W-0035

RESPONSES OF BLACK-TAILED DEER TO OFF-HIGHWAY VEHICLES IN HOLLISTER HILLS STATE VEHICULAR RECREATION AREA HOLLISTER, CALIFORNIA

Final Report

submitted by
Robert M. Ferris, Field Investigator
Michael J. Kutilek, Ph.D., Principal Investigator

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Department of Biological Sciences
San Jose State University
One Washington Square
San Jose, California 95192

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ABSTRACT

We studied responses of black-tailed deer (*Odocoileus hemionus columbianus*) to off-highway vehicles (OHV) at Hollister Hills State Vehicular Recreation Area (HHSVRA) in central California after capturing 14 female deer and equipping them with radio-collars. Movements, habitat use, and activity levels were recorded for one year and compared with OHV use levels. Home range sizes for deer living within the riding area were similar to those of previously studied deer populations living in similar habitats but not exposed to riding. There was no significant correlation between OHV activity levels and deer activity levels. Deer exhibited diurnal activity patterns similar to patterns observed in other populations. Does, fawns and yearlings preferentially used riparian habitats and avoided north slope woodlands. Deer avoided OHV riding areas during peak use but returned to their established home ranges after traffic levels subsided.

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INTRODUCTION

While off-highway vehicle (OHV) use on public lands has increased dramatically in the last 10-15 years, knowledge of the effects of this activity on large ungulates is lacking. Most research has concentrated in desert environments on rodents, birds and reptiles, with little research in other habitats or on larger animals (Jones and Kutilek 1988).

The objective of this study was to assess the responses of black-tailed deer (Odocoileus hemionus columbianus) to off-highway vehicle (OHV) use in Hollister Hills State Vehicular Recreation Area (HHSVRA). While it has been reported that deer adapt to motor vehicle traffic (Adams 1981, Schultz and Bailey 1978, Ward et al. 1976, Rost 1975), we felt that intermittent, high levels of OHV activity may cause significant changes in deer biology.

Exposure to OHV traffic may cause deer to move further distances than usual, remain active longer during the day, use their habitat differently, and move away from sources of disturbance. Therefore, we hypothesized that female deer exposed to OHV traffic: (1) have larger home ranges than those reported in the literature that have not been exposed to OHV traffic, (2) increase the duration of their active periods, (3) have unusual habitat preferences and, (4) retreat from the area when vehicles are in operation.

STUDY AREA

Hollister Hills State Vehicular Recreation Area (HHSVRA) is a 1356 ha unit of the State Park System located in San Benito County, California. The Park is located 12 km south of Hollister and is within easy driving distance of several major metropolitan areas including San Francisco 112 km to the north. Our study was conducted in the approximately 1000-ha Lower Ranch.

The dominant vegetation in the study area was chaparral; low hard chaparral consisting of chamise (*Adenostoma fasciculatum*) and toyon (*Heteromeles arbutifolia*) and high hard chaparral or North Slope Woodland consisting of toyon, wedgeleaf ceanothus (*Ceanothus cuneatus*), manzanita (*Arctostaphylos* sp.), scrub oak (*Quercus dumosa*), interior live oak (*Quercus wislizenii*), and mountain Mahogany (*Cercocarpus betuloides*).

Other vegetation types included grassland dominated by wild oats (*Avena fatua*), soft chess (*Bromus mollis*), ripgut grass (*Bromus rigidus*), filaree (*Erodium cicutarium*), and bur clover (*Medicago hispida*); riparian-oak woodland consisting of sycamore (*Plantanus racemosa*), willows (*Salix* sp.), alder (*Alnus rhombifolia*), and coast live oak (*Quercus agrifolia*); oak woodland made up of valley oak (*Quercus lobata*), blue oak (*Quercus douglasii*) and coast live oak; and coastal shrub consisting of sagebrush (*Salvia mellifera*), flowering monkeyflower (*Mimulus longiflorus*), bush mallow (*Malacothamnus* sp.) and coyote bush (*Baccharis pilularis*) (Dept. of Parks and Recreation, 1978).

Physical Characteristics

Elevation within the Lower Ranch ranges from 245 m to 830 m above sea level. The climate is Mediterranean. Precipitation averages 33 cm/yr consisting mostly of rain with occasional snow during the winter.

History

OHV use began in this area as early as 1956. In 1970 the area was opened to the public as the "Hollister Hills Motorcycle Playground". The State of California purchased the ranch in October of 1975 which it now operates (Department of Parks and Recreation 1978). Deer populations at HHSVRA have not been subjected to hunting for at least 20 years (Larry Helm pers. comm.).

METHODS

Capture

We used modified Clover traps (Clover 1956) initially to capture deer for our study. The traps were equipped with sensors that signaled when they were tripped minimizing an animal's time in captivity. The animals were restrained manually and handled in the manner prescribed by the California Department of Fish and Game (1978).

In August 1988, after limited success with the Clover traps, we began to use tranquilizer darts under supervision of California Department of Fish and Game personnel. Deer within HHSVRA

were extremely tolerant of motor vehicles consequently, darting efforts were conducted from four-wheel drive vehicles. In most cases, we were able to approach to < 25 m of the targeted animals. Drugs were delivered using Pneu-darts (Pneu-Dart, Inc., Williamsport, PA) containing a 2cc dose (approximately 1 ml/22 kg) of a ketamine hydrochloride and xylazine mixture (200 mg:40 mg/ml respectively), propelled by either CO2 or black powder dart rifles.

Data Collection

We captured deer to attach Telonics MOD-600 radio collars equipped with S6B mortality/motion sensors (Telonics, Inc., Mesa, AZ). In addition, tags were affixed to their ears to enable identification from a distance. Thirty cc blood samples were taken for analysis of trace mineral content and disease monitoring by the CDFG.

Movements and activities of the radio-collared deer were monitored an average of two days per week for a period of one year using a Telonics TR2 receiver. We made visual confirmations of locations, whenever possible, but when animals were hiding in dense brush or were outside of the park, locations were made by triangulation (Mech, 1983). The time of day, date, location, weather conditions, and temperature were all recorded with each location.

With each location we recorded the collar pulse rate (fast or slow) as an indication of relative activity levels. Slow

rates indicated that the animal had remained motionless for over 3 min, while a fast collar rate indicated that the animal was continuously active.

With each location, we noted the relative probability of the deer's exposure to vehicular traffic and assigned a vehicular traffic index (VTI) number. A VTI of 1 indicated that the animal was in a relatively open spot < 30 m from a primary road open to all types of traffic. A VTI of 2 was assigned to an animal in the open but > 30 m from a primary road, behind a fence or in cover < 30 m of a primary road, or in open areas within 30 meters of a secondary road (a trunk directly attached to a primary road). A VTI of 3 was assigned to an animal located in more remote parts of the riding area and a 4 was given to an animal in the Nature Area or in areas closed to riding. A VTI of 5 indicated that the animal was outside the park and that its chance of being exposed to vehicular traffic was negligeable.

We also recorded an avoidance index (AI) with each location. The AI measured how difficult it was to locate the animals with the radio-telemetry receiver, which was assumed to be inversly related to the level of disturbance. Equipment with a shorter receiving range was employed as we got closer to the animal. Calm deer fed in the open and were easily observed, but disturbed deer remained hidden or fled from the observer. Animals outside the park boundaries, located using a two-element yagi antenna and triangulation, received an avoidance index of 5. Animals in heavy cover located with the flexible antenna (rubber ducky)

received an AI of 4. Animals not seen but close enough to have their signal received with the antenna lead or with no antenna were given AI's of 3 and 2 respectively. Animals located visually received an AI of 1.

Data Analysis

We used a Lotus 1-2-3 worksheet on an IBM-PC XT for storing and collating the data from the field. Locations were converted to UTM co-ordinates.

Program Home Range (Samuel et al. 1985) was used to test for independence of serial locations and compute convex polygon home ranges (Hayne 1949). Convex polygon home ranges (CPHR) were given in three levels 100%, 95%, and 50%. The 100% CPHR's contained all points and included some outliers that resulted from exploratory wanderings that were not part of that animals normal home range. The 95% CPHR contained 95% of the locations and closely approximated the animals true use of an area. The 50% CPHR indicated areas of concentrated use and roughly outlined the animals core areas (areas of concentrated use). We elected to use the 95% and 50% CPHR for our analyses. The home range sizes were then analyzed using an analysis of variance (ANOVA) for any influence attributable to OHV traffic levels. Home range sizes were analyzed for differences due to seasons, ages of animals, and differences between animals living in the riding area, nature area, and Martin's Ranch.

We did not use other home range programs such as Anderson and the modified Dixon program (Timossi and Barrett, 1985) because the samples did not show independence of serial locations which makes the results of these two analyses questionable. Non-independent samples tend to under-estimate home range size (Swihart and Slade 1985).

Activity levels were recorded as active or inactive (1 or 0) and compared with traffic levels and temperature using a Pearson Correlation Matrix and a Spearman Rank Correlation.

Habitat selection was recorded using vegetation catagories already established (California State Deptartment of Parks and Recreation 1978). Habitat utilization and habitat preferences were analyzed by comparing habitat use with habitat availability in a method similar to Neu et al. (1974) and Alldredge and Ratti (1986). Annual and seasonal comparisons were made using G-tests.

Unless otherwise noted, statistical analyses were computed using Systat (Systat Inc. 1989) on an IBM XT, IBM PS2, or IBM PC.

For seasonal analyses, the year was divided into four seasons, the dry season (summer) from 1 June 1988 to 30 September 1988, the rutting season (fall) from 1 October 1988 to 31 December 1988, the wet season (winter) from 1 January 1989 to 30 March 1989, and the fawning season (spring) from 1 April 1989 to 1 June 1989.

RESULTS

Captures

A total of 14 animals were captured, 7 adult does, 6 yearlings, and 1 fawn (Table 1). Six were captured with modified Clover traps and 8 by darting (Ferris and Hunter 1988).

Sightings

As of 20 May 1989 a total of 1773 locations were recorded for all radio-collared and visibly identified animals. There were 210 visual sightings and the rest of the locations were gathered via triangulation. There were 153 visual sightings during summer and fall and the remainder during winter and spring.

Family Groups

We observed 13 groups in a 450 ha area of the Lower Ranch (Table 2) consisting of up to 5 individuals or less. The largest groups had 1 adult doe, 2 fawns and 2 yearlings. We estimated that the total deer population of a 450 ha portion of the Lower Ranch was 41-45 individuals or approximately one animal per 10-11 ha.

Activity Levels

There was no statistical correlation between vehicle traffic levels and the amount of activity of deer ($r= -0.020$ $p > 0.10$). There was, however, a negative correlation ($r= -.663$ $p= 0.013$)

Table 1. Summary of radio-collared black-tailed deer captured in Hollister Hills State Vehicular Recreation Area.

Capture Date	Animal ID	Age(a)	External Parasites	Capture Site
22 Jun 88	10AC	A	Few	Seismic Station
29 Jun 88	9AC	A	Few	Woodwardia Basin
14 Jul 88	4AC	A	Many	Turtle Lake
14 Jul 88	8YaC	Y	Few	Bird Creek
21 Jul 88	5AC	A	Many	Turtle Lake
17 Aug 88	11YC	A	Few	Seismic Station
2 Sep 88	3YC	Y	Many	Turtle Lake
2 Sep 88	3AC	A	Some	Turtle Lake
15 Sep 88	1YbC	Y	Few	Walnut Camp
15 Sep 88	1YaC	Y	Few(b)	Walnut Camp
15 Sep 88	2FaC	F	Few	Adobe Road
28 Sep 88	2AC	A	Few	Adobe Road
3 Nov 88	13YC	Y	Few	Radio Ridge
3 Nov 88	12AC	A	Few	Walnut Camp

a) A= adult Y= yearling F= fawn
b) Had eye worm parasites *Thelasia californiensis*.

Table 2. Groups of black-tailed deer in Lower Ranch, Hollister Hills State Vehicular Recreation Area, Hollister, California, June, 1988-May, 1989.

Group(a)	Doe	Yearling	Fawn	Area	Comments
1	1AU	1YaC 1YbC	2FaU 2FbU	Walnut Camp	1YaC died 28 Apr 1989
2	2AC	2YU	2FaC 2FbU	Radio Ridge- Adobe Rd.	
3	3AC	3YC	3FU	Turtle Lake	
4	4AC	4YU	4FaU 4FbU	Lodge Lake	4AC died 14 Apr 1989
5	5AC	5Y?	5FaU 5FbU	Lodge Camp	5AC died 27 Aug 1988 5FaU died 1 Sep 1988 5FbU died 26 Nov 1988
6	6AU		6FaU 6FbU	Lodge Camp	Replaced Family Group 5
7	7AU		7FaU 7FbU	Bee Camp	
8	8AU	8YaC 8YbU	8FU	Madrone Camp	
9	9AC		9FaU 9FbU	Woodwardia Basin	
10	10AC			Environmental Camp	
11	11A?	11YC	11F?	Seismic Station	
12	12AC	12YU 12Y?	12FaU 12FbU	Mini Bike Trail Area	12AC died 28 Nov 1988
13	12AU	13YC	13FU	Park Head- quarters	13YC lost collar 30 Nov 1988

(a) First numbers indicate family group affiliation.
Letters A,Y and F indicate age of animal (i.e., adult, yearling or fawn).
Lower case letters indicate multiple members in class.
Letters U or C indicate that the animal is uncollared or collared and ? refers to unconfirmed individuals or groups.

between temperature and activity levels which was consistent with Lindsdale and Tomich (1953).

Daily patterns of activity were also similar to those found in other studies (Kammermeyer and Marchinton, 1977). Deer showed normal crepuscular activity peaks throughout most of the year except during the winter season when the peaks were not as pronounced and activity levels were steady most of the day (Figure 1).

Home Range

Home range sizes varied greatly between individuals and seasons (Table 3). The seasonal differences were highly significant for the 95% home range sizes ($p= 0.001$) and barely significant for the 50% home ranges ($p= 0.052$). Several factors contributed to differences between seasonal home range sizes. Two of the most important factors were water availability and seasonal activity (e.g. eating, fawning, rutting). Family group 3 spent all summer in a stand of coastal scrub above Turtle Lake, their 95% home range was 16.5 ha. Their water supply during that time came from a leaking pipe. When the pipe was repaired and the water supply was no longer available, their 95% home range expanded to 38.5 ha. Family group 2 spent most of the rutting season near the Lower Field Road pond. When the rains came, they were able to move up to the pond below Super Hill. Family groups 9 and 4 also moved their centers of activity as water resources in Woodwardia Basin and Lodge Lake changed.

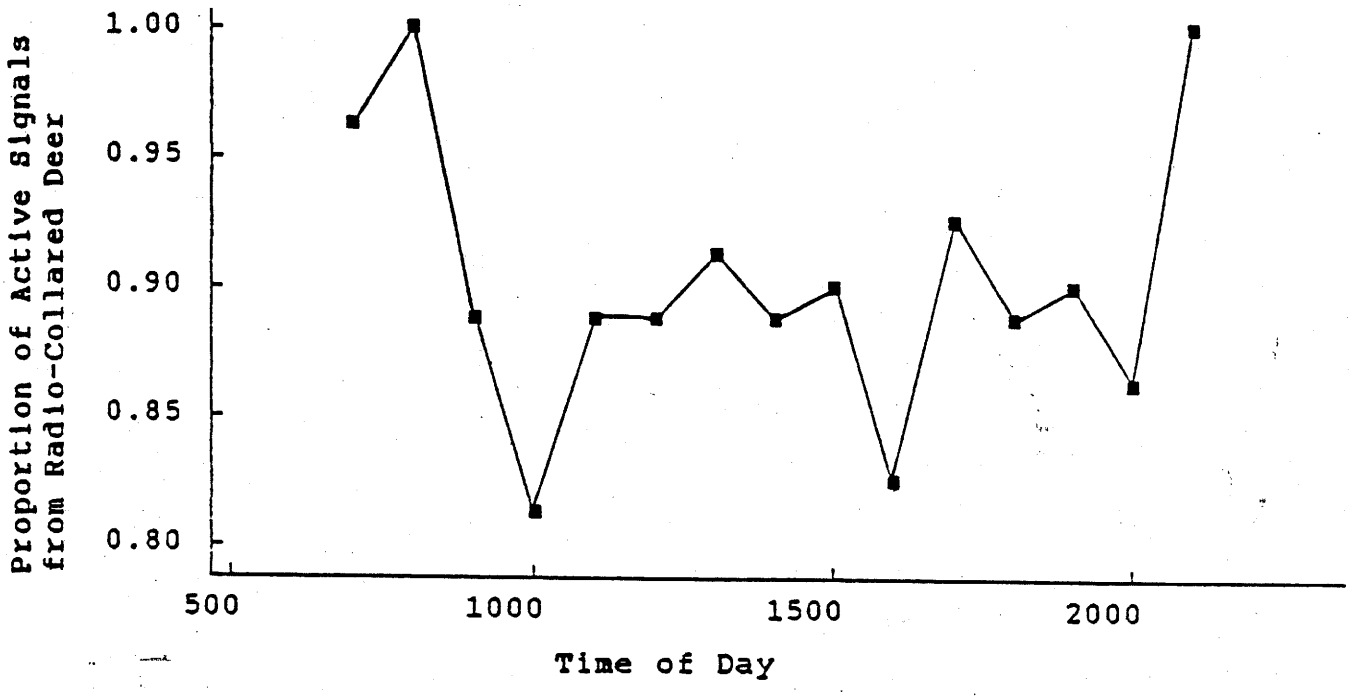


Figure 1. Diurnal activity patterns of collared black-tailed deer at Hollister Hills State Vehicular Recreation Area, Hollister, California, June 1988-May 1989.

Table 3. Convex polygon home range sizes (ha) of black-tailed deer at Hollister Hills State Vehicular Recreation Area, Hollister, CA June 1988-June 1989.

DEER	Summer 1988		Fall 1988		Winter 1989		Spring 1989		Year Round	
No.	95%	50%	95%	50%	95%	50%	95%	50%	95%	50%
11YC	63.3	5.3	100.0	5.0	18.0	3.5	10.5	0.5	92.5	9.0
1YaC	---	---	17.0	5.0	20.5	2.5	---	---	26.0	7.5
4AC	64.3	10.5	25.5	3.0	30.5	2.0	---	---	73.3	9.0
8YaC	153.0	19.0	58.0	14.0	35.0	8.0	15.0	0.5	202.5	28.5
10AC	204.7	4.0	37.0	3.5	32.5	17.0	26.5	4.0	204.9	13.5
3YC	23.8	0.8	42.0	2.6	26.0	6.5	3.3	0.5	42.3	6.1
1YbC	---	---	41.0	3.5	22.5	2.8	26.0	6.5	69.0	17.5
5AC	35.0	9.1	---	---	---	---	---	---	35.0	9.1
3AC	16.3	4.3	38.5	1.4	27.3	3.8	27.5	0.1	37.3	3.3
2AC	---	---	40.5	3.0	22.5	7.5	10.5	3.0	64.0	19.0
9AC	185.1	56.0	33.0	4.0	24.5	1.0	5.5	1.0	178.2	17.0
2FaC	---	---	40.5	3.0	26.5	3.3	---	---	60.5	19.0
13YC	---	---	65.0	1.5	---	---	---	---	65.0	1.5
12AC	---	---	6.0	0.1	---	---	---	---	6.0	0.1
Mean=	93.2	13.6	41.9	3.8	26.0	5.3	15.6	2.0	82.6	11.4
S.D.=	75.9	18.0	23.2	3.4	5.2	4.5	9.8	2.3	65.1	8.0

The smallest average home range sizes occurred during the fawning season when the fawns are hidden by does (Jackson et al. 1972, Riley and Dood 1984). Summer home ranges were the largest since the fawns were fully capable of extended travel (>1 km) at age 1 month (Riley and Dood 1984). Increased travel by fawns during summer was also linked to their diet; as their dependency on browse increased so did their home range sizes.

Home range sizes for adults, yearlings and fawns were not significantly different ($p= 0.784$ for 95% home range, $p= 0.688$ for 50% home range). There was no significant correlation between traffic level and home range sizes using Pearson's Correlation Matrix. Using Spearman's Ranked Correlation analysis, there was a barely significant relationship ($r= 0.564$ $p= 0.045$) between traffic and the 95% home range during the rut. There was no statistically significant size differences between 95% home ranges ($p= 0.280$) or 50% home ranges ($p= 0.695$) for animals with home range centers in the riding area, Nature Area or Martin's Ranch.

Avoidance Index

Deer showed definite patterns of avoidance behavior with increasing levels of OHV use. The mean daily AI's rose near the weekend as OHV use increased and declined during mid-week (Figure 2).

A Pearson Correlation analysis indicated that traffic levels strongly influenced AI's ($r= .685$ $p < 0.01$) (Figure 3). An

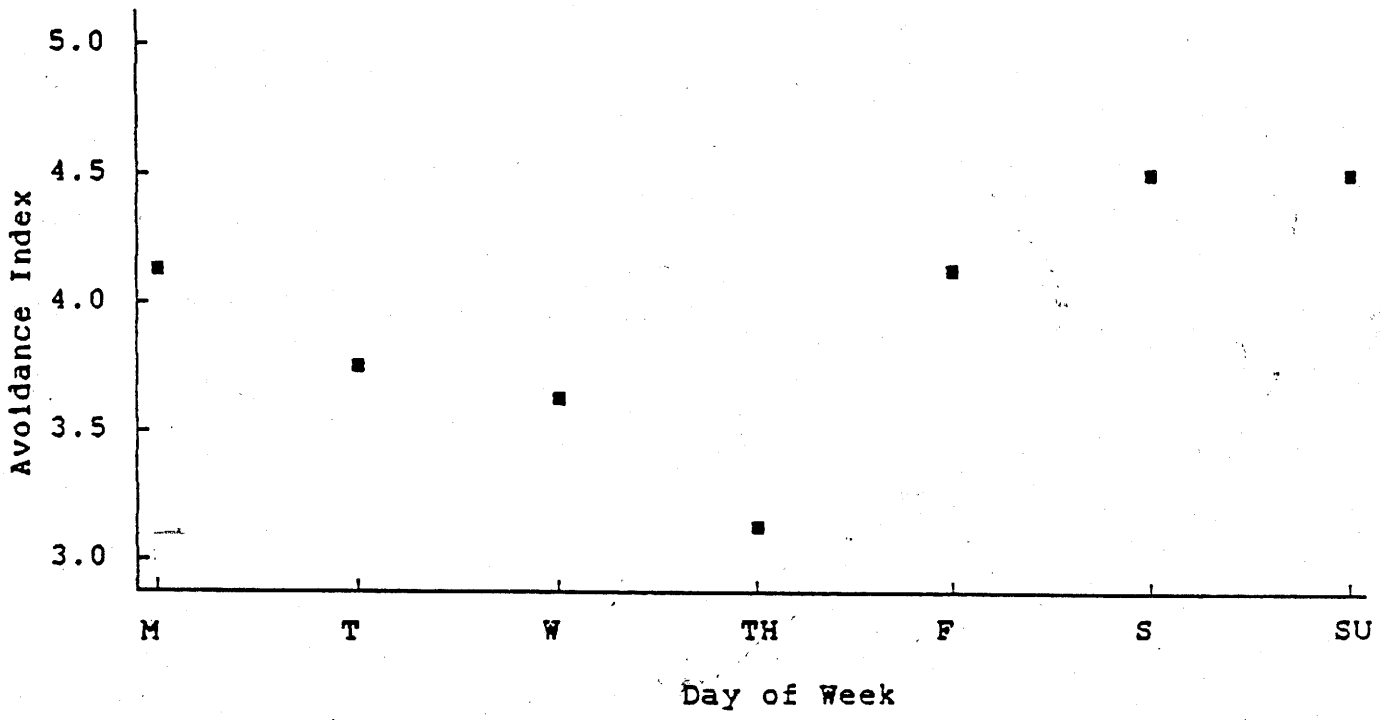


Figure 2. Mean avoidance index per day of week for all collared deer at Hollister Hills State Vehicular Recreation Area, Hollister, California, June 1988-May 1989.

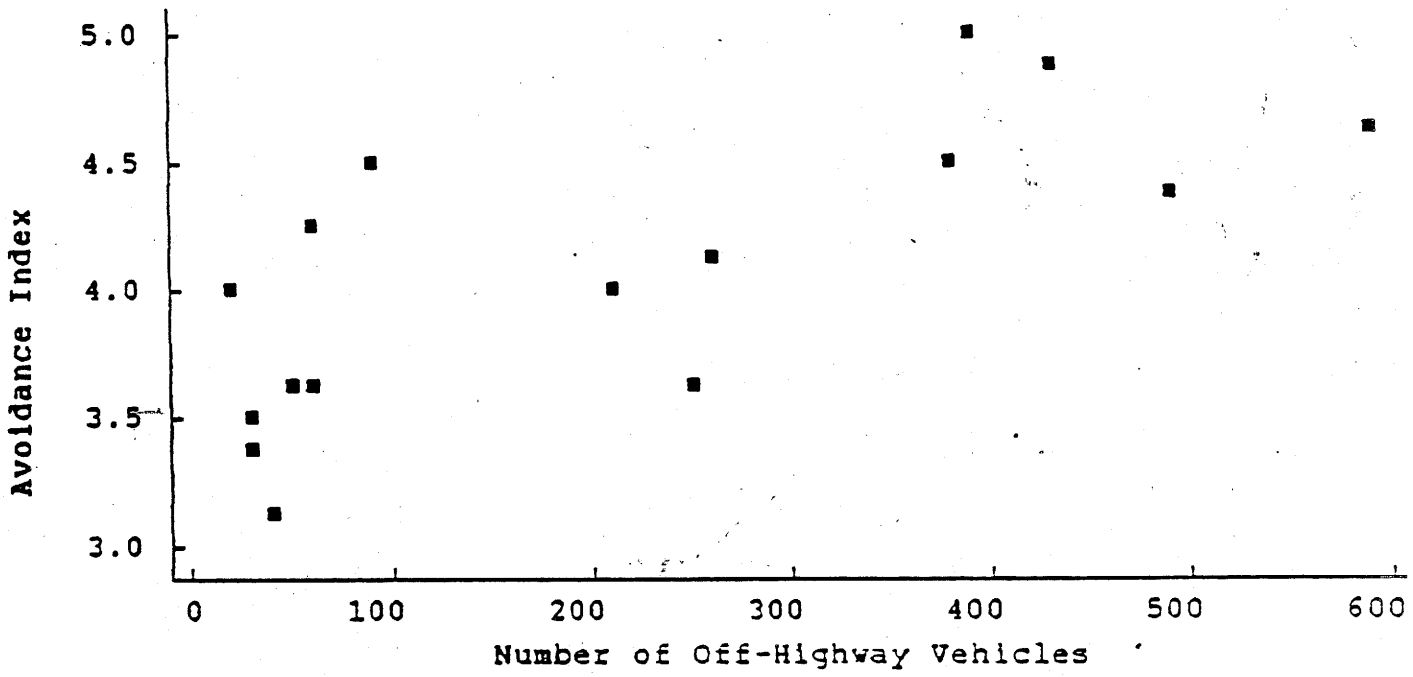


Figure 3. Mean avoidance index for all collared deer in relation to traffic levels at Hollister Hills State Vehicular Recreation Area, Hollister, California, June 1988-May 1989.

analysis of covariance (ANCOVA) showed that when the effects attributable to traffic were factored out, the levels were not affected by the various seasons. In other words, deer were not more sensitive to traffic during fawning season or less sensitive during the rut.

Vehicular Traffic Index

The relationship between VTI and the days of the week was similar but weaker than for the AI (Figure 4). The correlation between traffic levels and VTI was $r = .478$ ($p < 0.01$) (Figure 5) over the entire spectrum of exposures and $r = .511$ ($p < 0.1$) when only traffic levels > 50 units (motorcycles and ATV's) were considered. These data indicate that there was a tendency for deer to leave the park during traffic peaks.

The pattern for both AI's and VTI's recurred on a weekly basis. Reaction to increased traffic was immediate with deer leaving the park. Once traffic subsided, the deer took several days to return (Figures 2, 4 and 6).

Habitat Selection

A G-test comparing available habitat type with habitat use indicated that does, yearlings and fawns had a strong preference for riparian oak woodland and avoided the high hard chaparral (North Slope Woodland) and grassland areas ($G=16.75$ $df=5$, $p= 0.005$) (Table 4). Their use of coastal scrub and low hard

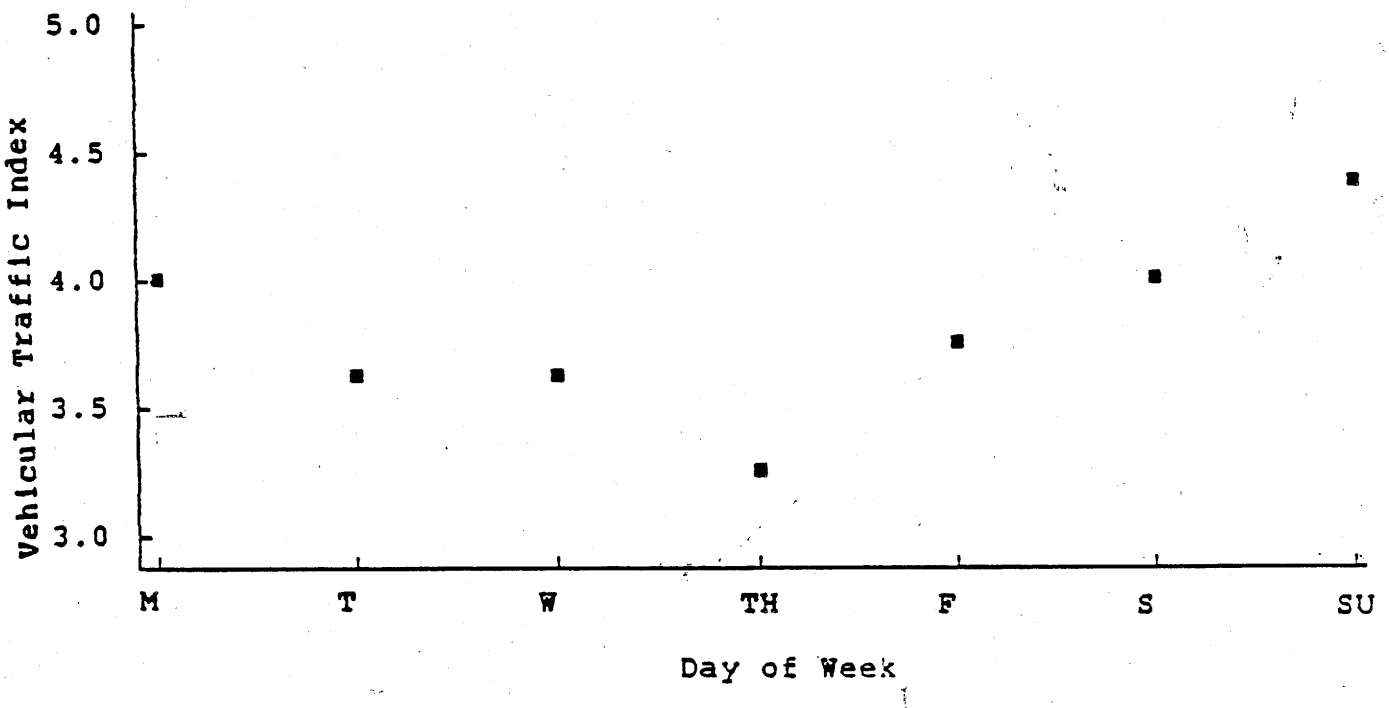


Figure 4. Mean vehicular traffic index per day of week for all collared deer at Hollister Hills State Vehicular Recreation Area, Hollister, California, June 1988-May 1989.

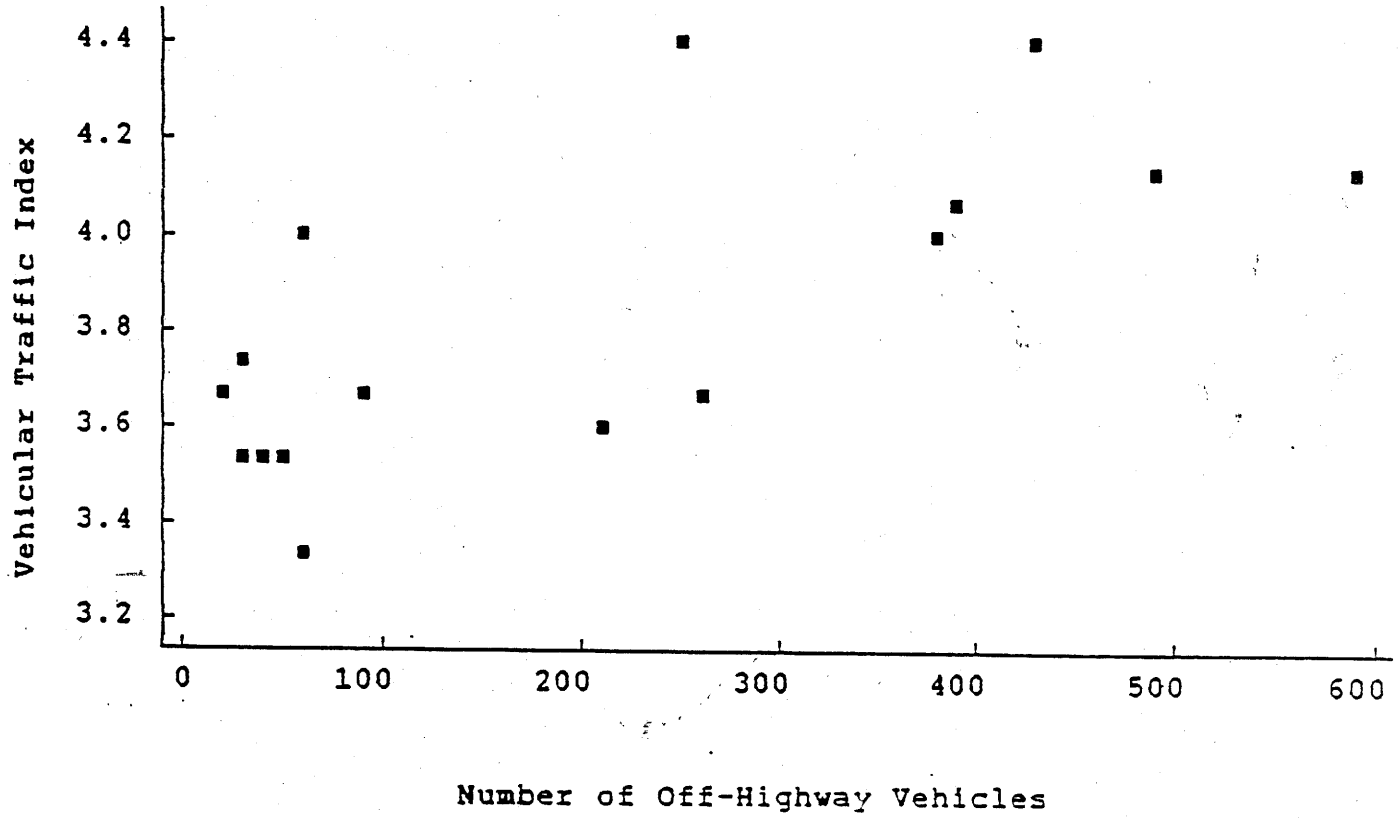


Figure 5. Mean vehicular traffic index for all collared deer in relation to traffic levels at Hollister Hills State Vehicular Recreation Area, Hollister, California, June 1988-May 1988.

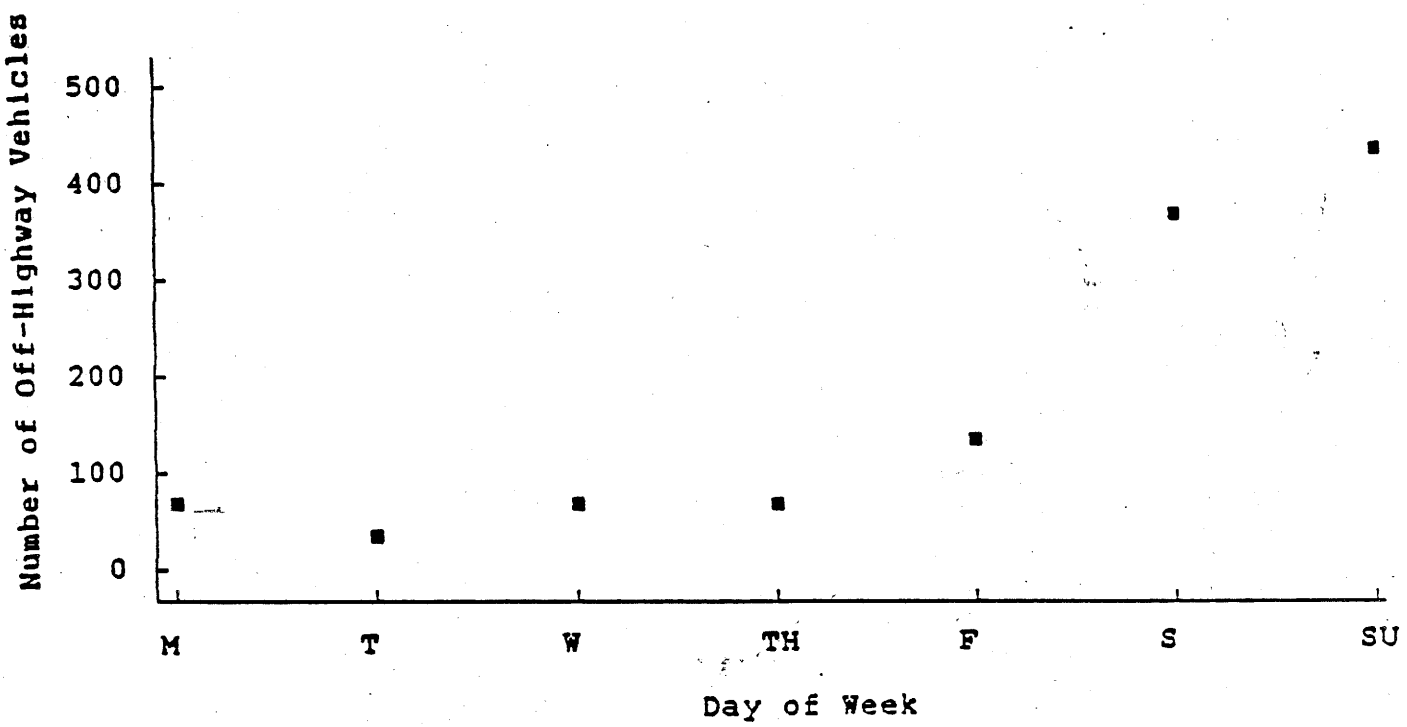


Figure 6. Mean traffic levels (motorcycles and all-terrain vehicles) per day of the week at Hollister Hills State Vehicular Recreation Area, Hollister, California June 1988-May 1989.

Table 4. Habitat Use and Habitat Availability at Hollister Hills State Vehicular Recreation Area, Hollister, California, June, 1988-May, 1989.

Habitat Type	Percent Available	Percent Used				
		Summer	Fall	Winter	Spring	Year
Grassland	18%	4%	5%	1%	1%	3%
Low Hard Chaparral	12%	20%	12%	15%	17%	16%
High Hard Chaparral	28%	7%	2%	3%	4%	4%
Riparian Oak Woodland	17%	58%	55%	43%	44%	50%
Oak Woodland	5%	6%	12%	8%	12%	9%
Coastal Scrub	20%	6%	15%	29%	21%	19%

chaparral were not significantly different from their availability.

Group Size

Observations of group size were peripheral to the study, however, we found that group size was smaller within the park than in the surrounding areas. We commonly observed groups of 10-15 animals browsing or resting in the oak woodlands of the Renz and Martin ranches but failed to see groups > 5 individuals within the park, even in the fall when group size usually increases (Jennings, 1985).

Females apparently outnumbered adult males within the confines of the study area. Males resided in the more remote areas of the park in deep cover or at higher elevations.

Territoriality and Dispersion

Deer at HHSVRA exhibited territorial behavior. Groups ranged over large areas (Appendices I-IX) but avoided the core areas of adjacent groups. We did not, however, observe deer families avoiding previously occupied areas as was reported by Dasmann and Taber (1956). These exclusive use areas or territories (Figure 7), similar to those described by Riley and Dood (1984), ocurred only in wooded areas further reinforcing the scent marking mechanism proposed by Muller-Schwarze (1971).

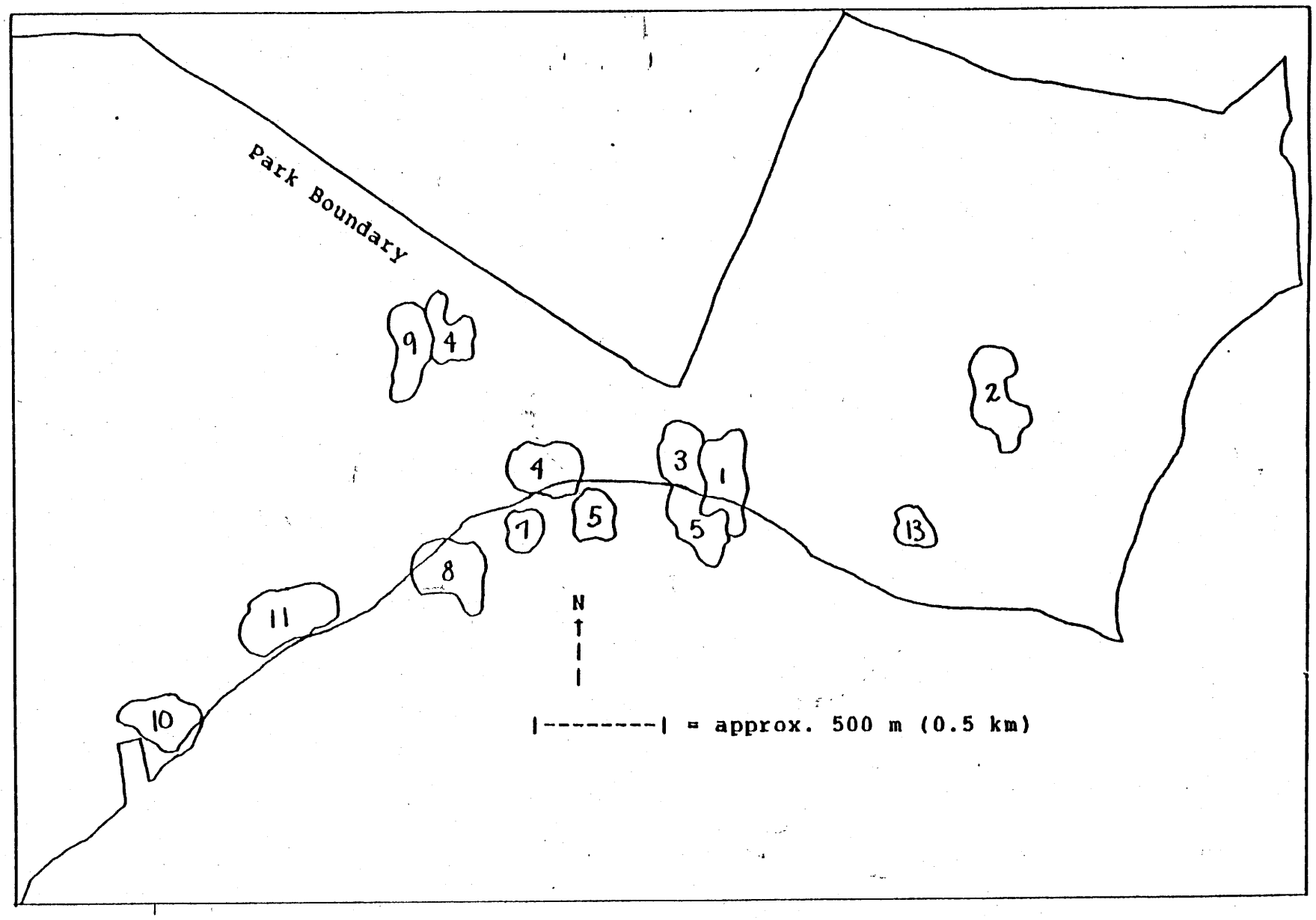


Figure 7. Approximate locations of exclusive use areas of black-tailed deer groups at Hollister Hills State Vehicular

Agonistic behavior was observed on three occasions. In each instance the interaction occurred between a yearling and a fawn. The yearling charged the fawn as a threat or actually pushed the fawn away from the doe. This behavior was similar to the "rush" behavior described by Cowan and Geist (1961). None of these activities took place in the open grassy areas.

We observed a general relaxing of territoriality during times of high OHV use. Animals with home range centers in the park tended to enter the Bird Creek drainage or the Renz property temporarily, but stayed away from the resident populations core areas. This behavior was consistent with observations by other workers (Dasmann and Taber 1956, Deblinger and Alldredge, 1989).

DISCUSSION

The convex polygon method (Hayne 1949) may often overestimates home range size because it includes all of the outlying points in the analysis. There is also a significant correlation between number of sightings and home range size (Eberhardt et al. 1984). Even so, home range sizes of deer at HHSVRA were similar to other studies using more conservative methods (Dasmann and Taber 1956, Miller 1970, Jennings, 1985). Therefore we rejected hypothesis 1 of the Introduction. We found no relationship between home range size and OHV use.

We also rejected hypothesis 2. It is well documented that more energy is expended as an animal increases its activity. Large increases in energy expenditure can be detrimental to survival (Hobbs 1989). Deer at HHSRVA did not increase the duration of their active periods in response to OHV's nor did they increase their activity while vehicles were absent. Throughout this study, diurnal activity peaks were similar in duration and position to other deer populations studied (Kammermeyer and Marchinton 1976, Eberhardt et al. 1984). Therefore, the presence of OHV's at HHSVRA appeared to have little impact on activity levels.

Regarding hypothesis 3, we found no evidence that deer changed their habitat utilization because of traffic levels. Deer used the riparian oak woodland and oak woodlands preferentially even during times of high traffic. Neither habitat

provided as much cover as chaparral for which the deer showed no significant preference.

While the data did not support hypotheses 1-3, it strongly supported hypothesis 4. Deer reacted to high levels of OHV traffic by moving to areas that were free from traffic, often within their normal home ranges. No collared animal left the area permanently, however, or failed to return to its core area when traffic levels lessened.

Although we have no numerical data, the presence of cattle on lands adjacent to park property appeared to influence the distribution of deer. Deer groups 1,8,10, and 11 all had activity centers in Martin's Ranch along Bird Creek. On several occasions, the deer in the Bird Creek corridor moved to steeper ground and into deeper cover when cattle grazing occurred. The overlap of preferred foods between deer and cattle is slight (Wagner 1977) but when areas are overgrazed, cattle begin to compete with deer and the deer are displaced to the steeper slopes (Barrett 1982).

The sexual segregation (males at higher elevations, females, young and fawns at lower elevations) observed at HHSVRA is similar to what has been observed in other studies with no OHV's (Bowyer 1984, McCullough et al. 1989). One explanation for the sexual segregation at HHSVRA is that the water requirements of males, with their larger body size and large rumen to body volume ratios, are less than for smaller does, yearlings and fawns (Bowyer, 1984). This allows bucks to inhabit dryer areas without

hardship. Another explanation is that bucks are able to eat lower quality food without suffering adverse effects (McCullough et al. 1989).

OHV use on public lands is an emotional and controversial issue. It seems intuitive that deer, with their well-developed hearing and other adaptations as a prey species, would be strongly affected by OHV activity. The data, however, generally did not support this conclusion.

RECOMMENDATIONS

The findings of this study result from a complex interaction between park design, the distribution of water and forage, land management practices such as cattle grazing on surrounding lands, and the availability of proximal escape areas. Water resources are of paramount importance to does, yearlings, and fawns (Bowyer 1984, Hervert and Krausman 1986). The development and maintenance of sediment ponds has enhanced deer habitat. An added improvement would be the protection of these basins from human interference during the drying period in late summer and early fall. Traffic through the ponds at Tule Lake, Lodge Lake, and Woodwardia Basin hastened evaporation and displaced some animals prematurely. Fences with signs explaining the reason for the closure may help to correct this situation.

Traffic should also be directed away from the drainages most used by deer. Bird Creek and the gully connecting Woodwardia Basin to Lodge Lake provide water and important cover. Vegetation in the Harmony Gate gully has been damaged severely by riders traveling between Harmony Gate and North Canyon roads. Seasonal closures of some of the connection routes would be beneficial to deer.

Information from this study is important in future trail placement. Programs should be established to redirect OHV use away from preferred habitat types such as riparian and oak woodlands and into adjacent areas of high hard chaparral (north slope woodland) and grassland.

An effort should be made to encourage OHV users to stay on established trails in the wooded areas particularly in the vicinity of Harmony Gate and the minibike area between Walnut Camp and Lodge Camp. Studies have shown that the animals reacted minimally to disturbances on established trails and roads but there were increased responses to disturbances where none had occurred before (McArthur et al. 1982, Schultz and Bailey 1978).

Campsites in the Lower Ranch are all located in the riparian-oak woodland. Deer would derive greater benefit from these areas in the future if camping facilities were located in other habitat types. The areas adjacent to the present campsites could be improved as deer habitat if native vegetation were planted or encouraged to grow along the Bird Creek fence line. The area surrounding Walnut Camp is excellent deer habitat, with year-round water, food resources and cover, but is probably not used to its full potential because of heavy human use. We recommend that Walnut Camp be redesignated as a day use area and that Radio Ridge, an area of limited value to deer, be improved to handle camping. Deer habitat would thus be enhanced with a minimum impact to park users.

Chaparral and north slope woodland in the Nature Area are overgrown and senescent and the habitat quality of the area could be improved by implementing a program of prescribed burns. Visitors to the Nature Area should be advised to stay on trails

since hikers tend to frighten deer (Freddy et al. 1986, McArthur et al. 1982).

We found little evidence that deer within the SVRA were unduly stressed by the activities of OHV's. All studies of this kind are site specific and one must exercise caution in extrapolating the results from one area to another. Caution is also needed in extrapolating from one time period to the next, given the fact that SRVA's are not only subject to annual change in precipitation but also to changes in traffic and other land uses. Therefore, we recommend periodic monitoring of the deer population to insure that an up to date basis for management is available.

This study demonstrated that deer tolerate OHV traffic and suggests, by the fact that deer keep returning after disturbance, that OHV areas may actually provide resources that typical overgrazed ranges do not. It is important to determine in the future whether there are positive aspects for deer from OHV land use by comparing populations exposed to different land management schemes, including OHV use.

LITERATURE CITED

Adams, L. W., 1981. Effects of highways on wildlife. Fed. Highway Off. Res. and Dev. Rep. FHWA-RD-81-067. 133 pp.

Alldredge, J. R. and J. T. Ratti. 1986. Comparisons of some statistical techniques for analysis of resource selection. J. Wildl. Manage. 50: 157-165.

Barrett, R. H., 1982. Habitat preferences of feral hogs, deer and cattle on a Sierra foothill range. J. Range Manage. 35: 342-346.

Bowyer, R. T., 1984. Sexual segregation in southern mule deer. J. Mammal. 65: 410-417.

California Department of Fish and Game. 1978. Animal restraint handbook. Calif. Dept. Fish and Game, Sacramento. 57 pp.

California State Department of Parks and Recreation. 1978. Hollister Hills State Recreation Vehicular Area resource management plan, general development and environmental impact. Unpublished report. 127 pp.

Clover, M. R. 1956. Single gate deer trap. Fish and Game, 42:199-201.

Cowan, I. Mc T. and V. Geist, 1961. Aggressive behavior in deer of the genus Odocoileus. J. Mammal. 42: 523.

Dasmann, R. F. and R. D. Taber, 1956. Behavior of Columbia black-tailed deer with reference to population ecology. J. Mammal.37: 143-164.

Deblinger, R. D. and A. W. Alldredge, 1989. Management implications of variations in pronghorn social behavior. Wildl. Soc. Bull. 17: 82-87.

Eberhardt, L. E., E. E. Hansen,and L. L. Cadwell. 1984. Movement and activity patterns of mule deer in the sage brush-steppe region. J. Mammal. 65: 404-409.

Ferris, R. M. and D. L. Hunter, 1988. Tranquilizer darts as a capture method for black-tailed deer. Unpublished report. 5 pp.

Freddy, D. J., W. M. Bronaugh and M. C. Fowler. 1986. Responses of mule deer to disturbance by persons afoot and snowmobiles. Wildl. Soc. Bull. 14: 63-68.

Hayne, D. W. 1949. Calculation of size of home range. J. Mammal. 39: 190-206.

Hervert J. J. and P. R. Krausmann. 1986. Desert mule deer use of water developments in Arizona. J. Wildl. Manage. 50: 670-676.

Hobbs, N. T. 1989. Linking energy balance to survival in mule deer: development and test of a simulation model. Wildl. Monogr. 101, 1-39.

Inglis, J. M., R. E. Hood, B. A. Brown, and C. A. DeYoung. 1979. Home range of white-tailed deer in Texas coastal prairie brushland. J. Mammal. 60: 377-389.

Jackson, R. M., M. White, and F. F. Knowlton. 1972. Activity patterns of young white-tailed deer fawns in south Texas. Ecology 53: 262-270.

Jennings, V. R. 1985. Home range, habitat utilization and activity patterns of the black-tailed deer of the Diablo Range of California. Unpubl. M.A. Thesis, San Jose State Univ., San Jose. 67 pp. + app.

Jones, S and M. J. Kutilek. 1988. Comparisons of low and high-use sites for vegetation and wildlife diversity and abundance in Hollister Hills State Vehicular Recreation Area, Hollister, California. Final Report to California State Department of Parks and Recreation. Sacramento, CA. 42 pp.

Kammermeyer, K. E. and R. L. Marchington. 1977. Seasonal change in circadian activity of radio-monitored deer. J. Wildl. Manage., 41:315-317.

Lindsdale, J. and Q. P. Tomich, 1953. A herd of mule deer: a record of observations made of the Hastings Natural History Reservation. Univ. Calif. Press, Berkeley. 567 pp.

MacArthur, R. A., V. Geist, and R. H. Johnston. 1982. Cardiac and behavioral responses of mountain sheep to human disturbance. J. Wildl. Manage. 46: 351-358.

McCullough, D. R., D. H. Hirth and S. J. Newhouse, 1989. Resource partitioning between sexes in white-tailed deer. J. Wildl. Manage. 53: 277-283.

Mech, L. D., 1983. Handbook of animal radio-tracking. Univ. of Minn. Press, Minneapolis, Minn. 107 pp.

Miller, F. L. 1970. Distribution patterns of black-tailed deer in relation to environment. J. Mammal. 51: 248-260.

Muller-Schwarze, D., 1971. Pheromones in the black-tailed deer (Odocoileus hemionus columbianus). Anim. Behav. 19: 141-152.

Neu, C. W., C. R. Byers, and J. M. Peek. 1974. A technique for analysis of utilization-availability data. J. Wildl. Manage. 38: 541-545.

Riley, S. J. and A. R. Dood, 1984. Summer movements, home range, habitat use, and behavior of mule deer fawns. J. Wildl. Manage. 48: 1302-1310.

Rost, G. R., 1975. Response of deer and elk to roads. Unpublished M. S. Thesis, Colorado State Univ. Fort Collins, CO. 51 pp.

Samuel, M. D., D. J. Pierce, E. O. Garton, L. J. Nelson and K. R. Dixon. 1985. User's manual for Program Home Range. University of Idaho, Moscow, ID. 70 pp.

Schultz, R. D. and J. A. Bailey. 1978. Responses of National Park elk to human activity. J. Wildl. Manage. 42: 91-100.

Spenser, W. D. and R. H. Barrett. 1983. An evaluation of the harmonic mean measure for defining carnivore activity areas. Acta Zool. Fennica. 171:255-259.

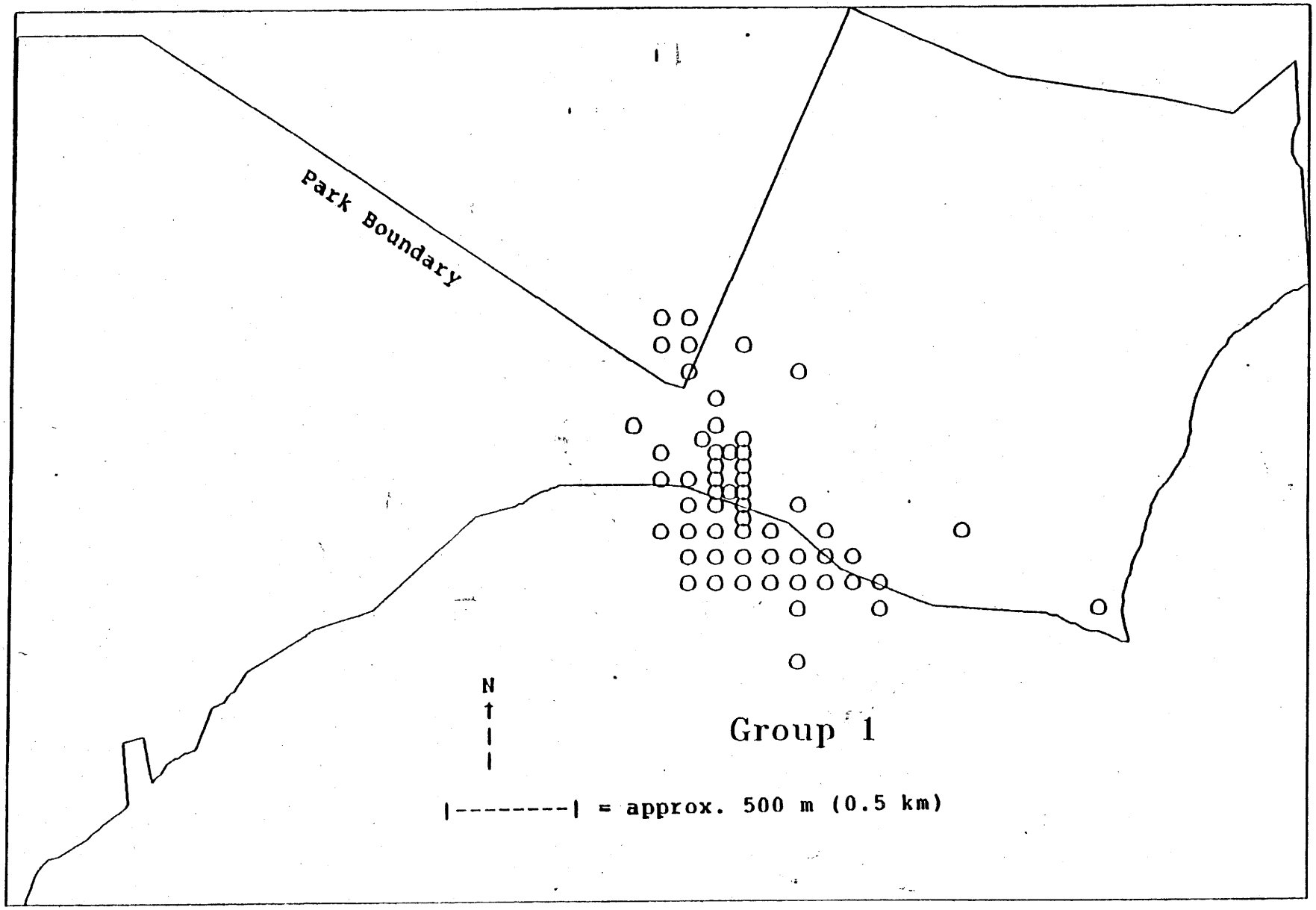
Swihart, R. K. and N. A. Slade. 1985. Influence of sampling interval on estimates of home range size. J. Wildl. Manage. 49: 1019-1025.

Systat Inc., 1989. Systat. Systat Inc., Evanston IL.

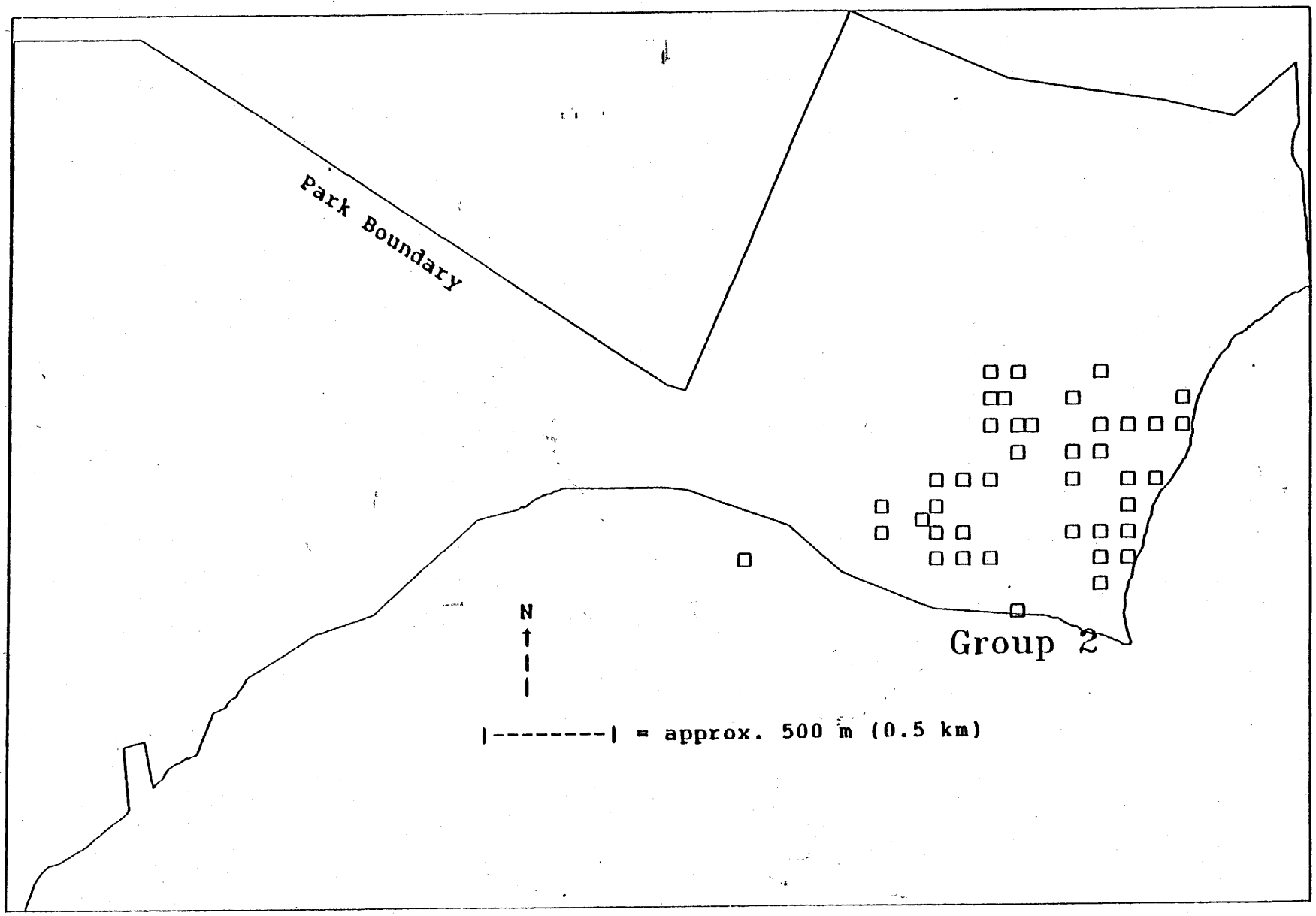
Tomossi, I. C. and R. H. Barrett. 1985. Micro-Dixon user's manual. Dept. of Forestry and Resources Management, University of California, Berkeley, Ca. 14 pp.

Wagner, F. H. 1977. Western rangeland: troubled American resource. Trans. N. Am. Wildl. and Natur. Resour. Conf. 43: 435-461.

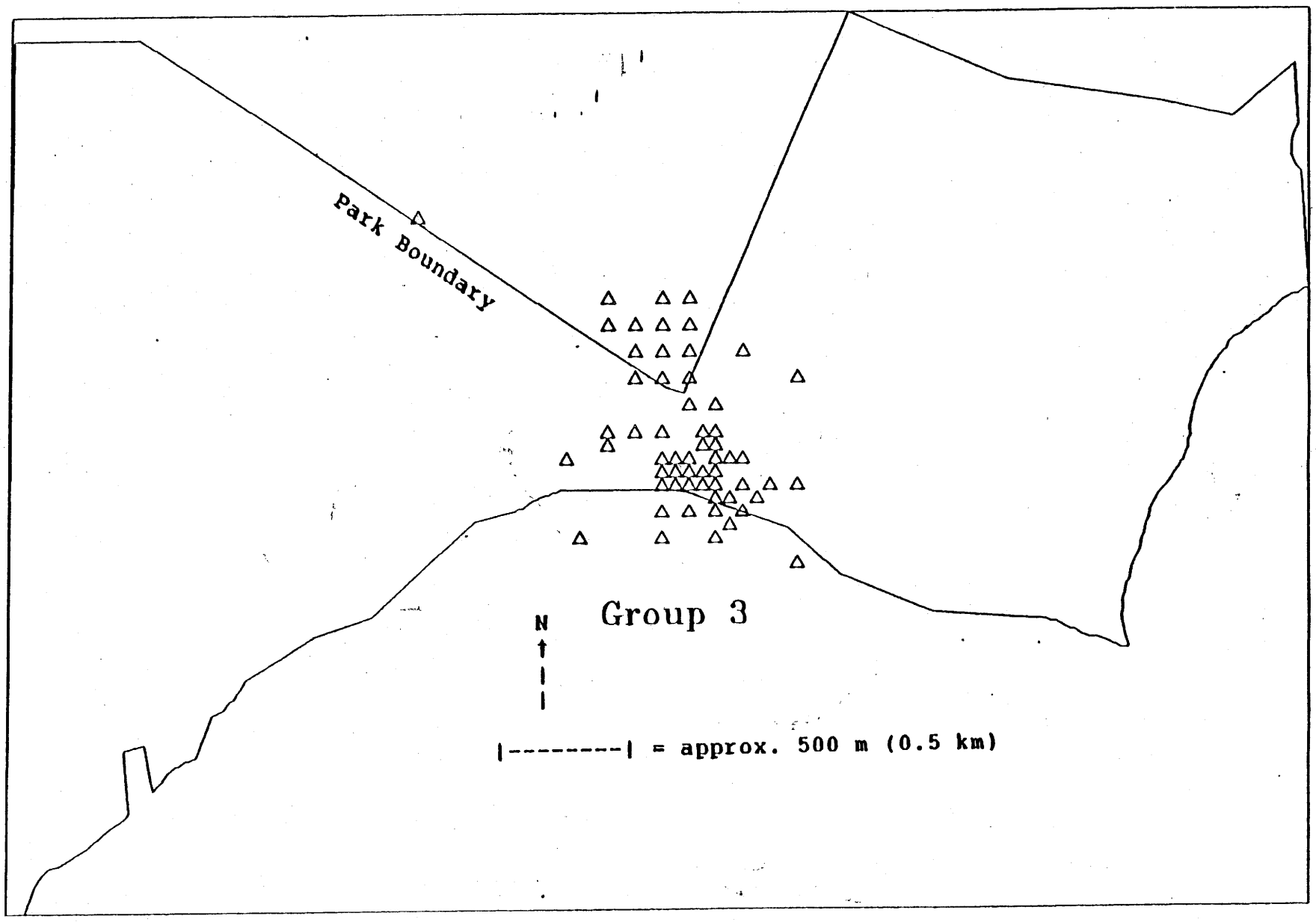
Ward, A. L. J. J. Cupal, G. A. Goodwin and H. D. Morris. 1976. Effects of highway construction and use on big game populations. Fed. Highway Off. Res. and Dev. Rep. FHWA-RD-76-174. 92 pp.



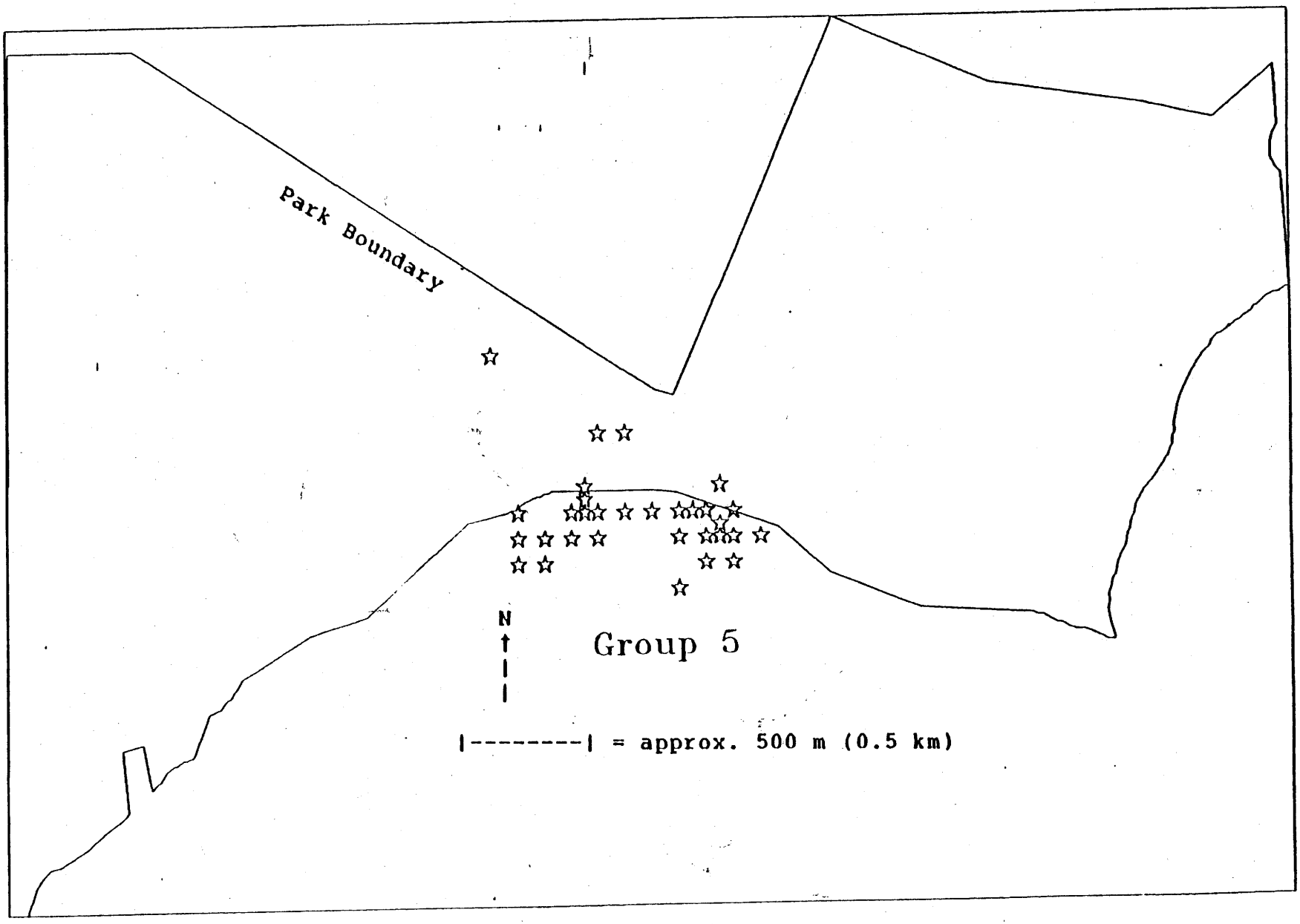
Appendix I. Black-tailed deer group 1 use of Hollister Hills State Vehicular Recreation Area, Hollister, California. June 1988-June 1989



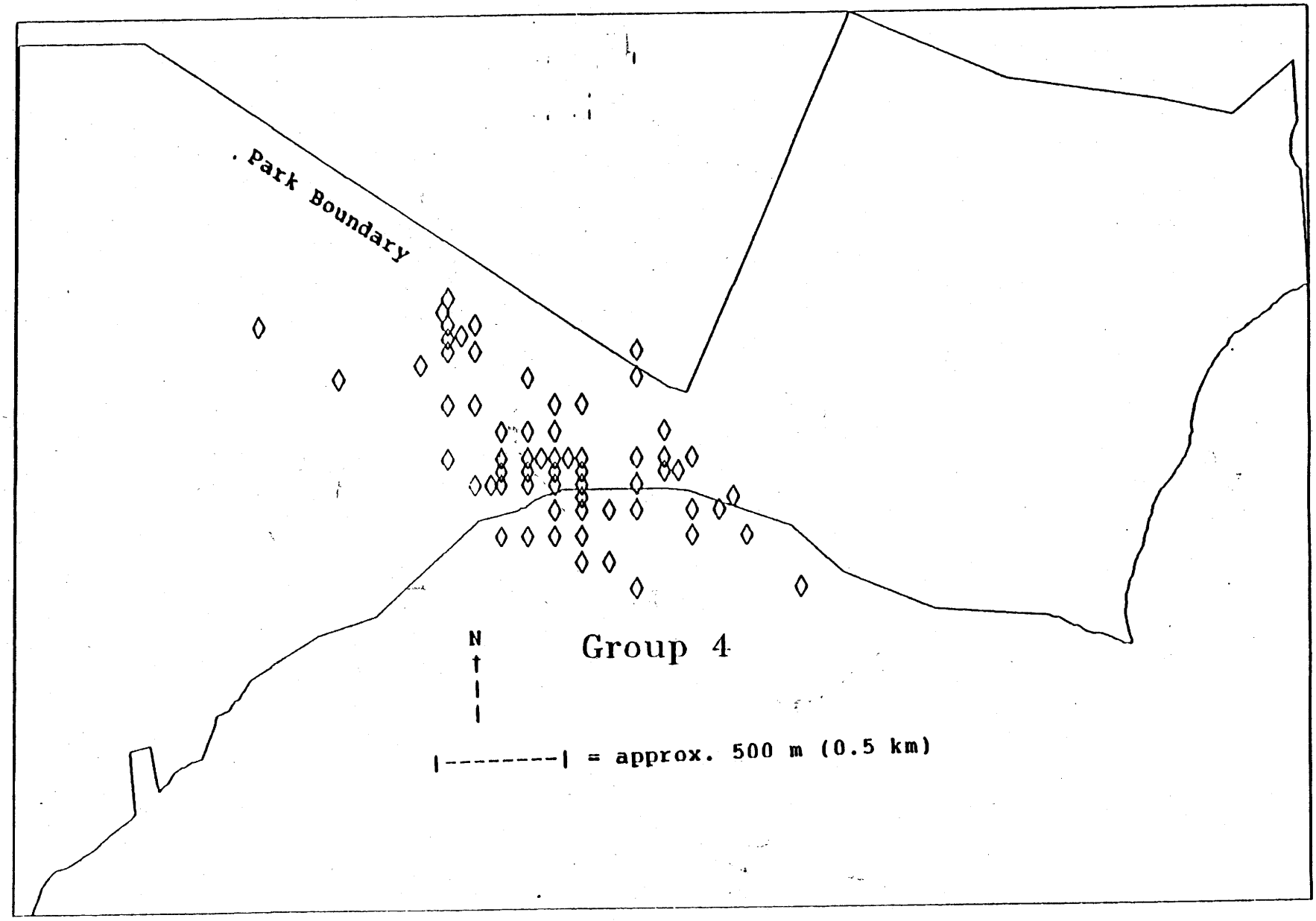
Appendix II. Black-tailed deer group 2 use of Hollister Hills State Vehicular Recreation Area, Hollister, California. June 1988-June 1989.



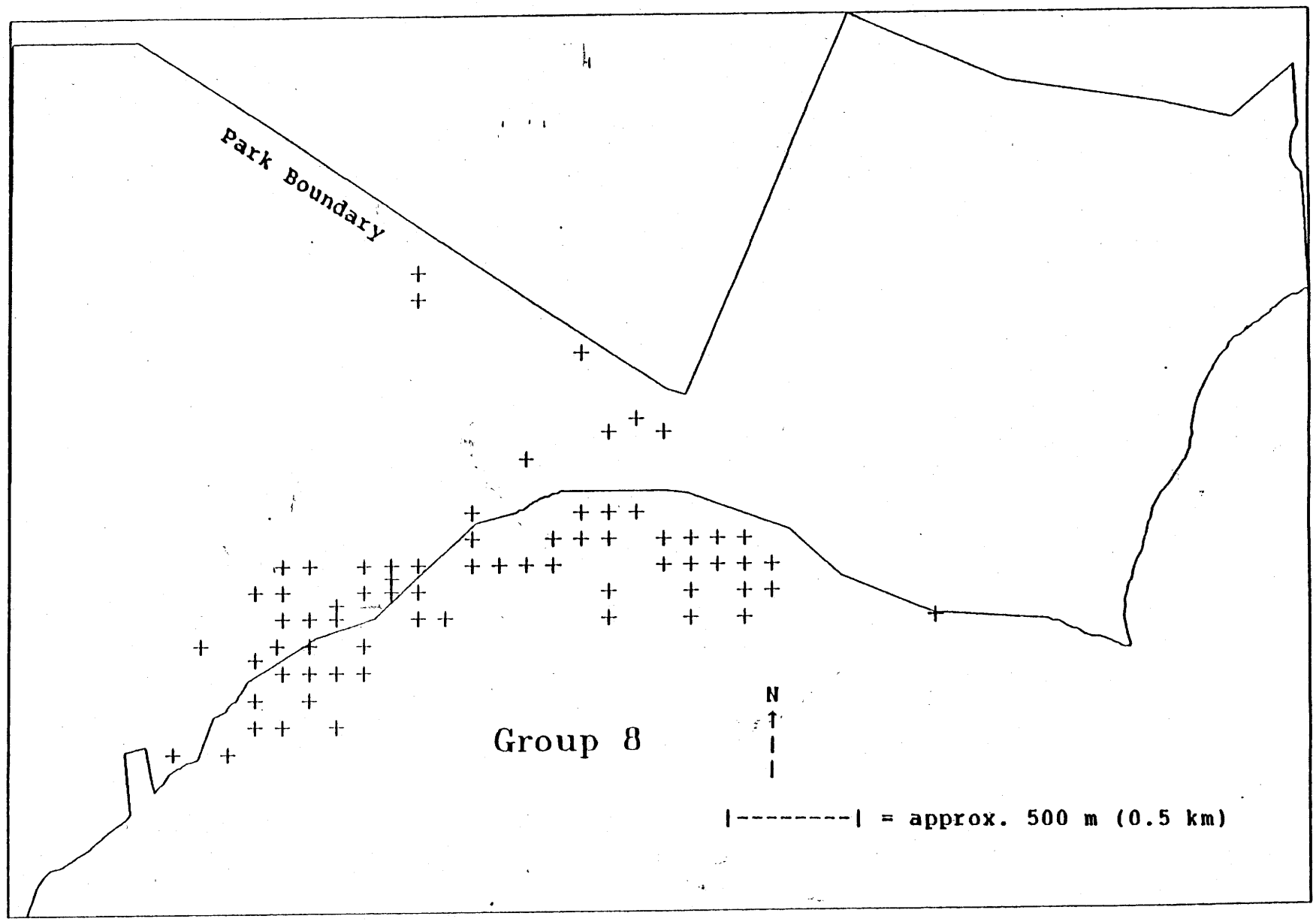
Appendix III. Black-tailed deer group 3 use of Hollister Hills State Vehicular Recreation Area, Hollister, California. June 1988-June 1989.



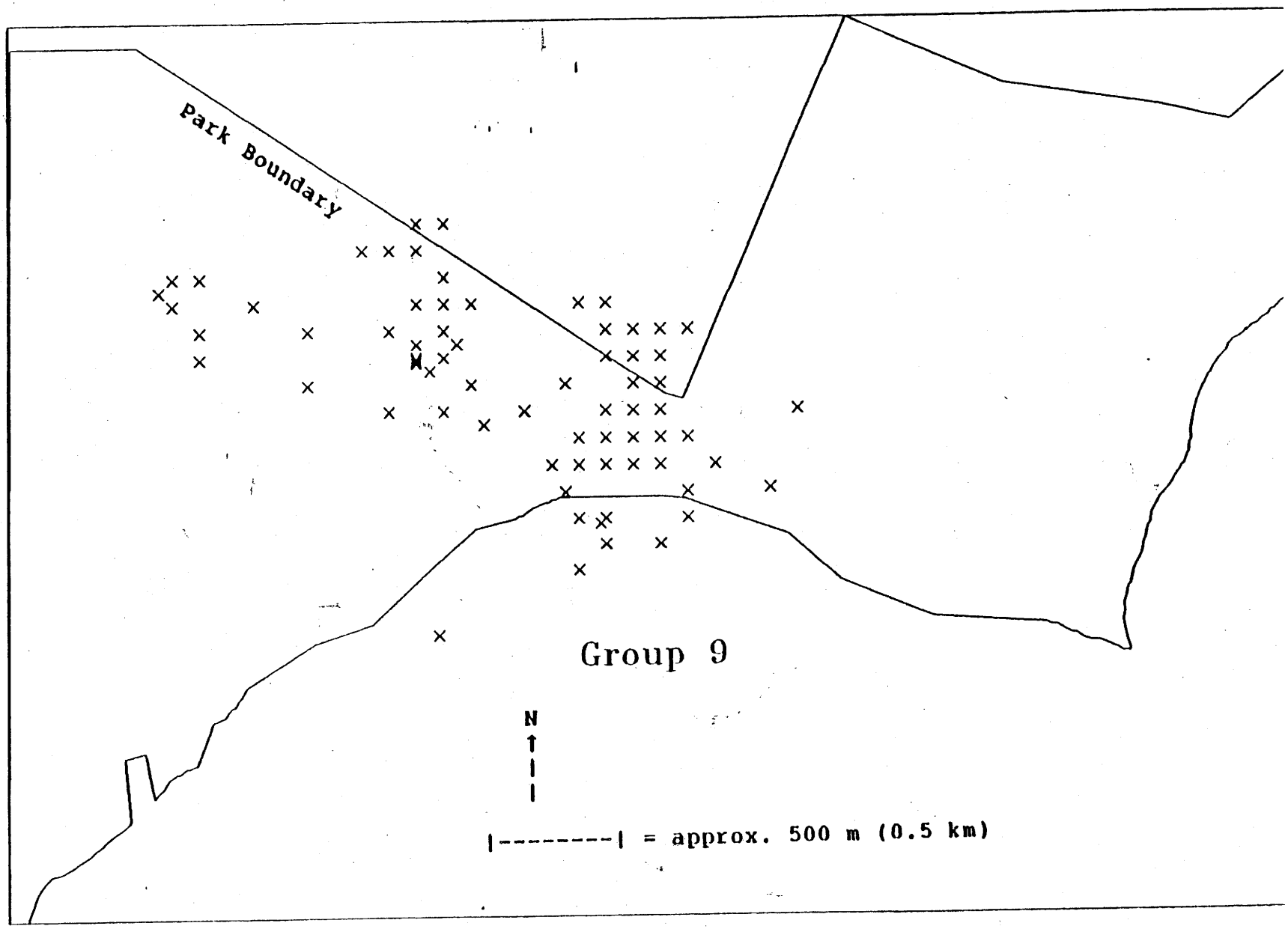
Appendix V. Black-tailed deer group 5 use of Hollister Hills State Vehicular Recreation Area, Hollister, California. June 1988-June 1989



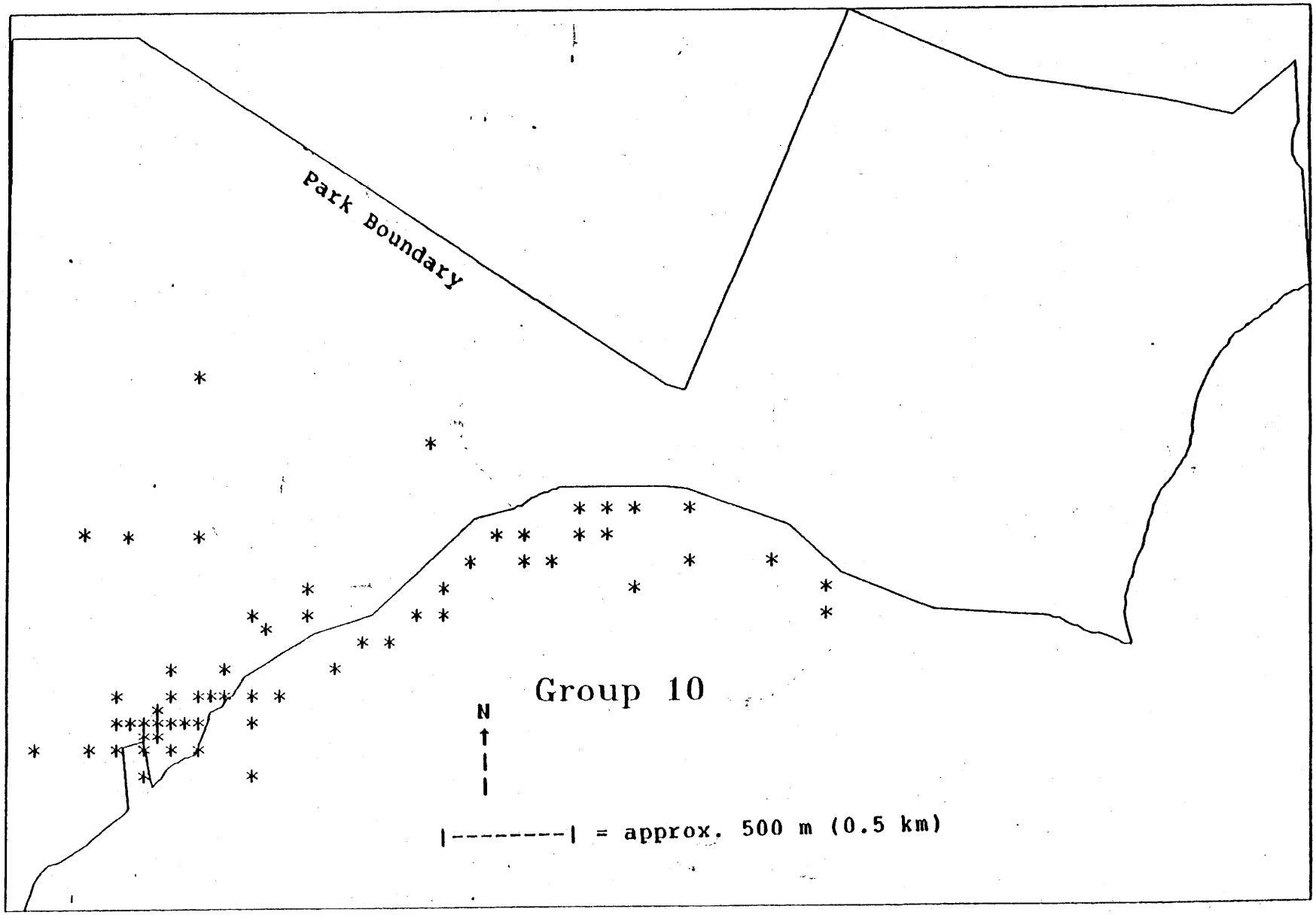
Appendix IV. Black-tailed deer group 4 use of Hollister Hills State Vehicular Recreation Area, Hollister, California. June



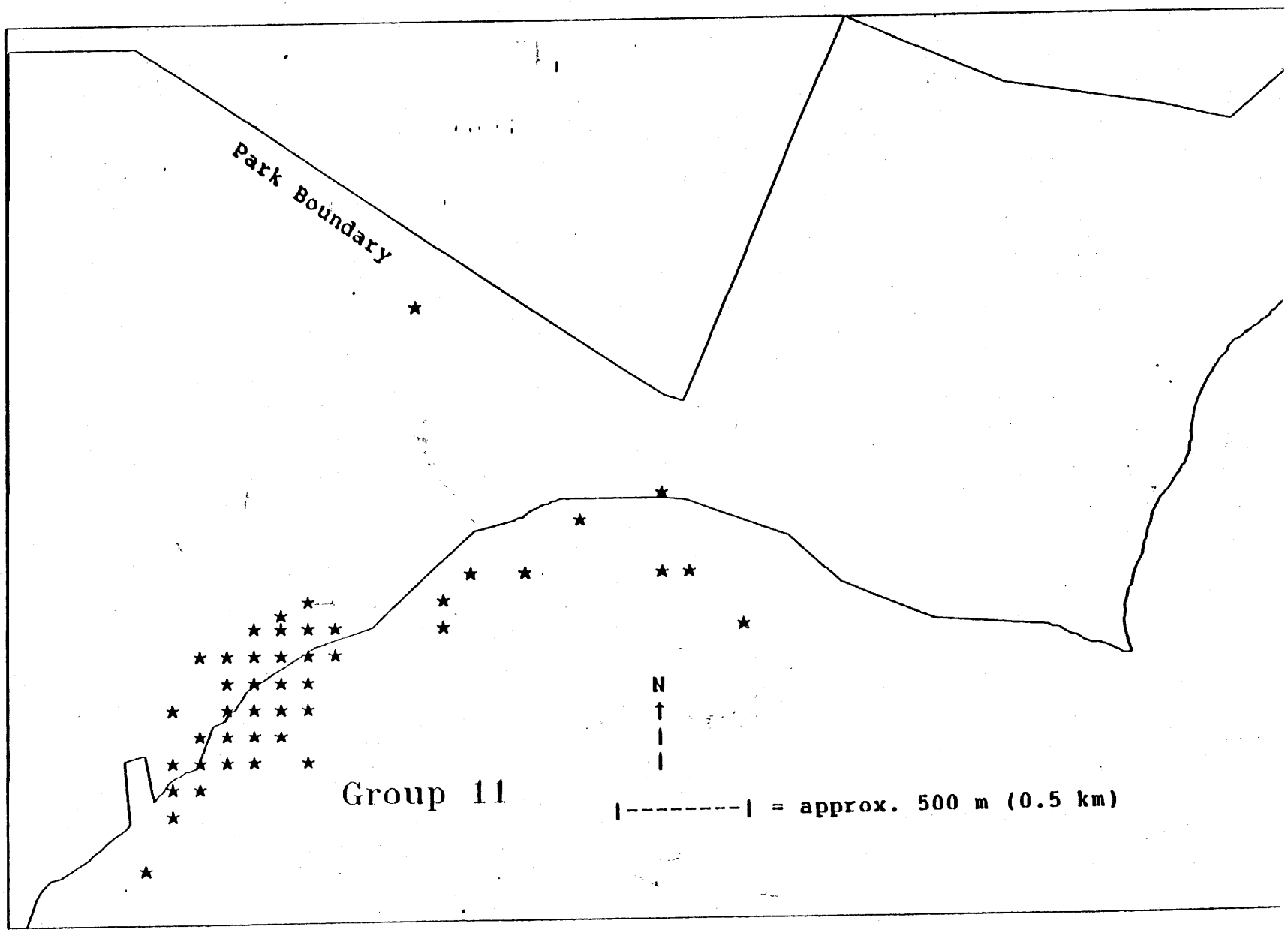
Appendix VI. Black-tailed deer group 8 use of Hollister Hills State Vehicular Recreation Area, Hollister, California. June 1988-June 1989.



Appendix VII. Black-tailed deer group 9 use of Hollister Hills State Vehicular Recreation Area, Hollister, California. June



Appendix VIII. Black-tailed deer group 10 use of Hollister Hills State Vehicular Recreation Area, Hollister, California. June



Appendix IX. Black-tailed deer group 11 use of Hollister Hills State Vehicular Recreation Area, Hollister, California. June