mals of North America. Ronald Press, New York, N.Y. 1083pp.
HEMKER, T. P. 1982. Population characteristics and movement patterns of cougars in southern Utah. M.S. Thesis, Utah State Univ., Logan. 66pp.
HORNOCKER, M. G. 1969. Winter territoriality in mountain lions. J. Wildl. Manage. 33:457–464.
———. 1970. An analysis of mountain lion predation upon mule deer and elk in the Idaho primitive area. Wildl. Monogr. 21. 39pp.
JENNRICH, R. I., AND F. B. TURNER. 1969. Measurement of non-circular home range. J. Theor. Biol. 22:227–237.
KEITH, L. B. 1974. Some features of population dynamics in mammals. Trans. Int. Congr. Game Biol. 11:17–58.
LAPIN, L. L. 1975. Statistics, meaning and method. Harcourt Brace Jovanovich, New York, N.Y. 591pp.
NOWAK, R. M. 1976. The cougar in the United States and Canada. U.S. Fish and Wildl. Serv., Washington, D. C., and N.Y. Zool. Soc., New York, N.Y. 180pp.
OSTLE, B. 1963. Statistics in research. 2nd ed. Iowa State Univ. Press, Ames. 585pp.
SEIDENSTICKER, J. C., M. G. HORNOCKER, W. V. WILES, AND J. P. MESSICK. 1973. Mountain lion social organization in the Idaho primitive area. Wildl. Monogr. 35. 60pp.
SHAW, H. G. 1977. Impact of mountain lion on mule deer and cattle in northwestern Arizona. Pages 17–32 *in* R. L. Philips and C. J. Jonkel, eds. Proc. 1975 predator symposium. Mont. For. and Conserv. Exp. Stn., Univ. Montana, Missoula.
VAN DYKE, F. G. 1983. A western study of cougar track surveys and environmental disturbances affecting cougars related to the status of the eastern cougar *Felis concolor couguar*. Ph.D. Thesis, State Univ. New York, Syracuse. 244pp.
———, R. H. BROCKE, AND H. G. SHAW. 1986. Use of road track counts as indices of mountain lion presence. J. Wildl. Manage. 50:102–109.
YOUNG, B. F., AND R. L. RUFF. 1982. Population dynamics and movements of black bears in east central Alberta. J. Wildl. Manage. 46:845–860.
YOUNG, S. P., AND E. A. GOLDMAN. 1946. The puma, mysterious American cat. Stackpole Co., Harrisburg, Pa. 358pp.

Received 3 February 1985.
Accepted 3 August 1985.

USE OF ROAD TRACK COUNTS AS INDICES OF MOUNTAIN LION PRESENCE

FRED G. VAN DYKE,[1] Environmental and Forest Biology, College of Environmental Science and Forestry, State University of New York, Syracuse, NY 13210
RAINER H. BROCKE, Environmental and Forest Biology, College of Environmental Science and Forestry, State University of New York, Syracuse, NY 13210
HARLEY G. SHAW, Arizona Game and Fish Department, Chino Valley, AZ 86323

Abstract: Interactions of mountain lions (*Felis concolor*) with roads and the effectiveness of searches for tracks on roads as a means of assessing mountain lion populations were examined in Arizona and Utah on 3 study areas. Road crossing frequencies were related to total home area road densities of individual lions. Unimproved dirt roads were crossed most frequently. Improved dirt roads and hard-surfaced roads were crossed less often and were less likely to occur within lion home areas, suggesting possible avoidance. Seventy searches for mountain lion tracks on roads were conducted in southern Utah in areas where densities and distributions of radio-collared mountain lions were known and where tracking conditions on roads were measured objectively. Changes in the density of resident female lions explained 61% ($r^2 = 0.61$) of the variation in track finding rates under ideal conditions. Under all tracking conditions, resident females required the least effort to detect (51.1 km searched/track set found) of all population cohorts. All resident lions, 78% of transient lions, and 57% of cubs were detected by track searches. Use of road track searches as indices of mountain lion populations is discussed.

J. WILDL. MANAGE. 50(1):102–109

The mountain lion once was indigenous throughout the Americas. By the late 1800's, however, the eastern subspecies of the mountain lion (*F. c. couguar*) was considered extinct (Young and Goldman 1946). The eastern subspecies was listed as endangered in 1973 although no existing populations could be located. In the absence of physical evidence, sighting reports and past kill records were used to doc-

[1] Present address: Fort Wayne Bible College, 1025 W. Rudisill Boulevard, Fort Wayne, IN 46807.

ument the presumed existence and geographic ranges of mountain lions in New Brunswick (Wright 1959), Arkansas (Sealander and Gipson 1973), and Louisiana (Yenke 1982).

Previous studies of mountain lions have been conducted in areas with relatively high lion densities using intensive capture-recapture efforts and radio telemetry (Hornocker 1969, 1970; Seidensticker et al. 1973; Shaw 1977; Hemker 1982). Other investigators have attempted to assess lion populations indirectly through track counts (Currier 1976, Koford 1978). None of the track count studies were able to estimate the local population through independent means, so the validity of the estimates could not be evaluated.

The objectives of our study were to: (1) evaluate the reactions of mountain lions to roads, (2) evaluate the relationship between lion tracks and lion density in an area where density could be determined independent of track counts, (3) assess the usefulness of road searches for tracks as a means of determining lion presence and abundance, and (4) if appropriate, devise a strategy for determining the presence and status of lion populations in the eastern United States through track searches of roads.

This study was part of a comprehensive effort to determine the status of the eastern mountain lion (Van Dyke 1983). Major funding was provided by the U.S. Fish and Wildl. Serv. and the World Wildl. Fund. Data were contributed through a cooperative effort of the Utah Div. Wildl. Resour. (UDWR), the Utah State Univ. (USU), the State Univ. New York at Syracuse-Coll. Environ. Sci. and For. (SUNY-CESF), and the Ariz. Dep. Game and Fish. A. J. Button, Utah Coop. Wildl. Res. Unit, supervised all lion captures in Utah. N. Woolsey, B. Powers, and N. Dodd assisted with captures in Arizona. T. Rettberg (UDWR) located radio-collared lions in Utah by airplane. R. C. Belden, leader of the Florida Panther (*F. c. coryi*) Recovery Team, provided information on the Florida panther. M. G. Hornocker, Leader, Idaho Coop. Wildl. Res. Unit, reviewed the original research proposal. R. T. McBride, Alpine, Tex., provided insights from his extensive field and research work with mountain lions. D. F. Behrend, P. Luner, D. J. Raynal, N. H. Ringler, W. M. Shields, and W. M. Stiteler (SUNY-CESF) and F. G. Lindzey (USU) reviewed the manuscript. E. J. Gustafson, C. K. Lowe, B. A. Louks, and C. E. Wolff assisted in manuscript preparation.

STUDY AREA

Data were combined from 3 study areas: 1 in central Arizona near Prescott (Spider-Cross U Ranch area), 1 in northern Arizona on the Kaibab Plateau, and 1 in southcentral Utah near Escalante.

The Spider-Cross U Study Area consisted of approximately 1,200 km^2 in Yavapai County. This included both an area closed to lion hunting during the study period (1971–76) as well as adjacent areas used by radio-collared lions. Principal vegetation types were chaparral, chaparral-juniper (*Juniperus utahensis*), and pinyon (*Pinus edulis*)-juniper.

The Kaibab Plateau Study Area included approximately 3,600 km^2. The plateau is located near the Utah state line in Coconino County. Elevations ranged from 1,525 to 2,800 m. Average precipitation was approximately 70 cm/year (Hall 1981:7). Vegetation varied from subalpine grassland and subalpine conifer forests to conifer forests, great basin conifer woodlands, and great basin scrub (Brown and Lowe 1977).

The Escalante Study Area included approximately 4,500 km^2 in Kane and Garfield counties, Utah. Elevation ranged from 1,350 to 3,344 m (Hemker 1982). Climate was characterized by moderate winters; hot, dry summers; and late summer rainfall. Average monthly temperatures ranged from a low of 2.8 C in January to a high of 21.6 C in July (Natl. Oceanic and Atmos. Adm. 1981). Over the entire study area, average annual precipitation ranged from 18 cm at some lower elevations to 60 cm at higher elevations (Hemker 1982). Vegetation of the study area was described by Ackerman (1982:3) and Hemker (1982:3).

All areas contained extensive public land holdings, and the Kaibab area contained portions of the Grand Canyon National Park. All areas had resident lion populations living in areas penetrated by roads. Average road densities (km of road/100 km^2) on the Spider-Cross U, Kaibab, and Escalante areas were 26, 43, and 25, respectively.

METHODS

Mountain lions were radiocollared and periodically located by aircraft on the Spider-Cross U area from 1971 to 1976, on the Kaibab area from 1977 to 1981, and on the Escalante area from 1979 to 1982, according to methods described by Hornocker (1969).

Table 1. Number of continuous surveillance periods (CSP's),[a] radio locations, and tracking days for radio-collared mountain lions on the Spider-Cross U (1971–76) and Kaibab Plateau (1977–80) study areas, Arizona.

Study area	Lion number (sex)	*N* CSP's	*N* radio locations	*N* tracking days[b]
Spider-Cross U	16 (F)	8	148	188
	2 (F)	7	207	246
	7 (F)	4	40	55
	9 (F)	1	10	19
	23 (F)	1	14	18
	17 (F)	3	82	104
	15 (F)	14	267	341
	19 (F)	5	92	112
	25 (M)	1	44	52
	13 (M)	3	47	69
	4 (M)	4	35	62
	5 (M)	2	15	22
	29 (M)	2	13	19
Total	13	55	1,014	1,307
Kaibab Plateau	39 (F)	21	166	315
	47 (F)[c]	5	76	154
	37 (F)	7	47	76
	46 (F)	1	23	29
	51 (F)	6	33	75
	55 (F)	1	4	12
Total	6	41	349	661

[a] A CSP is a time interval in which ≤4 days elapsed between any 2 successive radio locations and all locations were determined by airplane.
[b] Tracking days equal the sum of all days tracked in all CPS's.
[c] Shifted range during study. In subsequent analyses, each range was treated separately, increasing *N* on Kaibab Plateau to 7.

Home areas of lions were determined by planimetry of minimum area polygons drawn from plotted radio locations. One thousand fourteen locations for Spider-Cross U and 349 locations for Kaibab lions were obtained from December 1972 to June 1976 and from January 1978 to February 1981, respectively. Home areas of Escalante lions were based on 1,277 locations recorded between December 1980 and February 1982.

Road density (km of road/100 km^2) was computed in each lion home area. Road densities were categorized according to U.S. Geological Survey designations: (1) unimproved dirt roads, (2) improved dirt roads, (3) hard-surfaced roads, (4) all dirt roads, and (5) all roads.

Radio locations of Spider-Cross U and Kaibab lions were grouped into continuous surveillance periods (CSP's, Table 1). A CSP was defined as a time interval in which ≤4 days elapsed between any 2 successive radio locations and all locations were determined by airplane. We did not organize location data from

Table 2. Tracking condition classes as defined by mean road condition scores on the Escalante Study Area, Utah, 1980–82.

Condition class	Substrate	Tracking conditions	Range of $\bar{x}$ road condition scores
1	Dirt	Poor	10.0–15.0
2	Dirt	Fair	15.1–25.0
3	Dirt or dirt with patches of melting snow	Good	25.1–35.0
4	Snow (fresh powder)	Excellent	35.1–40.0

the Utah area into CSP's because time intervals of radio locations tended to be >1 week.

Road Crossing Frequencies

On the Spider-Cross U and Kaibab study areas inferred road crossings by lions were reconstructed by assuming straight line movement between consecutive locations of the same lion within a CSP, counting the number and types or roads intersected, and then repeating this procedure for all consecutive locations within a CSP. While the assumption will be false in most cases, it minimizes travel distances and road crossing frequencies. As an additional conservative measure, we assumed that a lion did not cross a road if it could have avoided the road by a deviation of ≤1 km from the straight line path. Therefore, our estimated road crossing frequencies probably were conservative.

Coefficients of determination (r^2) were calculated in order to correlate each categorical measure of road crossing frequency by a mountain lion with its corresponding measure of road penetration (km^2 of lion home area/km of road). Spearman rank correlation coefficients (r_s) were used to examine the relationship between road crossing frequency and road type.

Track Surveys

Track searches were conducted along selected dirt roads in the Escalante area from 15 December 1980 to 16 February 1982. The study area was divided into 3 sections, 1 of 518 km^2 and 2 of 466 km^2. Selected dirt roads were searched in a given section from a vehicle in 1 day. Average survey length was 36.4 km (N = 70). We stopped to examine every sighted lion track or track of questionable identity.

Tracking conditions on all searched roads

Table 3. Road densities (road km/100 km²) and mountain lion road crossing frequencies on the Spider-Cross U (1971–76) and Kaibab Plateau (1977–81) study areas, Arizona. *N* represents number of lions with road type in home area.

	Spider-Cross U				Kaibab Plateau			
		Road density				Road density		
Road type	*N*	Home area ($\bar{x}$ ± 95% CL)	Study area	Road crossings/100 days ($\bar{x}$ ± 95% CL)	*N*	Home area ($\bar{x}$ ± 95% CL)	Study area	Road crossings/100 days ($\bar{x}$ ± 95% CL)
Unimproved dirt	5	11 ± 6	16	12 ± 6	7	36 ± 16	36	21 ± 15
Improved dirt	4	10 ± 5	8	14 ± 8	1	5	4	1[a]
Hard-surfaced	4	1 ± 2	2	5 ± 3	1	4	4	11[a]
All roads	9	15[b] ± 8	26	18[c] ± 11	7	41 ± 17	44	23 ± 13

[a] One lion.
[b] Difference between areas ($P < 0.05$, test for confidence interval difference between means).
[c] No difference between areas ($P > 0.05$, test for confidence interval difference between means).

were assessed at 1.6-km intervals and at every spot where a lion track was found. At each stop the observer walked 10 steps across the road from shoulder to shoulder. Each boot impression in dirt or snow was given a point value from 1 to 4. One point was assigned where no boot track was visible, 2 points were assigned where a track was barely visible, 3 points were assigned to a track showing a complete outline and some detail, and 4 points were assigned to a track showing a complete outline and all details of the sculptured sole. The resulting point value assigned to each road location varied between 10 and 40. A mean road condition was calculated for each survey using the summed scores of all checked points, and the survey then was assigned to 1 of 4 condition classes (Table 2). Human tracks differ from lion tracks, and lion tracks seen on searches were sometimes made at previous times when tracking conditions were different. Despite these limitations, this method provided an objective, consistent means of evaluating tracking conditions on individual surveys and an objective index for comparing different surveys.

Since 1979, intensive trapping on the Escalante area indicated that most, if not all, resident lions in the 3 searched sections had been radiocollared. In order to estimate the density of collared lions and their distances from searched roads as precisely as possible, we attempted to conduct each search ≤24 hours of locating all collared lions in the section that would be searched. This normally meant conducting searches ≤24 hours of the weekly airplane flight.

Prior knowledge of home areas, movement characteristics, family associations of collared lions, gross differences in track size and configuration of certain individuals, and the fact that 2 lions had missing toes allowed us to assign most tracks to individual lions. We used this information to determine the average amount of effort, in km of road searched, necessary to find the tracks of any individual lion and of lions of similar characteristics under a variety of tracking conditions. We also examined the relationship between effort required to find tracks of individual lions and the density of searched roads in individual lion home areas.

Three measures of track finding frequency were computed for each survey. First was the number of track sets reliably assignable to different lions; hereafter, these are referred to as "independent track sets." Second was the total number of all track sets. This included different tracks of the same age judged to be made by the same lion at different points along a survey, as well as track sets that could not be assigned to an identifiable lion. For example, a particular lion might cross a section of surveyed road at 3 different places. If such tracks appeared to be of the same age, this was counted as 1 independent track set (assigned to 1 lion) and 3 total track sets (3 trails of tracks crossing a road or roads on the survey). Third, a track location was defined as any point on a road where a lion track was visible. One track set could have many track locations, but we counted locations only at 0.16-km intervals. For example, a single track set 1.6-km long would have 10 track locations. Tracks of the same set that persisted for more than 1 search also were counted as separate track locations. For example, a single track set persisting for 3 searches was counted as 3 track locations. Track location data measured persistence and visibility of tracks under a variety of conditions.

The relationship of road condition, lion density, and distances of collared lions to searched roads (independent variables) was related through stepwise multiple regression (Sokal and Rohlf 1969:488) to rates of finding independent track sets, track sets, and track locations (dependent variables). A separate analysis was performed for each dependent variable. The rate of track finding frequency was defined as the average length (km) of road searched/independent track set, track set, or track location found. Rate values were normalized by adding 0.5 and then taking the square root of each rate value (Sokal and Rohlf 1969:384). Unless otherwise noted, statistical significance was assigned at $P < 0.05$.

RESULTS

Road Crossing Frequencies

Road densities were higher on the Kaibab Plateau than on the Spider-Cross U area (Table 3). Road densities in individual lion home areas also were higher on the Kaibab. Kaibab lions appeared to have crossed roads slightly more often than Spider-Cross U lions, but differences were not significant. Home area road densities and road crossing frequencies did not differ between males and females.

On the Spider-Cross U and Kaibab Plateau study areas daily road crossing frequencies were related to overall road penetration in a lion's home area ($r^2 = 0.65$). The strength of this relationship fluctuated when study areas, sexes, and road classification types were examined separately. On the Spider-Cross U area variance in road penetration in a home area accounted for 67% of the variance in road crossing frequency ($r^2 = 0.67$). On the Kaibab unimproved dirt roads ($r^2 = 0.35$) yielded the most predictable road density-road crossing relationship.

When road densities and road crossing frequencies were ranked and normalized (Blom 1958:145), and then tested for association (Spearman rank correlation test, Lapin 1975: 532), there was an association between a lion's ranking in road penetration of its home area and its ranking in road crossing frequency. On the Kaibab the association was significant for unimproved dirt roads. On the Spider-Cross U it was significant for all dirt roads and all roads.

On all 3 study areas the presence of roads in lion home areas was influenced by road type. Twenty-two (85%) of 26 home areas contained unimproved dirt roads, 15 (58%) contained improved dirt roads, and only 6 (23%) contained hard-surfaced roads ($P < 0.01$, χ^2 test of independence, Daniel 1978:163). The home areas of lions on the Spider-Cross U area had lower road densities in their home areas than the average for the study area (Table 3). The home areas used by Kaibab lions had road densities that were nearly equal to road densities on their study area. Road crossings on the Kaibab were influenced by road type. Kaibab lions did not appear to have crossed improved dirt or hard-surfaced roads in their home areas (Table 4). In contrast, most Spider-Cross U lions appeared to have crossed all road types present in their home areas.

Table 4. Number of mountain lions with designated types of roads in their home area and percent crossing these roads on the Spider-Cross U (1971–76) and Kaibab Plateau (1977–81) study areas, Arizona.

	Spider-Cross U		Kaibab Plateau	
Road type	*N*	%	*N*	%
Unimproved dirt	8	75	8	100
Improved dirt	5	100	4	25
Hard-surfaced	4	100	2	50

Track Surveys

Seventy track surveys (2,552 km) were conducted on roads in the Escalante Study Area. A reliable estimate of the density of radio-collared lions in the area searched was possible on every survey. The distances of radio-collared lions to the nearest searched road, based on their radio locations, were known ≤24 hours of the search for 51 searches. Fifty-eight independent track sets, 76 track sets, and 122 track locations were recorded. The average density estimate of lions in searched areas at the time of search was 4.0 lions/area/search (SE = 2.9, range = 1–10).

Analysis of track searches by stepwise multiple regression did not indicate a strong relationship between track finding rates and measures of lion density, distances to searched roads, or tracking conditions. No 1-variable model accounted for >18% ($r^2 = 0.18$) of the variance in any measure of track finding rate, and no model (≤9 variables) accounted for >38% of the variance ($r^2 = 0.38$). Although all values of r^2 associated with the "best" models of each group were significant (Sokal and Rohlf 1969: 423), the large percentage of unexplained variance suggests that the independent variables were not particularly good predictors of track finding rates.

Table 5. Association between 3 measures of track finding frequency and tracking condition on roads and total radio-collared mountain lion density in searched area, as measured by Spearman rank correlation coefficients (r_s), on the Escalante Study Area, Utah, 1980–82. Only searches for which ≥1 independent track set, track set, or track location was found were considered in analysis.

	Independent variable			
	Tracking condition		Total lion density	
Track count type	N	r_s	N	r_s
Independent track sets	25	−0.61[a]	32	−0.45[a]
Track locations	28	−0.70[a]	35	−0.42[a]
Track sets	23	−0.59[a]	30	−0.52[a]

[a] $P < 0.05$ (Spearman rank correlation test, Lapin 1975:532).

The amount of variation in track finding rates explained by variations in lion density and spatial distribution of lions increased when surveys were stratified by tracking condition class of the roads. The rate of finding track sets was especially sensitive to changes in the density of resident females under Condition Class 3 ($r^2 = 0.61$).

It is unlikely that investigators using a track survey method to assess lion populations will have prior information about the distribution of lions in the area with respect to roads being searched. Therefore, to evaluate the power of the survey technique in regard to lion density alone, the variable measuring the distance of lions to searched roads was removed and the analysis repeated; only estimates of lion density were used as independent variables and road conditions remained stratified. Without knowledge of lion distribution, explained variance in track finding rates declined although the rate of finding track sets remained relatively sensitive to changes in the density of resident females in tracking Condition Class 3 ($r^2 = 0.38$). Over 50% ($r^2 = 0.54$) of the variance in the rate of finding track sets in Condition Class 3 could be explained by a 4-variable model that included the density of resident females and the densities of cubs in 3 subadult age classes.

We also evaluated whether areas with greater track finding frequencies actually had higher lion densities. The 3 measures of track finding frequency (dependent variables) and the values of road condition, lion distribution, and lion density (independent variables) associated with each search were ranked, and a Spearman rank correlation analysis was performed. Low ranks in track finding frequency (km/track) were associated with high ranks in lion densities and with high tracking condition scores (Table 5). Although track surveys are questionably reliable as estimators of absolute density, they may provide relative densities in different areas.

Over the 14-month period in which searches were conducted, all resident, radio-collared lions, as well as most local cubs and transients, were detected (Table 6). Detection effort (km searched/track set located) varied with tracking conditions (Table 7). For all lions, required effort was greatest for Condition Class 2 and least for Condition Class 3. Condition Class 3 also was associated with the highest detection rate of lions present (93%). Condition Class 4 had the lowest detection rate (29%).

DISCUSSION

On all 3 study areas individual mountain lions tended to reside in areas where improved dirt roads and hard-surfaced roads were underrepresented or absent. On the Escalante and Spider-Cross U study areas lions resided in areas that had lower road densities than the study area average. On the Kaibab, where road density was higher, lions tolerated higher road densities in their home areas. The fact that all radio-collared lions on the Kaibab area were

Table 6. Percentage of radio-collared mountain lions detected under various tracking conditions on the Escalante Study Area, Utah, 1980–82. N = number of radio-collared lions known to be present.

	Tracking condition class[a]									
	1		2		3		4		Total	
Lion class	N	%	N	%	N	%	N	%	N	%
Transients	0	0	4	50	5	80	4	0	9	78
Cubs	0	0	0	0	4	100	6	0	7	57
Resident females	4	50	4	100	4	100	7	71	8	100
Resident males	1	0	1	100	1	100	1	100	1	100
Total	5	40	9	78	14	93	18	33	25	80

[a] See text and Table 2 for explanation of tracking condition classes.

Table 7. Amount of effort (km searched/track set found) expended to locate track sets of different classes of mountain lions ($\bar{x}$ ± 95% CL) under various tracking conditions on the Escalante Study Area, Utah, 1980–82.

Lion class	Tracking condition class[a] 1	2	3	4	All conditions
Transients		132.9 (2)	103.4 ± 80.5 (4)		102.9 ± 85.5 (7)
Cubs			36.3 ± 18.1 (4)		42.7 ± 24.7 (4)
Resident females	78.9 (2)	157.3 ± 272.7 (4)	21.3 ± 10.3 (4)	41.5 ± 29.5 (5)	51.1 ± 27.4 (8)
Resident males		468.1 (1)	96.5 (1)	169.7 (1)	296.1 (1)
All residents	78.9 (2)	219.4 ± 252.4 (5)	36.3 ± 42.3 (5)	62.7 ± 59.4 (6)	78.4 ± 67.1 (9)
All lions	78.9 (2)	194.7 ± 158.5 (7)	56.9 ± 27.6 (13)	62.7 ± 59.4 (6)	79.8 ± 37.6 (20)

[a] See text and Table 2 for explanation of tracking condition classes.

females is noteworthy since females use smaller areas than males (Hornocker 1969, Seidensticker et al. 1973, Hemker 1982). Yet Kaibab female home areas did not have lower road densities than the study area average because such areas apparently were not available. Most lions on both the Spider-Cross U and Kaibab study areas appeared to have crossed most unimproved dirt roads within their home areas. Here, the frequencies of road crossings were related directly to some component of home area road penetration, but the exact nature of the relationship differed in each area. Such a relationship might be useful in predicting the frequency of road crossings by lions if road penetration in their home areas was known.

The type of road constructed in an area is not independent of terrain. Hard-surfaced roads are more likely to be constructed at lower elevations and in more open areas. Such areas may not represent suitable habitat for lions. If so, then any apparent avoidance in crossing such roads or in using areas where they occur may reflect habitat preference rather than road avoidance. The same could not be said of improved dirt roads on the Spider-Cross U and Kaibab study areas. Improved dirt roads occurred in the same areas as unimproved dirt roads. Therefore, less frequent crossings of improved dirt roads, and their underrepresentation in lion home areas, is more likely to represent the lion's reaction to the type of road.

Analysis of track surveys suggests that, under "good dirt" tracking conditions, there is a direct relationship between track finding frequency and lion density. The relationship appears to be particularly sensitive to changes in the densities of resident females and cubs which, in many cases, may be the most important cohort to assess for population management. The technique was less sensitive under poorer tracking conditions on dirt roads and in snow. The results in snow may be attributable partially to sampling bias. Roads at high elevations could not be reached or safely driven after heavy snows; therefore, some lion home areas were not searched adequately. However, even when all snow-covered roads can be searched, track counts in snow may still prove less sensitive to changes in lion density than track counts under the best dirt tracking conditions. Snow enhances track visibility but lowers track persistence because it is susceptible to freezing, thawing, and drifting and obliterates all signs made prior to the last snowfall. Also, lions tend to restrict movement after heavy snows (Seidensticker et al. 1973, Hemker 1982) and may have crossed roads less often.

Relationships between lion tracks and lion densities, while potentially direct and linear under ideal tracking conditions, are not easily interpreted, but they may be a reliable estimator of relative abundance. When lion densities were high measures of track finding frequency tended to be high. Track surveys also appeared to be effective in determining the presence of individual lions in specific areas. Inferred road crossing frequencies of lions in the Spider-Cross U and Kaibab Plateau study areas, when coupled with results of track surveys on the Escalante area, suggest that most radio-collared lions on the Spider-Cross U area, and probably all collared lions on the Kaibab, would have been detected by consistent track searches; however, it may have taken months to do so, depending on tracking conditions. Mountain lions should be detectable in any eastern area with equivalent or higher road densities, regardless of whether snow ever occurs, if searches are consistently conducted by competent trackers. Under good tracking conditions the majority of lions present will be found with relatively little effort. Even under the worst possible tracking conditions some members of a resident population should be detected.

Mountain lion populations are resident-female limited (Seidensticker et al. 1973). Of all classes of lions, resident females required the least effort to detect. The most important segment of an eastern mountain lion population, its resident females, should be relatively easy to detect through track surveys. We found no support for the idea that resident lions exist in the East but remain undetected by deliberately avoiding roads (Wright 1959, 1972).

Track surveys were less successful at detecting transient lions. Transients, by definition, tend to wander erratically and do not remain long in a local area. If the phenomenon of eastern mountain lion sightings is generated by transients, it is possible that such lions might go undetected by track surveys. However interesting this phenomenon may be, it has little biological significance because transients do not breed (Seidensticker et al. 1973). The source of eastern transients could be the western United States, Mexico, Florida, or escapees from captivity.

Potential differences exist between our Escalante (Utah) study population and our target population of eastern mountain lions to which we wish to apply our inferences about track finding frequencies. Our additional analysis of 2 lion populations in Arizona (Spider-Cross U and Kaibab Plateau), combined with information about the Florida panther population (C. Belden, pers. commun.), indicated that the Escalante population was not atypical in road crossing characteristics. An effort of 360 km searched/500 km^2 of area is the maximum effort that should be necessary to find the track of any mountain lion remaining within the area during the period when searches are conducted. Under ideal tracking conditions <90 km of effort should be required.

We believe that it is time to begin a serious investigation of the status of the eastern mountain lion. We look forward to refinements in the techniques and methods here described, and offer our preliminary conclusions as a 1st step toward solving the biological enigma of the eastern mountain lion and improving the assessment of mountain lion populations in areas of known mountain lion range.

LITERATURE CITED

ACKERMAN, B. B. 1982. Cougar predation and ecological energetics in southern Utah. M.S. Thesis, Utah State Univ., Logan. 95pp.

BLOM, G. 1958. Statistical estimates and transformed beta variables. John Wiley and Sons, Inc., New York, N.Y. 176pp.

BROWN, D. E., AND C. H. LOWE. 1977. Biotic communities of the southwest. U.S. For. Serv. Gen. Tech. Rep. RM-41. [Map.]

CURRIER, M. J. P. 1976. Characteristics of the mountain lion population near Canon City, Colorado. M.S. Thesis, Colorado State Univ., Fort Collins. 81pp.

DANIEL, W. W. 1978. Applied nonparametric statistics. Houghton Mifflin Co., Boston, Mass. 503pp.

HALL, J. G. 1981. A field study of the Kaibab squirrel in Grand Canyon National Park. Wildl. Monogr. 75. 54pp.

HEMKER, T. P. 1982. Population characteristics and movement patterns of cougars in southern Utah. M.S. Thesis, Utah State Univ., Logan. 66pp.

HORNOCKER, M. G. 1969. Winter territoriality in mountain lions. J. Wildl. Manage. 33:457–464.

———. 1970. An analysis of mountain lion predation upon mule deer and elk in the Idaho primitive area. Wildl. Monogr. 21. 39pp.

KOFORD, C. B. 1978. The welfare of the puma in California. Carnivore 1:92–96.

LAPIN, L. L. 1975. Statistics, meaning and method. Harcourt Brace Jovanovich, New York, N.Y. 591pp.

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION. 1981. Climatological data: Utah, annual summary. Natl. Climatic Cent., Asheville, N.C. [21pp.]

SEALANDER, J. A., AND P. S. GIPSON. 1973. Status of the mountain lion in Arkansas. Proc. Arkansas Acad. Sci. 27:38–41.

SEIDENSTICKER, J. C., IV, M. G. HORNOCKER, W. V. WILES, AND J. P. MESSICK. 1973. Mountain lion social organization in the Idaho primitive area. Wildl. Monogr. 35. 60pp.

SHAW, H. G. 1977. Impact of mountain lion on mule deer and cattle in northwestern Arizona. Pages 17–32 *in* R. L. Philips and C. Jonkel, eds. Proc. 1975 predator symposium. Mont. For. and Conserv. Exp. Stn., Univ. Montana, Missoula.

SOKAL, R. R., AND F. J. ROHLF. 1969. Biometry. W. H. Freeman and Co., San Francisco, Calif. 776pp.

VAN DYKE, F. G. 1983. A western study of cougar track surveys and environmental disturbances affecting cougars related to the status of the eastern cougar *Felis concolor couguar*. Ph.D. Thesis, State Univ. New York, Syracuse. 244pp.

WRIGHT, B. S. 1959. The ghost of North America—the story of the eastern panther. Vantage Press, New York, N.Y. 140pp.

———. 1972. The eastern panther—a question of survival. Clarke, Irwin, and Co., Toronto, Can. 180pp.

YENKE, W. H. 1982. History and present distribution of *Felis concolor coryi* in Louisiana. M.S. Thesis, Louisiana Tech. Univ., Ruston. 56pp.

YOUNG, S. P., AND E. A. GOLDMAN. 1946. The puma, mysterious American cat. Stackpole Co., Harrisburg, Pa. 358pp.

Received 7 August 1984.
Accepted 10 April 1985.

LINKED CITATIONS

You have printed the following article:

Use of Road Track Counts as Indices of Mountain Lion Presence
Fred G. Van Dyke; Rainer H. Brocke; Harley G. Shaw
The Journal of Wildlife Management, Vol. 50, No. 1. (Jan., 1986), pp. 102-109.
Stable URL:
http://links.jstor.org/sici?sici=0022-541X%28198601%2950%3A1%3C102%3AUORTCA%3E2.0.CO%3B2-2

This article references the following linked citations. If you are trying to access articles from an off-campus location, you may be required to first logon via your library web site to access JSTOR. Please visit your library's website or contact a librarian to learn about options for remote access to JSTOR.

Literature Cited

Winter Territoriality in Mountain Lions
Maurice G. Hornocker
The Journal of Wildlife Management, Vol. 33, No. 3. (Jul., 1969), pp. 457-464.
Stable URL:
http://links.jstor.org/sici?sici=0022-541X%28196907%2933%3A3%3C457%3AWTIML%3E2.0.CO%3B2-C