

THE EFFECT OF PREDATION ON DEER IN THE CENTRAL SIERRA NEVADA

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ABSTRACT: Two studies, one to determine the direct causes of fawn losses in the North Kings deer herd, and the other to examine mountain lion behavior as it relates to deer, are described. Predation was the largest cause of fawn loss, resulting in the death of 50.6% of all fawns during the first 12 months of life. Mountain lions were the principle predator, and were responsible for 49% of the fawn kills. Coyotes, bears, and bobcats took 27%, 22%, and 3% respectively. Mountain lion density was estimated at 1 per 8 square miles (12.4/100 mi²). Home-ranges averaged 102 square miles for adult females and 135 square miles for adult males. Home-range overlap was extensive. Most mountain lions migrated seasonally with the deer but some remained at low elevation throughout the year on foothill ranches and in the vicinity of rural communities.

Predator Management in North Coastal California: proceedings of a workshop held in Ukiah and Hopland, Calif., March 10-11, 1990 (G. A. Giusti, R. M. Timm, and R. H. Schmidt, eds.). University of California, Hopland Field Station Publication 101.

Most deer herds in California have been declining since the mid-1950s. The North Kings deer herd in eastern Fresno County declined from an estimated 17,000 animals in 1950 (Longhurst et al. 1952) to 1,800 in 1989 (M. Boland, personal communication). A long-term, interagency research and application program was conducted during the 1970s to discover the cause of the decline, develop remedial measures, and apply those measures to reverse the decline (Bertram 1984). Early in the program deer herd composition counts indicated that low fawn survival was limiting the herd. Habitat factors were assumed to be the major factor contributing to the loss, but the direct cause could not be determined because dead fawns were not being found in the field.

One of the studies conducted as part of the North Kings Program was to determine the influence of cattle on habitat use by fawns. New-born fawns were captured, equipped with radio transmitters, and radio-located each day to determine their habitat use patterns, with and without cattle present. Radio-monitoring of these fawns also provided an opportunity to locate fawns soon after they died and determine the direct cause of death.

The causes of fawn loss as determined from this radio-equipped population is the first study reported in this paper. The second study came about when early results indicated that predation, especially by mountain lions, was an important cause of fawn loss. As a result, mountain lion behavior and density within the range of the North Kings deer herd was studied by radiotelemetry.

STUDY AREA

The studies were conducted within the range of the North Kings deer herd, an 800 square mile area in eastern Fresno County, mostly within the Sierra National Forest. Elevation ranges from 800 to over 13,000 feet (Bertram 1984). Deer winter ranges are generally below 4,000 feet and include the upper oak woodland and lower yellow pine forest types (Barbour and Major 1977). Summer ranges are above 5,500 feet in elevation and include the upper yellow pine, white fir-mixed conifer, and red fir forest types. Recreation, logging, forest regeneration, hydroelectric development, and livestock grazing all have impacts on the range of the North Kings deer herd.

METHODS

Fawn Mortality

Newborn fawns were located, mostly by spotlighting from vehicles on logging roads (Steger and Neal 1981). Once located, the fawns were captured, examined, weighed, and equipped with radio transmitters attached with neck collars. The fawns were located daily by radio triangulation and locations were marked on maps and aerial photographs. The radio transmitters included a module which changed the transmitted pulse rate when a fawn died. When a transmitter signaled that a fawn was dead a search for the fawn was started immediately.

Dead fawns were usually found less than 12 hours after they died. When a dead fawn was found a detailed examination of the carcass and the site was carried out to determine the cause of death. Tracks in the vicinity, method of kill, size and distance between tooth punctures, and method of disposal or storage were used to determine the cause of death (Wade and Bowns 1979). If the carcass was whole and it was obvious the animal did not die of predation it was placed in a plastic bag, packed in ice or snow, and immediately transported to a laboratory for necropsy.

Mountain lion habits

Mountain lion movements were also studied using radio-location techniques. Animals were first captured by tracking and treeing with dogs, tranquilized with darts, examined, weighed, equipped with a radio transmitter, and released at the capture site. The mountain lions were located each day using radio-triangulation. Locations were recorded using the Universal Transverse Mercator system and the locations and associated information transferred to a computer data base. Maps of movement and home ranges could then be accurately drawn and placed on maps by the computer.

All mountain lion captures were restricted to a 215-square mile area within the boundaries of the North Kings deer herd range. This concentrated the work and provided the opportunity to capture a high enough

proportion of the animals within the study area to make an adequate estimate of mountain lion density.

RESULTS

Fawn predation

During seven of the eight years from 1978 through 1985 a total of 96 newborn fawns were captured, radio-equipped, and monitored. The fate of 89 (92/7%) of these fawns was determined through the first year of life (Table 1). Of the 89 fawns for which the fate is known, 34 (38.2%) survived through the first year of life. Disease and accidents accounted for 8 (9.0%) and 2 (2.2%) of the fawns respectively.

Predators killed 45 (50.6%) of the radio-equipped fawn population and the species of predator was identified in 37 cases. Of these, mountain lions killed 18 (49%), or 33.0% of all the fawns that died, or 20.2% of the total radio-equipped population. Coyotes were the second largest source of predation loss, accounting for 10 (11.2%) of the fawns, or 22.0% of those killed by predators. Bears took 8 (9.0%) and a bobcat killed 1 (1.1%).

Total fawn loss and rate of fawn loss through the first 12 months of life closely matched the loss of fawns as determined by herd composition counts made by

TABLE 1. Fate of fawns monitored through their first year of life.

Fate of fawns	1978	1979	1980	1981	1983	1984	1985	Total	Percent
Survived 1 year	3	2	2	1	1	11	14	34	38.2
Died of disease	1	0	0	1	1	2	3	8	9.0
Accidental death	0	0	0	0	0	1	1	2	2.2
Predator kills									
Mountain lion	2	2	0	4	2	3	5	18	20.2
Coyote	0	1	0	0	2	4	3	10	11.2
Bear	0	1	0	1	0	1	5	8	9.0
Bobcat	0	0	0	0	1	0	0	1	1.1
Unidentified predator	0	0	2	1	2	1	2	8	9.0
Total	6	6	4	8	9	23	33	89	100.0

California Department of Fish and Game personnel (Bertram 1984).

The average age of fawns at capture was 8 days (range 0-20 days). The average age of fawns when killed by predators was 79.3 days (range 15-363 days). The average age of fawns killed by mountain lions was 78 days (range 15-363 days). The fact that predation was not concentrated in the first few days after capture indicates that the fawns were not made more susceptible to predation by human handling at capture. There were no cases of fawn abandonment after capture.

Only one fawn appeared to be sick at the time of capture and it died at 4 days of age of a congenital kidney deformity. None of the fawns lost to predation were known to be sick or weak prior to being killed.

Computer modeling of the North Kings deer population indicated that the elimination of mountain lion predation alone would reverse the downward trend in the herd if all other factors remained the same (Neal 1985). This model did not consider the probability of increased loss to other predators but still serves to illustrate the importance of mountain lion predation in the dynamics of this herd. No other single factor in the model would reverse the downward trend.

Mountain lions

During the period from August 1983 through December 1986, 21 mountain lions were captured and equipped with radio collars within the 215-square mile study area. The period they were monitored averaged 793 days (2.17 years) and ranged from 1.5 months to 4.5 years (Figure 1). A total of 6,603 radio locations were recorded (Figure 2).

The radio locations for 16 mountain lions that were monitored for 4 months or longer were used to calculate home-range size. Home-ranges were delineated on maps by drawing a line connecting the outside radio-locations constructing a minimum sized polygon using both concave and convex angles (Figures 3 and 4). The home ranges of 9 adult females averaged 102 square miles (range 55 to 171 mi^2). For 7 adult males the home-range size averaged 135 square miles (range 70-304 mi^2).

Home-range overlap between females, between males,

and between females and males was extensive. For example, one adult female that was monitored for 28 months and radio-located 613 times, shared her home-range with 4 other radio-equipped adult females and probably an equal number of females without radios and an unknown number of males. The 9 radio-equipped females had home-ranges totaling 921 square miles within the boundaries of the 215-square mile study area. This is 2.6 times more home-range than area within the study area, precluding the opportunity to maintain exclusive home-ranges without large reductions in home-range size.

Crowding was further illustrated by the frequent radio-locating of several mountain lions in a small area at the same time. On several occasions 6 radio-equipped adults were found within a 7-square mile area, at other times 8 radio-equipped adults were found within a 19-square mile area. On one occasion 6 mountain lions remained along a 2-mile section of stream for two days.

To estimate density within the study area we selected January 1, 1986 as a date to estimate density because 15 lions were being monitored, the highest number monitored simultaneously during the study (Figure 1). In addition to these animals, 13 adults and 6 litters of kittens were detected within the study area by sight or sign during the capture period just prior to January 1, 1986, none of which were radio-equipped. This made the minimum number of adults known to be using the 215-square mile study area 28, 18 females and 10 males. The number of kittens in each litter was unknown but a review of 17 studies showed an average litter size of 2.67 kittens (Anderson 1983). Using a conservative estimate of 2.25 kittens per litter would mean that there 15.5 kittens, including a pair that were equipped with radios, using the area.

However, 28 adults using the study area does not mean that there was a density of 28 per 215-square miles. The home-ranges of all the radio-equipped individuals extended outside the study area, therefore these animals also contributed to the mountain lion density outside the study area. To compensate for this and prevent over estimating density we adjusted each radio-equipped individual's contribution to the lion density by the proportion of that individual's home-range that was included within the study area. For example, if half of a lion's home range was within the study area it was

Figure 1. Periods that the 21 radio-equipped mountain lions were monitored.

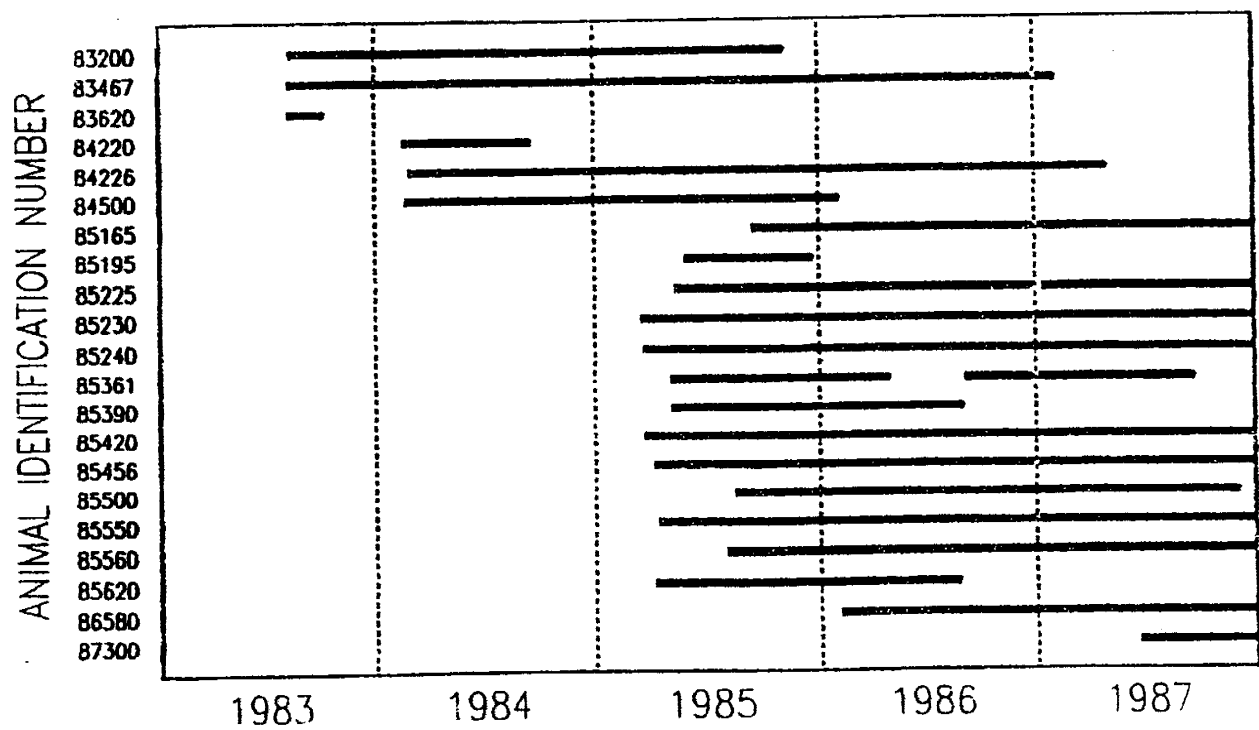


Figure 2. Map showing the 6,603 radio-locations obtained for all 21 mountain lions monitored during the study. The dashed line indicates the boundary of the 215-square mile study area.

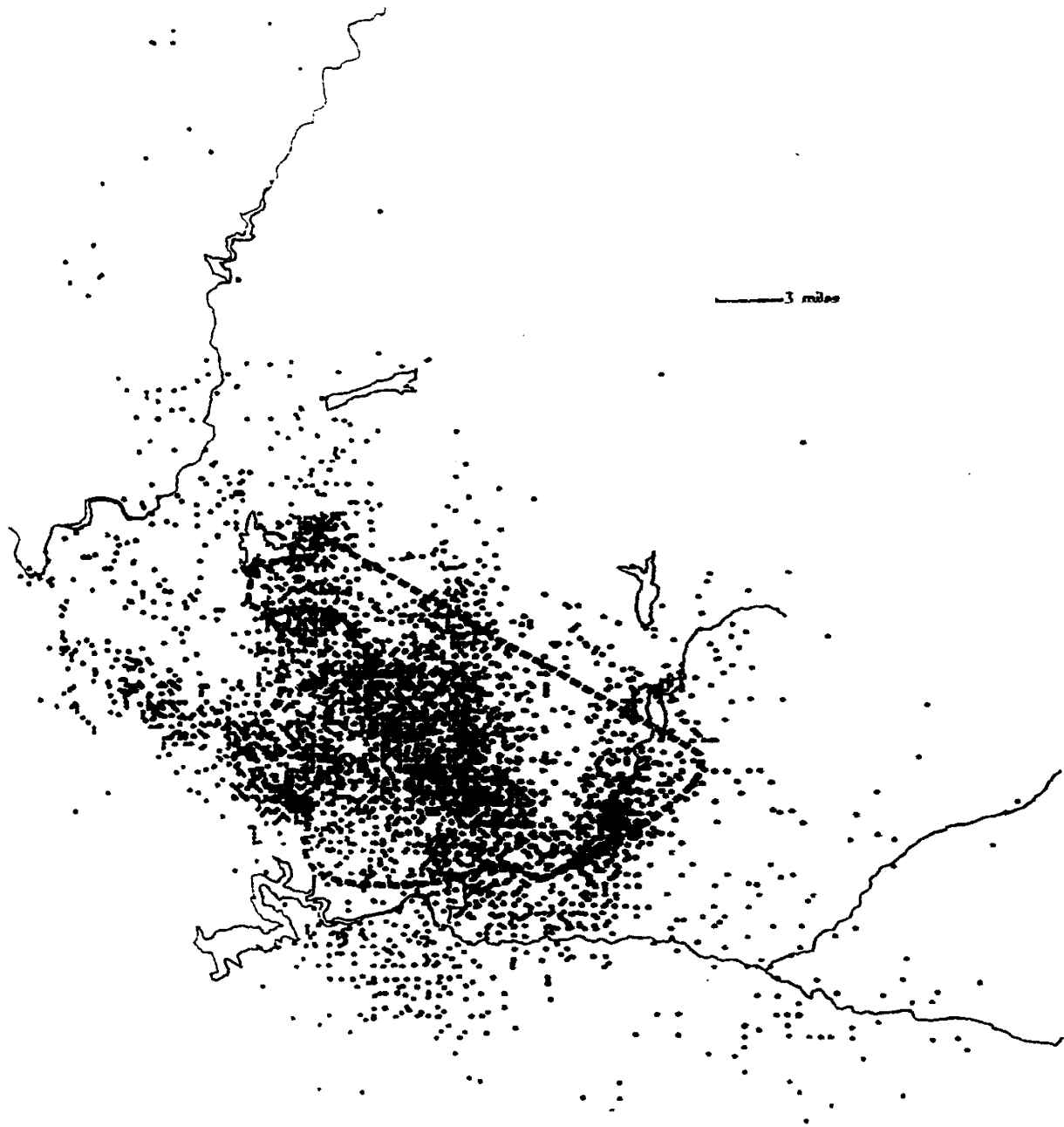
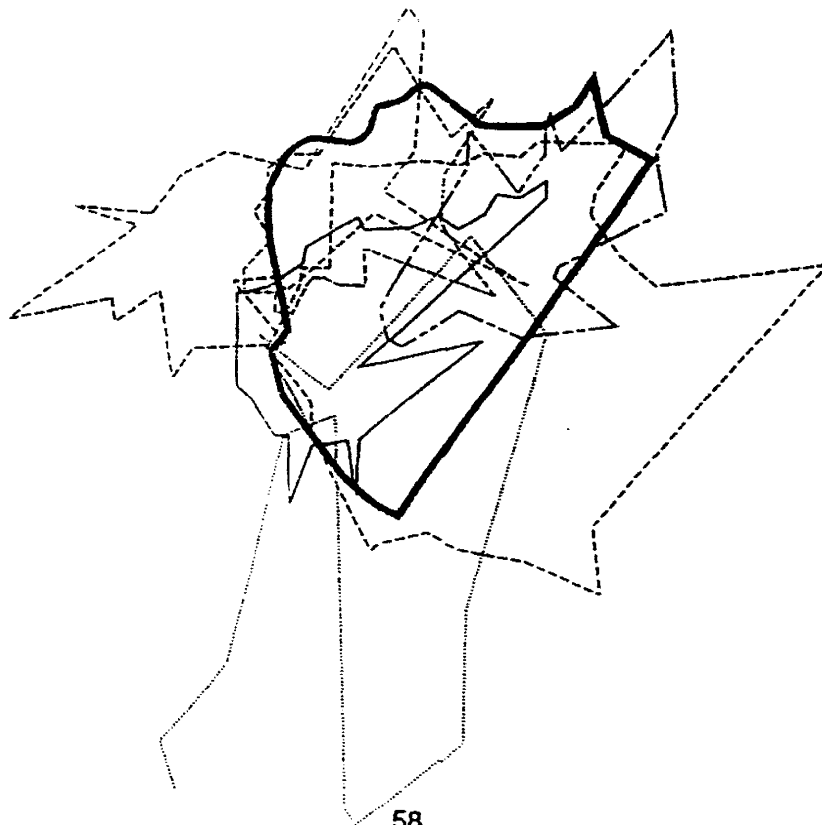


Figure 3. Home-ranges of 9 adult female mountain lions. The solid line indicates the boundary of the 215-square mile study area.



Figure 4. Home-ranges of 6 adult male mountain lions. The solid line indicates the boundary of the 215-square mile study area.



counted as 0.50 mountain lion. An average of 60.1% of the adult female's home-ranges and 59.1% of the adult male's home-ranges were included within the study area.

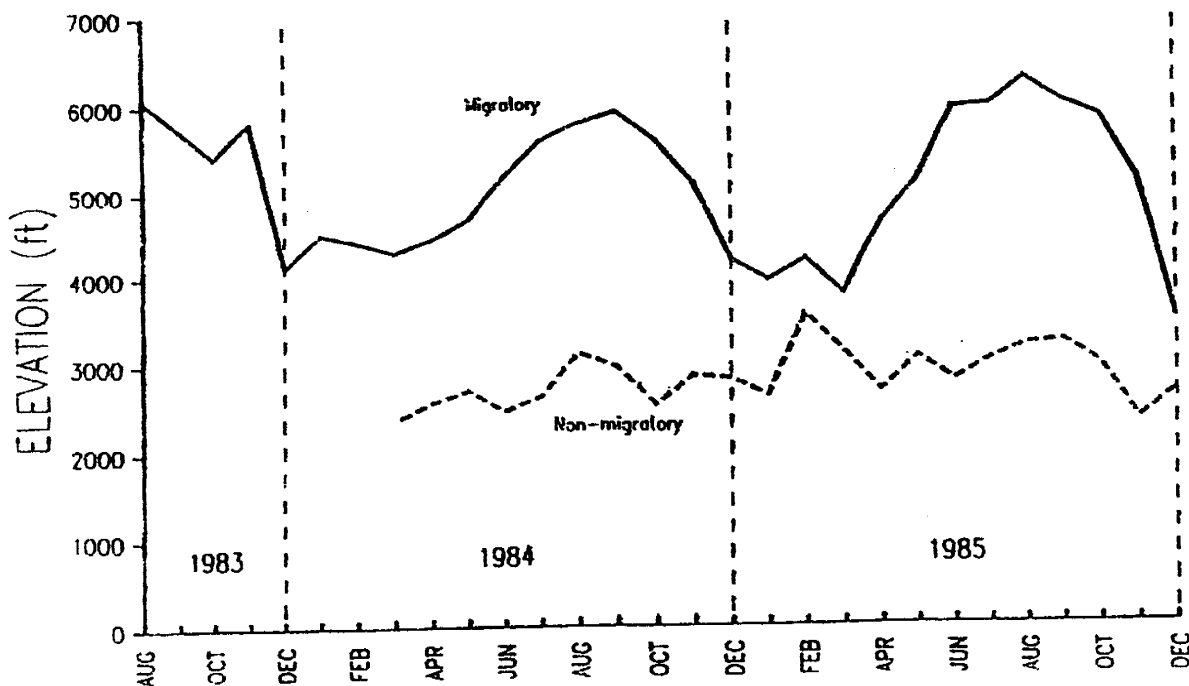
These calculations reduced the number of adults using the area to 16.7, for a estimated density of 12.9 square miles per adult mountain lion ($7.8/100 \text{ mi}^2$). The same adjustments brings the number of kittens to 10.0 or 21.5 square miles per kittens ($4.7/100 \text{ mi}^2$). Including both adults and kittens gives a minimum of 26.7 mountain lions using the study area, or 8 square miles per mountain lion ($12.4/100 \text{ mi}^2$).

Based on our knowledge of home-range size and overlap, sign, and predation we estimate that there is considerable variation in mountain lion density within the North Kings range. We estimate that the density of 8 square miles per lion applies to about 220 square miles. We conservatively estimate that the remaining 580 square miles average at least 25% of that density or 1 mountain lion per 32 square miles. This would mean that a minimum of 41 mountain lions are using the 800 square miles of the North Kings deer herd range.

Most of the mountain lions tended to migrate elevationally with the deer (Figure 5). During the spring and fall migrations mountain lions were noted to concentrate along the heavily used sections of the deer migration routes. Twelve of the 16 lions that were used to calculate home ranges, 7 females and 5 males, focused their summer activity above 5,250 feet in elevation and their winter activities between 3,300 and 4,600 feet in elevation. This pattern closely matches the migrational activity of the deer. In contrast, two females and 2 males were found to be nonmigratory and remained at low elevation throughout the year. Few, if any, deer were available to these lions during the 4 to 6 month period that the deer were on the summer range. These individuals were frequently found on foothill cattle ranches and in and around rural communities. Livestock and pet losses have been increasing in these areas in recent years.

A concurrent study of mountain lion diet using scat analysis was carried out in the North Kings area by Boland and Briden (1985). A total of 62 mountain lion scats were examined to determine the frequency of

Figure 5. Monthly mean elevations of migratory and nonmigratory mountain lions monitored within the range of the North Kings deer herd.



occurrence of diet items. Results showed a diet of 61% deer, 18% small mammal, 6% cattle, 4% pine marten, 3% porcupine, 3% mountain lion, 1% bobcat, 1% dog, 1% vegetation, and 2% unidentified animals. The collection methods used in this study may have underestimated the importance of cattle in the mountain lion diet.

DISCUSSION

This study indicates that predation is the largest source of fawn loss in the North Kings deer herd. The validity of this conclusion is supported by the close match between the disappearance of fawns from the radio-equipped population and the herd as a whole as determined by herd composition counts. There was no evidence to suggest that fawns were made more susceptible to predation by handling or by the carrying of the radio transmitters. There was also no evidence that the predation was focused on old, weak, or diseased animals.

Computer simulation modeling indicates that under the conditions that exist in the North Kings deer herd, predation was probably not a significant contributor to the original deer decline in the 1950s and 1960s, but is the most important contributor to the continued decline during the 1970s and 1980s.

The mountain lion alone accounted for 49% of the predation loss and 33% of all fawn deaths. Our model indicates that mountain lion predation alone accounts for enough fawn mortality to prevent recovery of the deer herd from its present depressed level.

Bruce (1922) estimated mountain lion density in the area of the North Kings deer herd range at 1 per township and Longhurst et al. (1952) estimated the deer herd at 17,000 animals. If both of these estimates were valid for the early 1950s there was a deer:mountain lion ratio of 765:1.

Using our current estimates of at least 41 lions and 1,800 deer we have a deer:lion ratio of 44:1. Our

simulation model indicates that a deer:mountain lion ratio of 200:1 is required to maintain the deer population if all other factors remain the same. Interpolation indicates that the herd was very close to the 200:1 ratio in 1971 when the mountain lion was given protection.

Our monitoring work clearly shows that much of the conventional wisdom concerning mountain lion behavior is incorrect or at least does not apply to the animals in eastern Fresno County. This study provides only an estimated minimum density and yet it is among the highest reported in the literature. It is generally believed that lack of exclusive home-ranges will prevent breeding. Despite complete overlap between adult female's home-ranges, breeding has continued and the population has maintained itself or increased in recent years.

The scat analysis shows the variety of food items used by mountain lions on the North Kings range. However, this limited study of diet did not provide enough information to determine if the prey base is adequate to sustain the mountain lion population.

CONCLUSIONS

Results of this study indicate that the largest single factor limiting fawn survival and probably the deer herd, is mountain lion predation. Predation by coyotes and bears is also contributing to the lack of herd recovery. Recovery of the deer herd will require major changes in the predator-deer dynamics and may only occur after the limited prey base declines to the point that it causes a crash of the mountain lion population. This may result in a loss of viable populations of both deer and mountain lions.

It is clear that the present high number of mountain lions cannot be maintained without coming in conflict with humans. Livestock, pets, and people are increasingly at risk as the deer population declines.

LITERATURE CITED

Anderson, A. E. 1983. A critical review of literature on puma (*Felis concolor*). Spec. Rept. 54. Colorado Div. Wildl. 91 pp.

- Barbour, M. G. and J. Major. 1977. *Terrestrial vegetation of California*. J. Wiley and Son, New York. 1002 pp.
- Bertram, R. D. 1984. *The North Kings Deer Herd*. California Dept. Fish and Game. 202 pp.
- Boland, M. and L. Briden. 1985. Food habits of the mountain lion on the North Kings deer herd range, eastern Fresno County, California. A report to the Calif. Cattlemen's Assoc. 24 pp.
- Bruce, J. 1922. The why and how of mountain lion hunting in California. *Calif. Fish and Game* 8(2):108-114.
- Longhurst, W. M., S. Leopold, and R. F. Dasmann. 1952. A survey of California deer herds: their range and management problems. *Game Bul. No. 6*, Calif. Dept. Fish and Game. 136 pp.
- Neal, D. L. 1984. The effect of mountain lion predation on the North Kings deer herd. *Trans. 2nd Mountain Lion Workshop*. Zion Nat. Park, Utah (J. Roberson and F. Lenzey, eds.), Utah Dept. Nat. Res., pp. 138-140.
- Steger, G. N. and D. L. Neal. 1981. Night lighting: a technique to locate and capture fawns. *Trans. Cal-Neva Wildl., Western Sect., The Wildlife Soc.*, pp. 155-158.
- Wade, D. A. and J. Bowns. 1979. Procedures for evaluating predation on livestock and wildlife. *U.S. Fish and Wildl. Serv. Bull.* 1429. 42 pp.