailey (1972) classified areas dominated by sagebrush (*Artemesia tridentata*) with nearby caves and sagebrush/ juniper (*Juniperus osteosperma*) areas near volcanic outcroppings as being good bobcat habitat in Idaho. Most of the bobcat preference for these habitats was accounted for by prey density and cover availability.

The density of several bobcat populations has been estimated. For example, Bailey (1972) believed that the number of adult bobcats in a 3-year study of the pallid bobcat in Idaho remained constant at 0.05 bobcats per km^2 (O.O2/m^2). Lembeck (1978) determined densities of 1.27 to 1.52 bobcats per km^2 (3.37 to 3.94/mi^2) during a radio-telemetry study of the California bobcat in the chaparral of San Diego County, California. Two density estimates are available for the desert bobcat; Brownlee (1977) estimated bobcat densities ranging from 2.46 to 5.96 bobcats per km^2 (0.95 to 2.3/mi^2) in Texas whereas Jones (1977) estimated that bobcat density in his study area in Arizona was 0.28 bobcats per km^2 (0.11/mi^2). Brownlee based his estimate on the results of intensive removal trapping while the lower estimates of Bailey and Jones were based on the number of bobcats captured and released within their respective study areas.

Several investigations have been made to determine home range parameters of bobcats (the home range of an animal is generally understood to be the area it utilizes during the course of normal activity). Marston (1942) reported home range estimates of 47 to 104 km* (18 to 40 mi^2) for bobcats in Maine. Erickson (1955) estimated bobcat home range size to be 38 to 52 km2 (15 to 20 mi^2) in Michigan, and Rollings (1945) estimated that bobcats in Minnesota have home ranges of 25 to 38 km2 (10 to 15 mi^2). Kight (1962) describes maximum bobcat home ranges of 2.6 km^2 (1.0 mi2) in South Carolina, and Pollack (1949, 1950) reports that bobcats in northeastern United States have home ranges from 3.9 to 14.2 km2 (1.5 to 5.5 mi^2). These data were obtained by snow-tracking techniques as investigators trailed hunting bobcats through swamps, spruce, hemlock or cedar thickets. Some estimates were made of the area utilized by bobcats which left distinctive, identifiable tracks.

As the feasibility of utilizing radio-telemetry equipment in wildlife investigations increased, home range estimates based on repeated locations of individual bobcats were obtained. Bailey (1974) reported home ranges of 42.1 km2 (16.3 mi2) for four male, and 19.3 km2 (7.4 mi^2) for eight female bobcats in Idaho. Marshall and Jenkins (1966) reported 4.64 km2 (1.79 mi^2), 3.52 km2 (1.36 mi^2), and 2.46 km2 (0.95 mi2) home ranges for an adult female, a juvenile male, and a juvenile female bobcat, respectively, in South Carolina.

Because the extent of movement is probably closely associated with survival potential, bobcat movement patterns have been the subject of several investigations. Bailey (1974) found no significant difference between the average daily consecutive movements of female (1.2 km or 0.8 mi) and male (1.8 km or 1.1 mi) bobcats in Idaho. These averages were based on movements from one day to the next and represent the minimum movements in terms of distance traveled. Marshall and Jenkins (1966) reported average daily movements of telemetered bobcats in South Carolina to be from 1.88 to 4.78 km (1.17 to 2.97 mi). Bobcats are reported to move up to 11.7 km (7.3 mi) per day in Michigan (Erickson, 1955) and 4.8 to 11.2 km (3.0 to 7.0 mi) per day in Minnesota (Rollings, 1945). It should be noted that the data from Michigan and Minnesota, as well as a 3.2 km (2.0 mi) bobcat movement in Idaho (Bailey, 1974) were obtained via snowtracking; and the effects of snow on the extent of bobcat movements has not as yet been determined.

Bobcat sex ratios vary greatly with lows of 0.40 males per female in Vermont (Foote, 1945) and 0.60 adult males per adult female in Idaho (Bailey, 1972) to a high of 2.1 males per female in San Diego County, California (Lembeck, 1978). Ratios of male to female bobcats lie between these extremes in the following states: 1.04:1 in the northeast United States (Pollock, 1950); l.ll:l and 1.29:1 in Utah (Gashwiler et al., 1961); 1.7:1 in Arkansas (Fritts and Sealander, 1978), 1.26:1 in Arizona (Young, 1958); 1.01:1 in Wyoming (Crowe, 1975). These sex ratios may not be indicative of actual population sex ratios since the larger home range and greater movements of male bobcats may create a differential susceptibility to trapping, thus resulting in a higher male to female ratio than actually exists. For example, Robinson and Grand (1958) determined that the mean recapture distance for 22 male and 24 female bobcats was 8.5 km (5.3 mi) and 5.1 km (3.2 mi), respectively. Bailey (1972) found that the male bobcat home range was 4 to 12 times as large as that of the female.

Crowe (1975) determined that female bobcats are capable of breeding at one year of age, whereas males are sexually mature at two years of age. Both sexes remain reproductively active throughout their life which may extend beyond 14 years in the wild. Fritts and Sealander (1978) reported an average of 2.5 bobcats per litter in Arkansas. An average litter size of 2.8 bobcats was determined in studies in Idaho (Bailey, 1972) and in Wyoming (Crowe, 1975). Gashwiler et al. (1961), found that litters averaged 3.5 in Utah. Crowe (1975) and Gashwiler et al. (1961) report a higher number of corpora lutea (averages of 3.4 and 4.8, respectively) than the actual number of bobcats born which indicated the possibility of intrauterine embryo loss. While the majority of bobcat young are born in April or May in Utah (Gashwiler et al., 1961) and in May and June in Wyoming (Crowe, 1975), both studies indicate that young may be born during any month between March and October.

Various bobcat food habit studies have been conducted where the frequency of occurrence, percent by weight or percent by volume of various prey species have been determined from bobcat stomach contents. Rodents are the most frequent bobcat prey item in California (Leach and Frazier, 1954; Grinnell et al., 1937; McLean, 1934), Vermont (Hamilton and Hunter, 1939), and in Virginia and North Carolina (Progulske, 1955). Rabbits and hares constitute the next most important prey item in these states (except in Vermont) but are the most important prey item in Utah and eastern Nevada (Gashwiler et al.,

1960) and Minnesota (Rollings, 1945). Deer were the most important prey item in Massachusetts (McCord, 1974) but ranked second in Utah, Nevada, and in Minnesota. These three groups of prey are consistent food items of bobcats and probably vary in importance with their relative abundance within the habitats studied.

OBJECTIVES

Previous studies document that bobcat sex ratios, reproductive rates, density, home range size and extent of overlap, movements, and prey items consumed vary greatly as a function of habitat type and the population of bobcat studied. The present study investigates certain aspects of the biology of bobcats in a habitat representative of the California Desert Conservation Area. The study was conducted in the Mojave Desert well within the boundaries of the Joshua Tree National Monument. This location reduced the affects of artificial mortality (hunting and trapping of bobcats) and minimized man's influence on the bobcat population.

The objectives of the study include: (1) evaluate bobcat home range and extent of home range overlap, (2) determine the density of bobcats as revealed from home range and capture data, (3) analyze the movements of bobcats within their home range in relation to varying habitat and prey item abundance, (4) determine the activity patterns of the bobcat on a daily and seasonal basis and, (5) determine aspects of reproduction, hunting behavior/success, prey selection, and utilization of denning and resting sites.

In order to achieve the above objectives we opted to detail the biology of a small sample of the population rather than attempt a larger scale study and diffuse our efforts beyond the primary objective of the study. The goal was to capture all bobcats within an area the size of which was ultimately defined by the areas utilized by the radio-collared bobcats. Additional bobcats utilizing at least the fringes of our study area surely existed but probably did not greatly interact with the radio-tagged bobcats utilizing the core of the study area. The capture and study of these individuals was beyond the extent of the telemetry equipment and manpower available.

We believe that the primary data upon which bobcat management can be formulated is best obtained by the detailed study of the biology of interacting animals as opposed to fragmented data from many, non-interacting animals. This seems especially germane when the density of animals, such as existed during our study, was relatively high. Additionally, because of extensive tracts of similar habitat and the lack of human disturbance on the Monument, the data obtained from the bobcats on our study area has a much wider geographical application.

THE STUDY AREA

The Queen Valley area (R.8E., T.2S.) of Joshua Tree National Monument was selected as the study area. A considerable degree of protection from human disturbance occurs on a National Monument which can contribute to stability of the age/sex structure and density of resident animal populations. The topography and vegetation of Joshua Tree National Monument, particularly the creosote bush/shadscale scrub, Joshua tree woodland, and pinyon-juniper woodland are comparable to adjacent areas. Acknowledging appropriate factors such as degree of exploitation, data obtained on the Joshua Tree National Monument may be applied to bobcat populations on adjacent lands of similar habitat.

Queen Valley (elevation 1351 m, 4435 ft) is a relatively flat plain with surrounding mountains which rise to an elevation of 1730 m (5677 ft). The mountains are uplifted Pinto gneiss with exposed areas of intruded quartz monzonite. The sand in Queen Valley is predominantly eroded Pinto gneiss and covers the plains between uplifted areas.

Dominant vegetation of the valley includes creosote bush (*Larrea divaricata*), Joshua trees (*Yucca brevifolia*), Mojave yucca (*Y. schidgera*), and antelope bitterbrush (*Purshia glandulosa*). This vegetation continues up the mountain slopes where Utah juniper (*Juniperus osteosperma*) and pinyon pine (*Pinus monophylla*) become more common.

The average annual percipitation of the Joshua Tree National Monument weather station is 10.6 cm (4.2 in). We measured temperature extremes which varied from -6.7° C. (20° F.) in the winter to 44.4° C. (112° F.) during the summer months of this study. Temperature changes of 22° C. (40° F.) during a dial period were not uncommon.

METHODS AND MATERIALS

Bobcats were trapped in box-type live traps (61 x 61 x 122 cm or 2 x 2 x 4 ft.) and were immobilized with ketamine hydrochloride. Drug dosages varied between 17 and 21 mg/kg (7.6 to 9.7 mg/lb). Heart and respiration rates were monitored while the bobcats were tractable. Blood samples were taken to be tested for disease. Standard field measurements and weights were recorded and each bobcat was tagged with numbered, size 3 fingerling tags in both ears and fitted with a collar containing a radio transmitter.

The radio transmitters were manufactured by AVM Instrument Company and operate at frequencies from 150.85 MHz to 151.15 MHz. Transmitters were attached to flexible antennas (30.5 cm or 12 in long) and size 660 or 660-3 lithium batteries (Power Conversion Inc.) were used to power the transmitter. The transmitter package was embedded in dental acrylic and laminated between two layers of neoprene-impregnated nylon belting (2 x 38 mm or 0.06 X 1.5 in). The radio-collars were fastened around the necks of bobcats and the antenna was between belting layers of the collar and protruded dorsally approximately 17 cm (6.5 in). The finished transmitter-collar weighed 150 to 165 grams (5.3 to 5.8 oz) and possessed a theoretical life expectancy of 26 to 31 months.

Radio receivers and null-peak directional antenna systems manufactured by AVM Instrument Company were used to locate the bobcats. Directional bearings were taken using the receiver/antenna system mounted in a 4-wheel drive vehicle from the monitoring sites which provided the most accurate triangulation of each bobcat's position. These bearings were corrected for deviation from true north and plotted on plastic overlays of 15 minute U.S. Geological Survey maps of the study area. Animal location points were plotted when two or more intersecting bearings were obtained. Distances between each plotted point were measured and the minimal home range size for each bobcat was determined from irregular polygons made by connecting the peripheral location points with lines.

Activity levels were determined by changes in the signal strength of 10 transmitter pulses monitored at the time each radio-location was taken. Three pulses monitored prior to the l0-pulse sample established a preliminary activity level and reduced the bias of when the sample was initiated. Zero change in the strength of the transmitter pulses indicated a completely immobile animal whereas ten changes within the ten monitored radio signals indicated an animal in constant motion (constant motion might include behavior such as eating, grooming, or constant travel). Intermediate changes of radio signal strength (1 to 9 changes) indicate various degrees of animal activity. The validity of the pulse-strength as an indicator of animal activity was verified by direct observations via spotting scope or binoculars. Weather conditions were noted at the time telemetry readings were taken.

In addition to radio-telemetry techniques, observations of bobcats and bobcat sign (tracks and feces) were noted. Potential bobcat prey species were censused while driving between the various mobile monitoring sites. The number of each genera of prey observed and the time and location of each observation was recorded.

Statistical evaluation and comparisons of distance, activity, and home range data were analyzed using analysis of variance, SS-STP test for differences of means, Student's t-test and Chi square tests where appropriate (Sokal and Rohlf, 1969).

RESULTS AND DISCUSSION

Capture of Animals and Bobcat Density

Eight adult bobcats were captured a total of 12 times during 2,634 trap-nights between December 2, 1978 and April 1, 1979 (Table 1). The number of trap-nights required to capture or to recapture (N=12) bobcats on the study area averaged 219. However, the initial capture of a bobcat required a greater trapping effort in that an average of 329 trap-nights were required. A total of 21 observations of uncollared bobcats were made on the study area. Seven grey fox (*Urocyon cinereoargenteus*) were captured during the study (379 trap-nights/capture). Bobcats and grey fox were the only predators captured.

Cumulative bobcat captures became asymptotic after capture of the sixth bobcat. Captures of the seventh and eighth bobcats required a two-fold and three-fold increase of trap-nights, respectively. A decreasing rate of bobcat captures per unit effort as cumulative bobcat captures increased yielded a Leslie Method (regression of captures per unit effort, De Lury, 1947) population estimate of 6 bobcats, although 8 bobcats were captured in the study area.

The eight captured bobcats represent the minimum number of bobcats utilizing the study area during the trapping phase of the study (2 Dec 78 - 1 Apr 79). The fact that cumulative bobcat captures became asymptotic after 6 captures and that 6 bobcats is the population estimate based on the rate of bobcats captured per unit effort versus total bobcat captures does not necessarily contradict the number of bobcats captured.

Table 1. Temporal and biological aspects of adult bobcats (7 male and 1 female) captured on Joshua Tree National Monument, Riverside County, California (no juveniles were captured).

BOBCAT No.	SEX	WEIGHT kg	WEIGHT (lbs)	CAPTURE DATE
1	M	8.1	(17.9)	4 December 1978
2	M	8.9	(19.6)	28 December 1978
3	F	6.2	(13.7)	1 January 1979
4	M	8.3	(18.3)	5 January 1979[a]
5	M	7.7	(17.0)	12 January 1979
6	M	7.3	(16.1)	23 January 1979
7	M	8.1	(17.9)	7 February 1979
8	M	7.2	(15.9)	3 March 1979[b]

a Bobcat No. 4 was recaptured on 7 and 10 January and on 9 February 1979.
b Bobcat No. 8 was recaptured on 14 March 1979.

Most population estimators assume no immigration, emigration, natality or mortality and estimate the population during the concise period of capture. These assumptions are seldom realized when studying a free-living population. This bobcat population displayed dynamic conspecific interaction based on analysis of bobcat home ranges. Bobcat home ranges were often severely altered, presumably as the response of avoidance behavior exhibited when a solitary mode of existance is operant.

Home Range Size and Bobcat Density

During this study we obtained sufficient numbers of bobcat locations via radio-telemetry (1,310) to determine the size of the home ranges occupied by seven of the eight animals that were captured (Fig. 1, Table 2). Analysis of these data indicate considerable variation in the size of the areas occupied as shown by a range of 4.7 to 53.6 km^2 (1.8 to 20.7 mi^2) with a mean of 26.3 km^2 (10.3 mi2) and a standard error of 5.75. Bobcat home ranges at Joshua Tree National Monument were smaller than those reported for the pallid bobcat in Idaho (Bailey, 1972) and northeastern California (Zezulak, 1978), but were larger than the home range of the California bobcat studied in

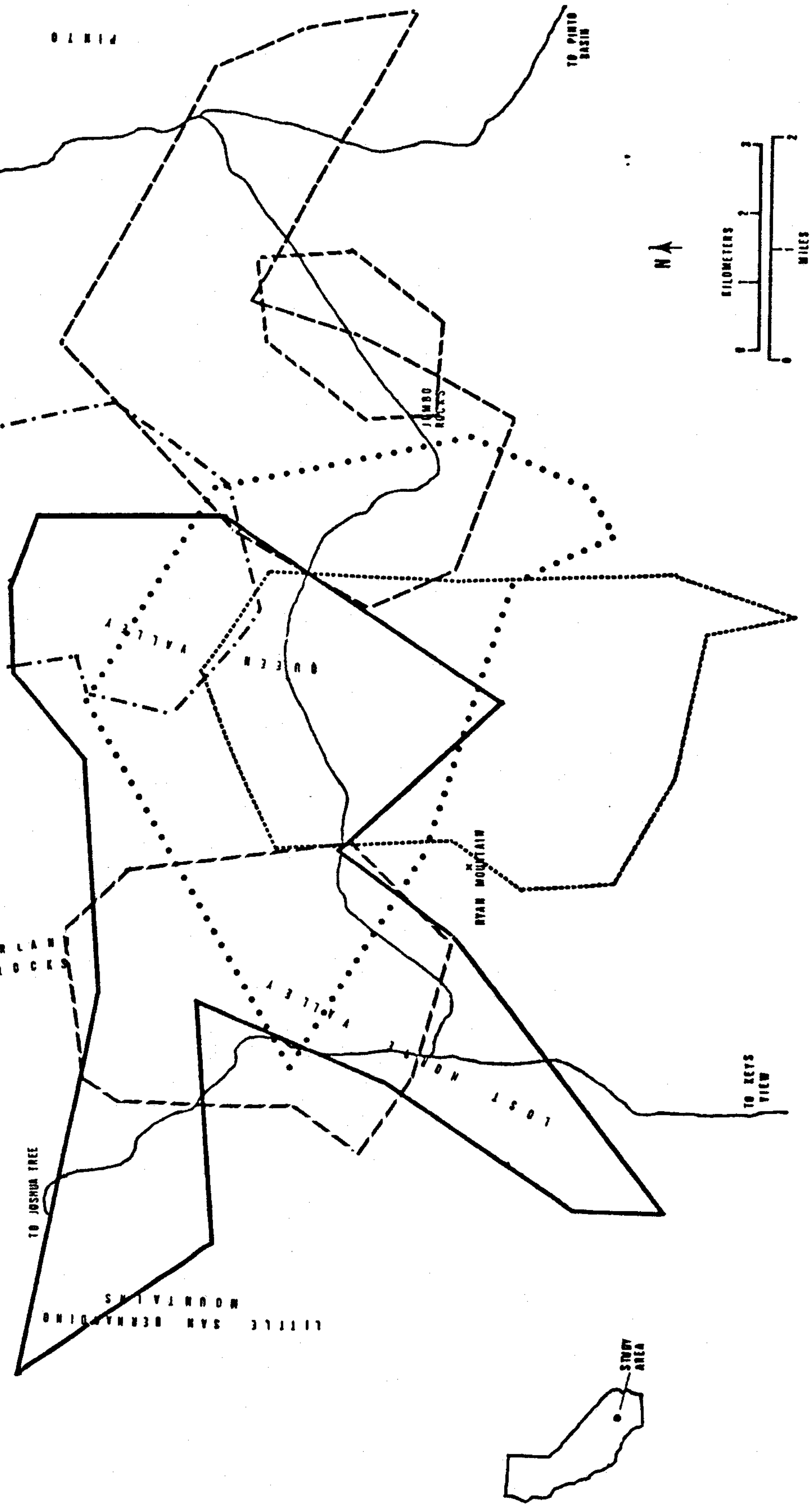

FIGURE 1. HOME RANGES OF SEVEN BOBCATS DETERMINED BY RADIO-LOCATION TECHNIQUES AT JOSHUA TREE NATIONAL MONUMENT, RIVERSIDE COUNTY, CALIFORNIA (4 DEC 78 - 29 JUN 79).

BOBCAT NUMBER

1 —— 5 — — —
2 .... 6 —.—.—
3 — — — 8 ——
4 • • • • •

San Diego County, California (Lembeck, 1978). Bobcat home range size is known to vary among the subspecies studied, but it is difficult to discern the relationship between bobcat home range size, their population density, habitat type occupied, and prey availability.

Table 2. Home range size for 7 adult bobcats determined by radio-location techniques at the Joshua Tree National Monument, Riverside County, California.

	BOBCAT NUMBER						
	l(M)	2(M)	3(F)	4(M)	5(M)	6(M)	8(M)
RADIO LOCATIONS	60	145	385	394	51	151	124
PERIOD STUDIED							
date captured	12-4-78	12-28-78	1-1-79	1-5-79	1-12-79	1-23-79	3-3-79
date last located	5-6-79	3-29-79	6-28-79	6-29-79	6-6-79	6-28-79	6-28-79
days studied	153	91	178	174	145	156	117
HOME RANGE SIZE							
kilometers^2	25.7	27.8	17.5	34.2	4.7	20.5	53.6
miles^2	9.9	10.8	6.8	13.2	1.8	7.9	20.7

Bobcat 1 displayed a well defined home range, indicated by the southern and western portion of the home range shown in Figure 1 during the 20 day period following its capture. Subsequently, bobcat 1 abruptly abandoned this area and was later located to the northeast and did not return to the originally documented portion of its home range during the course of the study. Eleven days later Bobcat 4 was captured in the area previously occupied by Bobcat 1. During that 11-day period 3 traps within that area were sprung by an unknown bobcat. Bobcat 4 was captured and recaptured twice in the same area and radio-locations showed that Bobcat 4 occupied 90% of the home range previously occupied by Bobcat 1. While not necessarily a causal relationship, this sequence demonstrates the flux of home range occupancy by these bobcats.

The dynamic flux of areas occupied by bobcats is further demonstrated by Bobcat 8. Bobcat 8 displayed a bi-modal and even tri-modal home range. While Bobcat 8 primarily occupied the Queen Valley portion of its home range, it left Queen Valley and occupied a secondary area on the east slope of the

Little San Bernardino Mountains and a tertiary area in Lost Horse Valley. Both ancillary areas were 9 kilometers (5.6 mi) from the primary home range. Bobcat 8 stayed in these secondary or tertiary areas up to 2 weeks before returning to Queen Valley. The discovery of the secondary and tertiary areas utilized by Bobcat 8 was fortuitous.

Bobcat 7 was radio-collared, released and subsequently not located again. Whether this bobcat was a true transient (Bailey 1974) or transmitter failure occurred is unknown. Specific efforts (672 trap nights) to recapture this bobcat were unsuccessful. In contrast Bobcat 8 was captured twice in 286 trap nights and Bobcat 4 was captured 4 times with an average of 182 trap nights required per capture. Bobcat 2 was not located after 29 March 1979. Extensive efforts to retrap or locate 4 missing bobcats were only successful in the cases of Bobcats 1 and 8. Due to the possibility that some transient bobcats occur and the dynamic nature of home range occupancy, the previous population estimate of 6 bobcats within the core study area (62 km^2, 24 mi^2) at any given time may be quite accurate. The simultaneous occupancy of the core study area by no more than 6 bobcats yields a minimum known density of 1 bobcat per 10.36 km^2 (4 mi^2) as determined by radio-telemetry. Translated to numbers of bobcats per square kilometer, 0.1 bobcats per km^2 (0.25 bobcats/mi^2) represents the minimum known bobcat density determined during this study.

The density estimate determined by trapping and the density estimate based on radio-telemetry are in close agreement. The fact that eight bobcats were captured is ameliorated by the fact that radio-telemetry revealed that some bobcats were transients and/or left the area. Additionally, radio-telemetry showed that the average area used by the bobcats was twice the size predicted by their density. This can only be accounted for by the common use of space by more than one bobcat.

Home Range Overlap

The home range size and degree of home range overlap among conspecifics largely determines the density of a particular population. Bobcats have been described as being territorial in Idaho where home range overlap of pallid bobcats was slight among females and less among males (Bailey, 1972). In northeastern California the pallid bobcat displayed up to 30% overlap among individual females, and a female could be overlapped by 2 or more other females (Zezulak, 1978). In the same study only slight overlap existed among male bobcats. Lembeck (1978) reported almost no overlap among female bobcats but as much as 89% overlap between male California bobcats in San Diego County, California. Whether these disparate results are due to subspecific differences or other factors remains unanswered. A parallel between home range size and home range overlap is suggested. The desert bobcats of this study displayed density, home range sizes and extent of home range overlap that were intermediary of the other two subspecies and could be catagorized within this continuum (Table 3).

Table 3. Extent of bobcat home range overlap determined by radio-location techniques at Joshua Tree National Monument, Riverside County, California. The percentage of individual bobcat home range (Y) overlapped by adjacent bobcats (X) is presented below. The extent that an individual bobcat home range is overlapped by adjacent bobcats may exceed 100% since individual bobcat home ranges are often overlapped by several conspecifics.

PERCENT INDIVIDUAL BOBCAT HOME RANGE OVERLAPPED BY ADJACENT BOBCATS

	Bobcat (Y)				
Bobcat (X)	2(M)	4(M)	6(M)	8(M)	3(F)
2 (M)		38	1	19	
4 (M)	47		18	42	28
6 (M)	1	11		14	
8 (M)	36	66	37		75
3 (F)		14		25	
Total Overlap (%)	83	129	56	100	103
Home Range Not Overlapped (%)	46	24	63	28	17

While territorial in some instances, it appears that bobcats have the behavioral flexibility to accomodate denser population levels and concomitant increased conspecific interaction. The presence of one bobcat within the home range boundaries of another bobcat occurred 795 times during this study (Table 4). These data may not reflect a dominance hierarchy but certainly indicate the extent that some bobcats utilize common areas. An example of differential use occurs within the area shared by bobcats 4 and 8. Bobcat 4 was located within this area 206 times compared to the 53 times that bobcat 8 was in their common area. The ability to interact, primarily through temporal spacing, permits these bobcats to utilize a larger area than they would be able to occupy if they were strictly territorial. More investigation and analyses are required to evaluate the importance of the physical/biotic parameters operant in the extent of home range overlap displayed by bobcats. However, it is certain that the amount of overlap of bobcat home ranges has a profound effect on bobcat density and resource utilization.

Table 4. The occurrence of home range overlap demonstrated by bobcats at the Joshua Tree National Monument, Riverside County, California. The number of times bobcat "X" was located within the home range of bobcat "Y" is shown.

OCCURRENCE OF OVERLAP BY BOBCAT "X" ON THE RANGE OF BOBCAT "Y"					
	Bobcat (Y)				
Bobcat(X)	2(M)	4(M)	6(M)	8(M)	3(F)
2(M)		42			
4(M)	94		14	206	18
6(M)		32		43	
8(M)		53	8		22
3(F)		145		118	

Habitat Utilization

Home range utilization by bobcats in this study was primarily a function of habitat. Key features such as boulder piles, the desert plain and dry washes were associated with various types of activity and utilization by bobcats.

Three relatively small rocky areas that were elevated less than 30 meters (100 ft) from the surrounding desert plain were the sites of 6 captures of 4 different bobcats. The fact that these rocky areas were surrounded by desert plain for a radius of at least 1 kilometer (0.6 mi) increased their value as a sanctuary and as den/resting sites. Bobcats were observed to utilize rocky areas during periods of heavy rain and periods of high temperature almost exclusively. Although bobcats were observed resting under bushes or next to fallen Joshua trees on the desert plain during the winter months, most resting/denning activity was associated with rocky areas. Rocky areas were the key unique resource and as a result were the situations where most bobcat interaction occurred.

Observations of hunting behavior were confined to two habitat types. The undulating terrain at the base of mountains generally supported relatively lush vegetation and had higher populations of cottontail rabbits (Sylvilagus auduboni). Jackrabbits (Lepus californicus) were most abundant in the sparsely vegetated plains or valleys. Bobcats presumably hunted in these habitats in response to prey density.

Movement

The sequential radio-location of each bobcat indicated whether movement occurred during the time period since the previous radio-location. The occurrence of movement (standardized for sample size) was analyzed hourly and no difference in the time of day bobcats moved was found ($P < 0.05$). The distance bobcats moved varied on an hourly basis. Movements greater than 2 kilometers occurred during distinct time blocks (80% between 0800 and 1000 hours; 13% between 1400 and 1600 hours; 7% between 1600 and 1800 hours). While short distance movements (less than 2 km) occurred during all hours of the day, 30% of these movements occurred between 1400 and 1800 hours. Short distance movements were generally associated with hunting activity. Long distance movements were usually between different denning sites and/or in response to the presence of another bobcat. Conspecific interaction usually resulted in one or both bobcats moving into the exclusive area of their respective home range.

Bobcat Activity Patterns

Daily bobcat activity patterns were determined by analyzing variations of radio-signal strength. Since the daily photoperiod lengthens from winter to spring, the activity data were analyzed by season. All activity data were divided into 2-hour time blocks beginning at midnight. A crepuscular activity pattern was displayed by bobcats during winter months (Fig. 2). The shift to a nocturnal activity pattern during the spring (Fig. 3) may have been induced by several factors. Ambient temperature is a prime factor that may affect

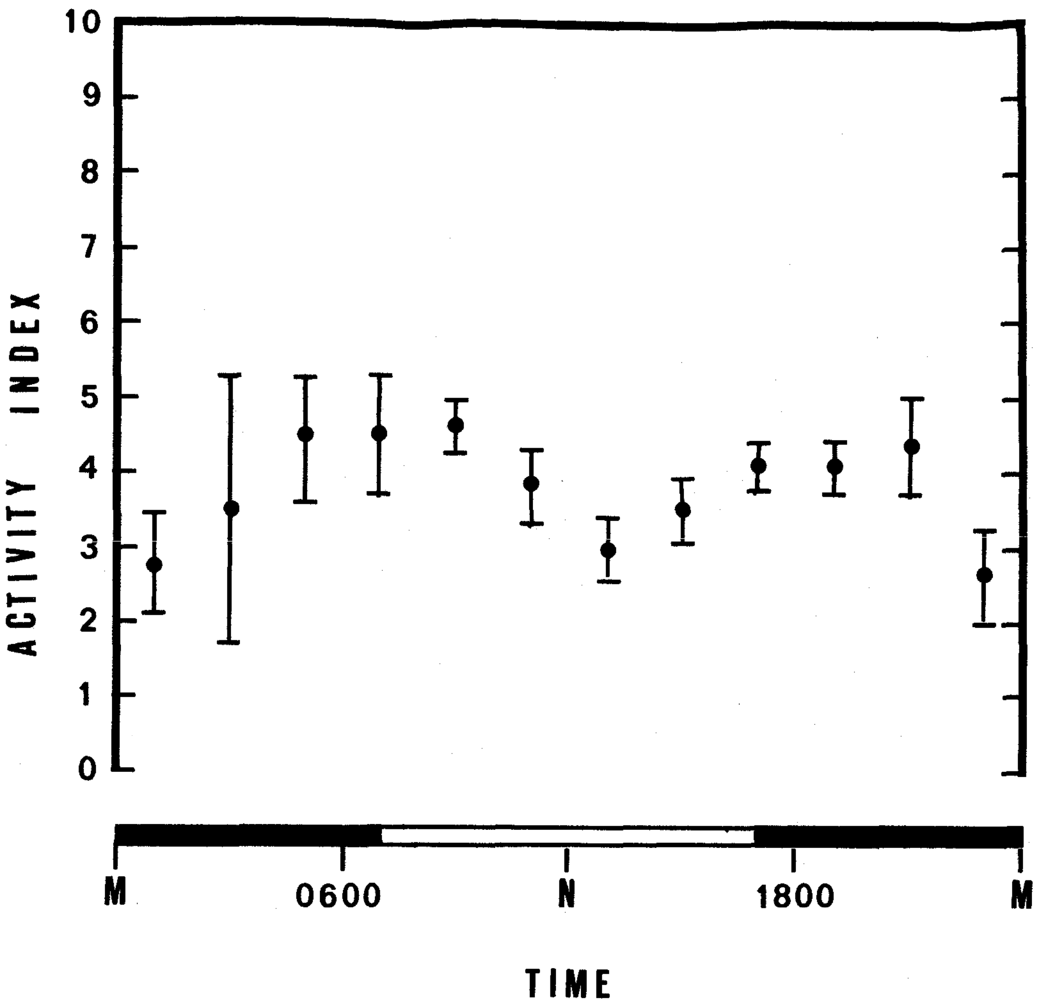

FIGURE 2. Winter bobcat activity pattern determined by radio-telemetry techniques at Joshua Tree National Monument, Riverside County, California. See text for description of technique. The mean activity level for 2 hour time-blocks is presented as a dot. Bars represent 2 standard errors on each side of the mean (n=1125). Average seasonal photoperiod is shown by the solid (hours of darkness) and open (hours of light) bars at the bottom of the figure.

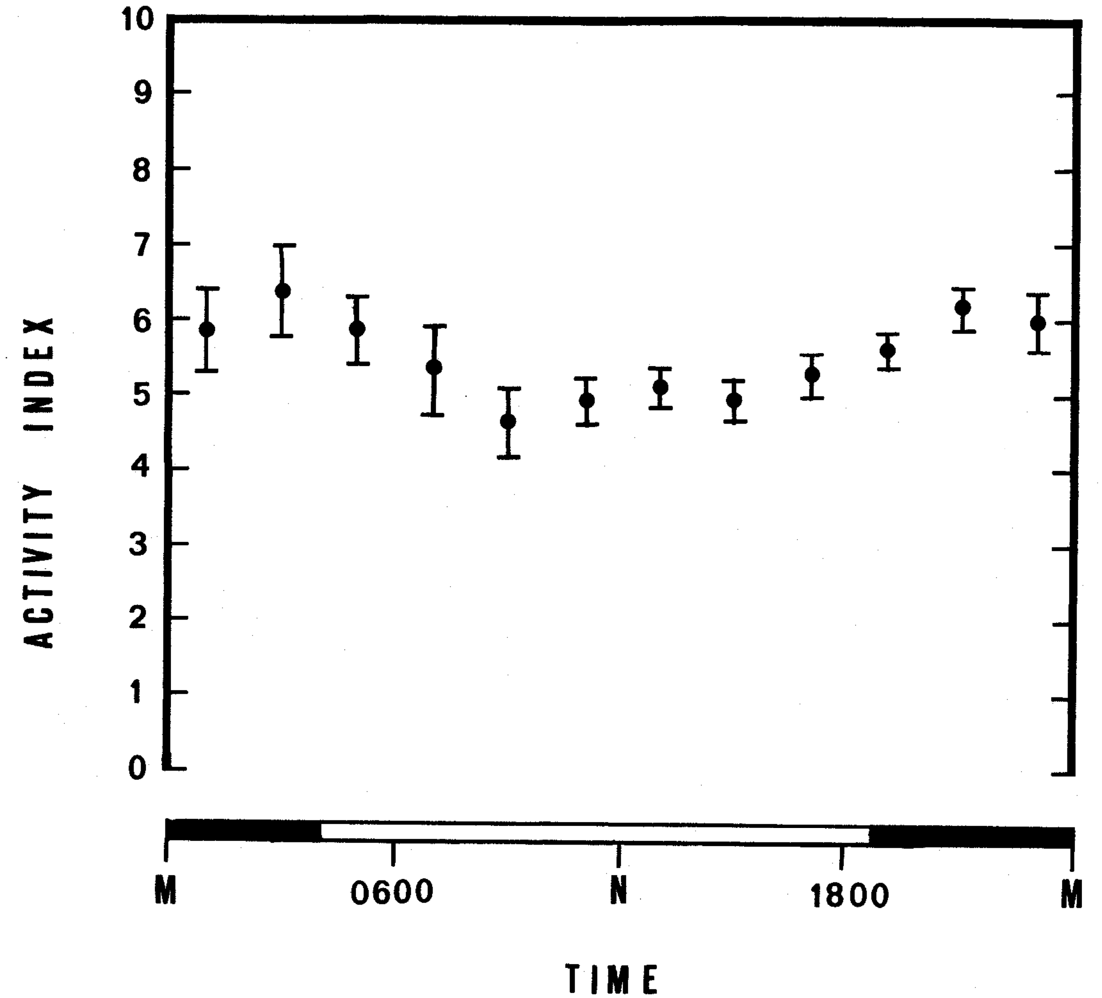

FIGURE 3. Spring bobcat activity pattern determined by radio-telemetry techniques at Joshua Tree National Monument, Riverside County, California. See text for description of technique. The mean activity level for 2 hour time-blocks is presented as a dot. Bars represent 2 standard errors on each side of the mean (n=1773). Average seasonal photoperiod is shown by the solid (hours of darkness) and open (hours of light) bars at the bottom of the figure.

bobcat activity levels. Nighttime temperatures were often as low as -6.7° C. (20° F.) in winter, during which bobcat activity peaked between 0400 and 1000 and again from 1600 to 2200. This pattern allowed at least 3 hours after sunrise and 2 hours before sunset when higher ambient air temperatures generally prevailed. The lowest levels of bobcat activity observed during the winter occurred from 2200 to 0200. During the spring season high amibient air temperatures (above 26° C., or 78° F.) were associated with reduced bobcat activity. Bobcats typically sought the cooler temperatures of large boulder piles when temperatures became excessive. While decreased bobcat activity appears associated with temperature extremes, it is not necessarily the proximate factor regulating the level of bobcat activity. The bobcats may have responded to other factors influenced by or related to air temperature such as the activity of prey species. Further, non-thermal environmental factors such as humidity and duration of daily darkness may have influenced the level of bobcat activity as well as the activity pattern of their prey.

Activity Patterns Of Prey Species

The activity patterns of potential prey species were analysed to determine a possible relationship to the patterns of bobcat activity. During winter 1,243 km of roadside census resulted in the observation of 39 jackrabbits, 37 cottontail rabbits, and 16 rodents. A similar census during spring in which 1,763 km. were assayed resulted in observation of 155 jackrabbits, 31 cottontail rabbits, and 294 rodents of various species. The level of prey activity, presumably representing the relative abundance, was considerably less during the winter season than during the spring (Fig. 4). The increased levels of prey observed during the spring season was largely due to the increased observations of jackrabbits and rodents.

Peaks of abundance of cottontail rabbits and jackrabbits corresponded to the onset and termination of bobcat activity during both seasons. The increase of spring prey activity during the middle portion of the night was largely due to the abundance of rodents. These differences in prey activity/ abundance may be an important factor contributing to the establishment of bobcat activity patterns. Maximum efficiency of a predator is attained when predator and prey activity patterns are in phase. Bobcat activity patterns are likely the result of various multi-dimensional factors, but dissection of any single factor obscures its significance.

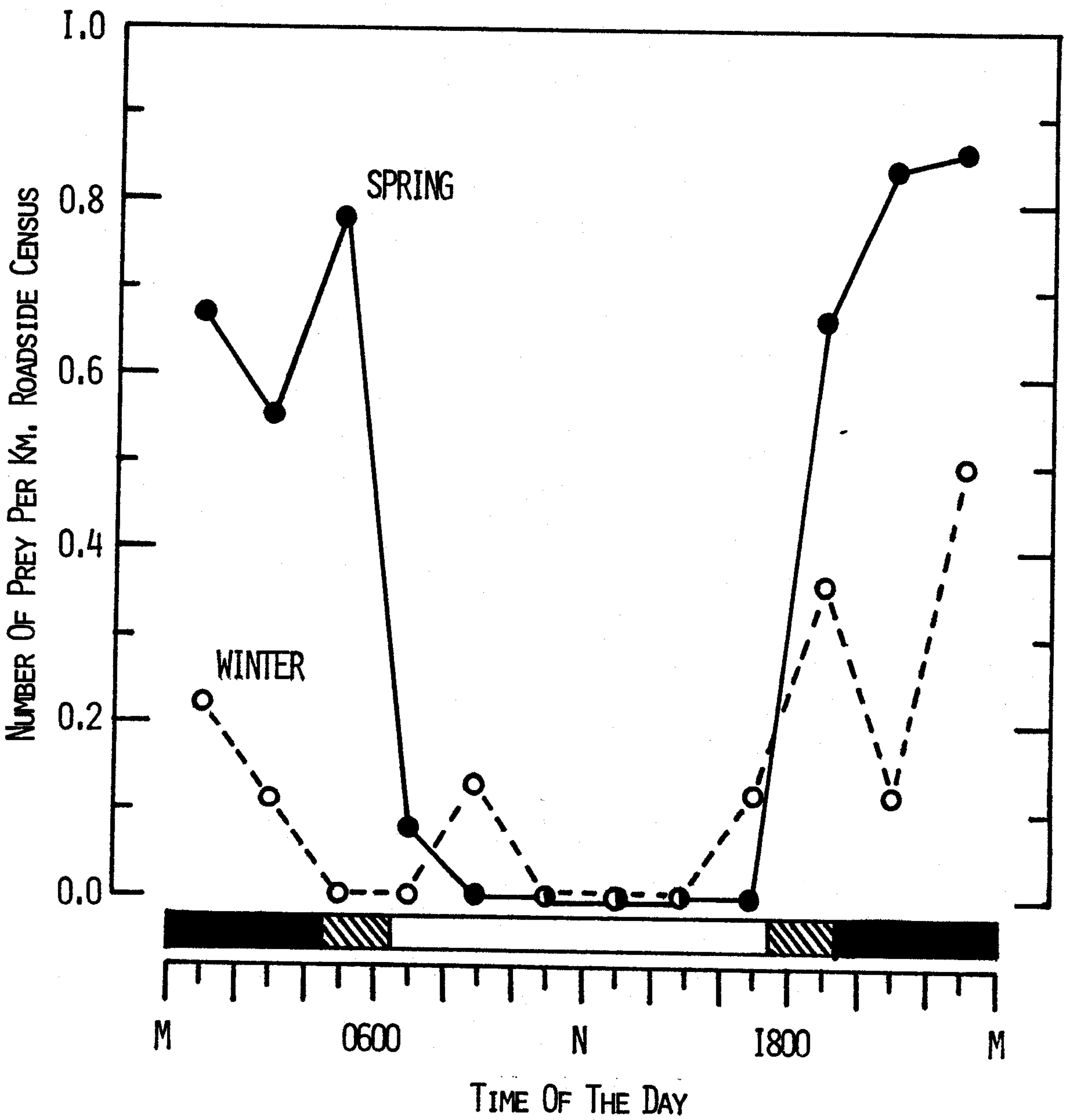

FIGURE 4. Numbers of bobcat prey (rodents and rabbits) observed during 1243 km (winter, 1979) and 1763 km (spring, 1979) of roadside census on the Joshua Tree National Monument, Riverside County, California. The seasonal abundance of prey observed is indicated by open circles and broken lines (winter) and solid circles and lines (spring) relative to the respective average daily duration of darkness shown by hatched and solid horizontal rectangles.

Bobcat Population Dynamics

The sex ratio of Joshua Tree bobcats was 7 males per female and no kittens were observed or captured during this study. The radio-collared female (Bobcat 3) did not display any signs of reproduction. She was recaptured in September and had not lactated nor was she pregnant. Few bobcat studies have demonstrated a complete absence of reproduction. In Idaho, Bailey (1972) noticed a decrease in reproductive output during one year of his three year study and attributed this to a decrease in the rabbit population during that year. Lembeck (1978) studied a very dense (1.5 bobcats/km^2) population of California bobcats (*F. r. californicus*) in San Diego County, California. No reproduction was documented until the last year of his 2 l/2 year study and occurred only after the population experienced a major decline (13 of 31 bobcats died due to trappers, disease, starvation, and predation). Thus, bobcat reproduction may be subject to influence by such proximate factors as prey density or bobcat densities and sex ratios.

An experimental control is, in part, provided for the Joshua Tree population of desert bobcats. Trappers harvested 110 bobcats in similar Mojave desert areas. The harvested bobcats had a sex ratio of 1.12 males per female and an examination of dental cememtum annuli (Crowe, 1972) revealed that 62% of these bobcats were less than two years old. This is an extreme contrast to the age and sex ratios of the population studied in the Joshua Tree National Monument which was effectively buffered by distance from trapping pressure.

The absence of reproduction by the Joshua Tree bobcats may represent a physiological response to the high density and degree of conspecific interaction within this population. One might envision that a sex ratio and adult/juvenile ratio which is highly skewed towards adult male bobcats might be the result of high intraspecific competition within the population. Juvenile bobcats may be less able to survive due to inexperience and female bobcats experience the additional stress of pregnancy and lactation during a considerable portion of the year. Hence, a population principally dominated by adult males exhibiting high levels of competition for limited resources may exemplify the stability/density characteristics established and maintained by near-pristine conditions on a bobcat population.

CONCLUSIONS

The density of several bobcat populations has been estimated on the basis of trapping results. However, the accuracy of such estimates may be influenced by the existance of transient bobcats. The density estimated by extrapolation of home range size and amount of home range overlap evidenced by a number of bobcats takes variation of these parameters into account and provides a better estimate of population size. The techniques utilized in this study provide an estimate of the density and age/sex structure of this sample population and is probably indicative of that existing in areas of comparable habitat throughout the monument. Parameters of bobcat biology vary greatly with respect to density, age/sex structure, prey availability, habitat and the particular subspecies being studied.

The desert bobcats occupying the Mojave desert habitat of Joshua Tree National Monument displayed a relatively high population density and commensurately small home ranges with a high degree of overlap. If differential competitive ability exists between bobcats of different ages and sex, highly skewed age/sex structures may appear in conjunction with high population density, as occurred in this study. Indeed, the productivity of bobcat populations appear to be enhanced by moderate man-induced mortality (Bailey 1972, Lembeck 1978, Zezulak 1978). This is reflected by a well stratified age structure and a reproductive level which approaches the maximum potential.

Bobcats may live to be 14 years old in the wild. In the absence of artificially induced mortality some form of natural population regulation must occur. Aspects of population dynamics, density, and behavior noted in this population differed from those bobcats in other studies where, at least, some level of man-induced mortality occurred. Indeed, the possibility that increased conspecific contact and competition reflected by behavioral changes, shifts in the age/sex structure and decreased reproduction may be factors regulating bobcat populations.

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