DESIGN AND ANALYSIS OF MOUNTAIN LION TRACK SURVEYS

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ABSTRACT.

In this paper we examine practical and theoretical aspects of the study design and data analysis of a mountain lion track survey. A survey route should consist of 64-96 km of dusty dirt roads or snow, resurveyed periodically. Roads closed to traffic, or roads with logging traffic or other frequent vehicle traffic are not acceptable. Of the three choices of vehicles for the survey, pickup trucks, all-terrain vehicles or motorcycles, the latter offers advantages of economy, maneuverability and superior visibility of tracking surfaces. Train personnel in motorcycle operation, track identification and track tracing techniques prior to the survey. Schedule surveys when dust conditions or roads are optimum, but prior to hunting or hound training seasons. Starting shortly after sunrise, two trackers ride motorcycles at 4.8-8.0 km per hour, each surveying half of the route. Document any mountain lion tracks found by photographs and by tracings using plate glass and transparent film. At the track site record heel pad width and length for all tracks, odometer reading, road condition rating, soil surface type, depth of surface layer and habitat name. Optimize finding tracks by surveying during periods of optimum light condition (early to mid-morning), riding the motorcycle so as to keep tracks between the observer and sun, being alert for visual cues such as flattening or color change of tracking surfaces and paying particular attention to potential mountain lion travel routes.

Distinguish tracks of individual mountain lions by size, shape, angle patterns, on-site evidence and gaits. Use a decision matrix when assigning track sets to individual mountain lions. Different amounts of judgement may be accepted for different purposes. The number of track sets may be more useful than the number of lions for statistical comparisons. Different route and home range patterns provide different sampling probabilities, making comparison of different areas invalid. Research is needed to quantify the variation in the tracks of individual mountain lions in different soil and surface conditions and the variation in the tracking and survey sampling techniques.

INTRODUCTION

The mountain lion (*Felis concolor*) is currently classified in California as a protected nongame animal. With the moratorium on mountain lion sport hunting due to expire in January 1986, the mountain lion has become the object of renewed public interest and debate. Controversy surrounds the true meaning of the increased number of depredation reports and mountain lion sightings and the accuracy of statewide population estimates.

Track studies may be especially useful with large predators, such as the mountain lion which are secretive and are found in rather low densities. In addition, track studies are less expensive than radio-telemetry studies used to determine population trends. In California, Koford (1978) and Kutilek et al. (1981) employed track surveys on dirt trails and roads to obtain baseline information on mountain lion population trends. In 1984, we initiated mountain lion track surveys in California to enlarge the previous data base and determine its utility for indicating local population trends. The objective of this paper is to focus on the design and conduct of a mountain lion track survey for a limited area and to provide guidelines for a person undertaking one. There is need to standardize methods so results from future studies will be comparable. This paper is an effort to begin standardization, at least insofar as is possible considering the different goals of different studies.

MATERIAL AND METHODS

Selecting the Study Area

In selecting a study area, consider the goals and how the results will be applied. The study area should adequately represent the total area to which results will be applied, using vegetation, topography and geographical location as indicators of similarity. The area must contain dusty roads suitable for tracking; graveled or paved roads are inappropriate. Dirt roads closed to traffic are unsuitable because some vehicular traffic is needed to produce dust. Also, grass and other vegetation growing on unused roads inhibits tracking. Logging traffic and associated grading, watering, and dust suppression activities destroy tracks. For similar reasons, any kind of frequent vehicle traffic is undesirable. Coordinate with local, state, and federal natural resource agency personnel and private landowners to identify suitable roads and areas of logging activity. In any case, make contact with such personnel as a professional courtesy before starting field work.

Statistical Sampling

Mountain lions probably travel through their home ranges in a non-random manner, and roads are not built according to random designs, either. Road design often is influenced by the same factors that influence wildlife movements, therefore, randomness in local mountain lion track surveys usually is not possible. For comparison of trends from one year to the next, randomness is not needed. Nor would randomness aid in preserving the comparability of the route with itself in the event a different road must be chosen, because topographic and ecological factors influence the outcome so strongly with what is essentially a very small sample size. It is better in such a situation to selectively, but objectively, choose the most similar available route segment (see Kish 1965, section 1.7).

Consider statistical sampling principles in designing the route layout. When roads intersect, or when they "switchback" up a slope, the areas with more intensive road coverage will be sampled in excess of their proportion to the total area available. If the goal is to describe the average situation across the whole area, then proportional sampling should be sought (since randomness is not possible). The proportions may concern vegetation types, aspects, slopes, topographic features, or just area alone. The investigator must depend upon goals of the study, information available to measure the underlying proportions, and expectations concerning differential use of the area by mountain lions to guide route selection.

Van Dyke (1983) found that it required 195 km (121 mi.) of transect to detect all lions in his Utah study area with fair tracking conditions (±159 km [99 mi.] at 95% confidence). It was not clear whether Van Dyke studied the same route multiple times or simply traveled all of the roads available. Theoretically, five days of searching at 64 km (40 miles) per day should provide a reasonable likelihood of detecting most of the lions in an area, assuming routes adequately cover the home ranges. However, when we surveyd an area near Fresno, California, using a 77 km (48 mile) route for four days, we failed to detect five radio-collared lions whose home ranges were substantially, but not entirely, within the route area.

What Statistic to Use

Both the number of individual lions identified and the number of track sets have been used to present survey results. A set of tracks or "track set" has not been clearly defined so we propose the following arbitrary definition as a standard. A set of tracks is a line of tracks made continuously by the same lion, as evidenced by physical connection with each other. Ignore lapses of a few meters as a lion leaves a road and re-enters if the observer is certain that the tracks are from the same lion -- based on line of travel and short distance between continuous groups of tracks. Tracks separated more widely, so that there is a possibility that a different lion was present, are considered different sets, even though they may appear to be similar in size and shape. Even if there is a peculiar characteristic in the track that positively identifies the lion as being the same one, these data are considered different sets in order to maintain consistency for comparative purposes. Failure to do so would invalidate comparisons of numbers of sets from year to year. The fact that one animal is more easily distinguished than another would create a bias in the data unless the same easily recognized animal were present both years. This definition is reasonably consistent with Van Dyke's (1983) "single, continuous, undirectional trails."

A series of tracks made on different days, or going different directions on the same stretch of road are considered different sets. However, a maze of tracks made the same night, at the same location and all indistinguishable from each other must be considered one set. These are arbitrary guides to minimize the influence of observer variability and provide consistency between studies.

The small numbers (0-4) of individual lions detected in most surveys render the surveys insensitive to detecting downward shifts. The number of sets of tracks is more easily defined than the number of individual lions and results in a larger number for comparison with previous surveys. The number of sets of tracks probably will vary because of differences in behavior of different lions or the same lion at different times. Whether this additional variability, yet undocumented, will negate the advantage of higher numbers is unknown. Van Dyke (1983) concluded that, under ideal tracking conditions, track numbers were sensitive to changes in the density of adult females, but sensitivity declined under poorer tracking conditions.

Selecting the Route

In most wildland situations, location of the survey routes is determined by available and suitable roads within the selected study area. When a choice is available, selection is guided by sampling considerations and the goals of the project. If the goal is to locate the maximum number of tracks, then select routes along ridges or rivers or to intersect saddles, or other logical travel routes.

The arrangement of home ranges influences how many tracks of different mountain lions are detected. The greater distance between parts of the route, the greater probability that another home range will be intersected, and thus the greater probability of finding the track of a different mountain lion. The greater the length and the more widespread a route is within a single home range, the greater the probability of finding tracks of one mountain lion in that area. Any information on the probable size, shape, and orientation of home ranges in the area is helpful in designing the route. If the goal is to find the greatest number of different lions, select roads to presumably intersect the maximum number of mountain lion home ranges. If the goal is to locate one mountain lion in a known area, disperse the route only within the known or expected home range. On the map, finding the most lions would require a long, linear survey route covering a large total area as opposed to a dense network of roads encompassing a relatively small total area.

Schedule field time prior to the survey to locate and select suitable roads. If the study area is new, three or four days may be required to explore it. Each observer should carry adequate up-to-date maps showing the road system.

Selecting a Vehicle

There are three choices of vehicles for such a survey: pickup trucks, three- or four-wheeled, all-terrain vehicles (ATVs), and off-road motorcycles.

We feel motorcycles offer several advantages on dry roads. They are economical, highly maneuverable, and allow the rider to turn around and circle back easily, causing a minimum of disturbance to the tracking surface. Motorcycles with 125 to 175 cc (7.6 to 10.7 cu.

in.) engine displacement have adequate power and are small enough to operate easily. Each motorcycle must be street-legal, registered, and equipped with trail tires, odometer, approved spark arrestor, and a luggage rack. A clear plastic envelope taped to the top of the gasoline tank is a convenient map holder.

ATVs suffer from several disadvantages. They are illegal on public roads, unstable on steep, bumpy roads, and are physically demanding to ride. ATVs also have three or four large tires, each with a 20.3 - 25.4 cm (8 to 10") contact patch that could obliterate animal tracks before the rider stops the vehicle. Due to the knobby-checkerboard nature of ATV tire tracks, new lion tracks made over ATV tracks are difficult to see. Four-wheeled ATVs may be better than motocycles on mud or snow because of greater stability and traction on slippery surfaces.

Of the three vehicle choices, pickup trucks are the least economical, with high gas consumption, a four-wheel drive requirement on some routes, and higher labor costs. A minimum of two workers is required for a pickup; one driver and one observer. Two trucks and four workers are needed for a 96 km (60 mi.) transect compared with two trackers working separately on smaller vehicles. In previous studies employing pickups, the observer sat on the hood to see tracks in front and to the right side of the vehicle. To avoid slipping off the hood, the observer sat on a seat or pad and held a rope jammed into the doors. For safety reasons, we recommend the observer sit in the cab, and the vehicle be stopped where tracks are most likely to be found, to allow a search on foot. Whether seated on the hood or in the cab, observers are farther from the tracks than on smaller vehicles and their vision to the rear is blocked.

Training Personnel

If motocycles or ATVs are used, each rider must receive an orientation session covering control locations and operations, riding techniques, safety, and a supervised riding session. Riders need a motorcycle license and at least eight hours riding experience on dirt roads with various surface conditions prior to starting a survey. Without a period of familiarization, an inexperienced rider will concentrate more on riding the motorcycle than looking for tracks.

Instruct each rider in track identification, including not only mountain lion tracks but the tracks of any species likely to be encountered on the survey route. Provide field guides such as Murie (1954) and Shaw (1983) to be consulted in the field. (Shaw's guide is excellent, but the illustration on page nine is incorrect. The drawing shows the hind foot of the lion falling behind the front paw. Usually the hind paw falls on top of or in front of the front paw print.) As with riding skills, practice sessions identifying tracks in the field are necessary. If possible, a field trip with a professional lion trapper is helpful.

Proficiency and standardization in the technique of tracing are needed. Prior to the actual survey, all riders must practice tracing tracks together to reduce the variation between the tracings of different trackers. Comparing the same track traced by different trackers is useful in standardizing technique. Lion tracks are not necessary for the exercise; dog tracks will serve.

Scheduling Surveys

Schedule surveys during the dry season when dust conditions are adequate and rain infrequent, but prior to hunting and hound training seasons. Hunter vehicle traffic destroys tracks, and hunters afield could influence lion movements. Dog tracks hinder detection of lion tracks. For some survey routes where vehicle traffic is a problem, it may be necessary to survey the heavily used sections early in the morning, and the remaining roads later.

Survey Procedures

1. Plan to arrive one day early to locate and check previously selected roads and place plastic flagging to mark the route at intersections and end points. Remove all flagging at the end of the survey.

2. Kutilek et al. (1981), working five consecutive days in each area, discovered new lions on the fourth or fifth day in four out of eight surveys. We found by conducting a survey where five lions were being radio-tracked that only one entered the portion of its home range covered by the route in the 5-day period and that one was not detected by the track survey. In order to detect the maximum number of lions, a more effective sequence would be to allow one or more days of track accumulation time between survey efforts. On many roads, traffic will limit the effective accumulation period to one or two days. Part of the reason for allowing "accumulation time" is to allow animals to move into the survey route area, so more than two days may be desirable. Efficiency may be increased by using non-consecutive daily surveys, following the logic of Roughton and Sweeny (1982). Whatever choice is made, consistency in method is necessary to obtain comparable data.

3. Starting shortly after sunrise, two observers on motorcycles survey the selected roads, each covering about half the survey route. Riders trade routes every day so each can verify the other's track identifications and eliminate biases caused by variations in ability to find tracks.

4. Ride at 4.8 to 8.0 km per hour (3 to 5 mph) looking for tracks, backtracking or dismounting as needed to check faint marks in the roadbed. Record mileage and times between landmarks, intersections, and road signs in a pocket notebook to facilitate plotting tracks on the map. Record times of arrival, departure, and rest stops to define the effort required on the transect.

5. Record road and tracking conditions. To quantify tracking conditions, Van Dyke (1983) suggested that the tracker walk 10 steps diagonally across the road from shoulder to shoulder then rate each boot impression with a point value of 1 (no boot track visible), 2 (track barely visible), 3 (track showing complete outline and some detail), or 4 (track showing complete outline and all details of the sculptured sole). Points are totaled and each rating recorded on the field form if done where lion tracks were found, or in the pocket notebook for ratings at the start and finish of each route segment, separate roads, or where conditions change.

6. Document each separate set of tracks with tracings, even if it appears to be made by the same lion whose tracks were found previously. The basic method for tracing tracks follows Panwar (1979). If the tracks are in a straight line, stretch a thread along the center of the line of travel for a distance of 3-5 m (9.8 - 16.4 ft.). Place a piece of clear, 4.8 mm (3/16") thick, 21.6 x 27.9 cm (8-1/2 x 11 in.) plate glass over the track. (Plexiglass becomes scratched and causes problems with static electricity.) Lay the glass as close as possible over the track without disturbing it. Use pebbles and sticks found at the site to provide the proper spacing between track and glass, since the depth of dust varies. As the distance between the glass and track increases, the accuracy of the tracing decreases due to error from parallax.

Lay a sheet of transparent film on the glass with the top in the direction of travel. Each transparency should be imprinted previously as a separate field form. Trace each track with a fine-tipped permanent-ink pen. Many pens will not continue to write on some types of transparent film because of clogging caused by a coating on the film. Test your pens before beginning field work, and carry extra ones. While tracing, keep your line of vision directly over the track to avoid error from parallax. Trace the proper relationship of each paw print to the line of travel, using the thread previously laid down as a guide. It aids later analysis to use the center line of the pre-printed form as the center of the line of travel. Use a solid line on the tracking to represent a definite boundary at the edge of a feature to be represented. If the exact boundary is unclear on the ground, trace the apparent edge of the feature with a dashed line. If the boundary fades so gradually no edge can be observed, leave the tracing blank for that portion. Be sure to include creases and other marks in the print as well as the outline. If rocks, sticks, etc. are present in the track, include them as part of the tracing, with appropriate identification.

After removing the glass, measure the heel pad width and length from the track itself, using the longest and widest dimensions (Figure 1). (Measurements taken from the drawings or with the glass in place may include parallax errors.) A draftsman's compass can improve accuracy. Indicate on the tracing where the measurements were taken.

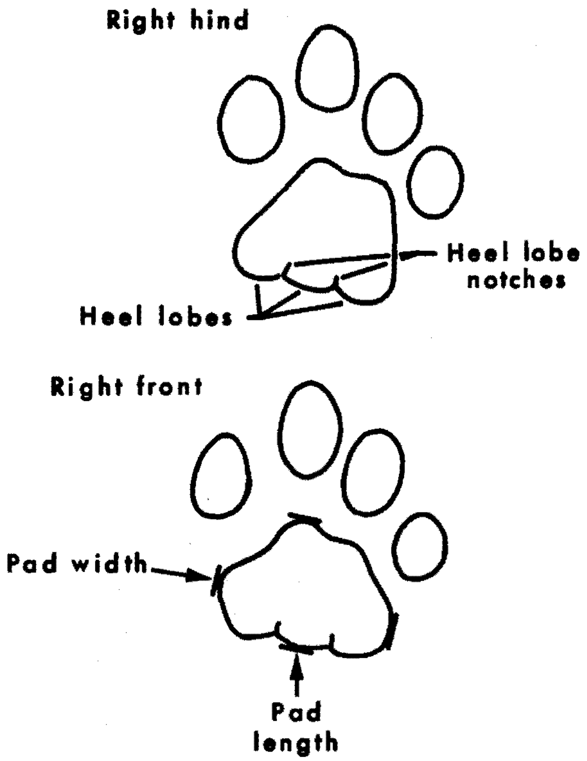

FIGURE 1. Right front and hind mountain lion tracks. Note on front track the locations for measuring heel pad width and length. Heel lobes and lobe notches are indicated for hind track.

It is important to trace several prints of each foot to document the consistency of features that may later be important in identification. Investigate unusual patterns in the field to determine whether they are the same in all prints of the same paw. For example, unevenness in the soil may change the appearance of a print. Note any consistent pattern on the field form.

7. Take closeup and general location photographs of each set of tracks, with an identifying number or letter in the photograph. Other information to record at the site on the field form includes the rider's name, date, track identification number, location (descriptive

and legal to quarter section), odometer reading at the track location, odometer reading of the nearest landmark, habitat name, topography, soil surface (e.g., dust, sand, gravel, mud), road condition rating, depth of surface layer, photograph number, and any other comments.

8. After all pertinent information is recorded, mark the tracks by drawing a circle in the dirt around them and placing a small pile of stones or dead wood next to them to deter vehicles. Indicate in a similar manner the beginning and end of the string of tracks so that the other rider can verify the tracks the next day and not record them again. Flagging tied to roadside vegetation also can be used as a marker.

9. Document factors that inhibit tracking and abandon the route if they are excessive. Trend studies are based on the assumption that there is an equal probability of observing tracks each year. If excessive logging, rain, or other major disturbances occur, the probabilities are unequal and the data will not be comparable.

Tracking Techniques

On clear days the best lighting conditions for tracking are from shortly after sunrise to mid-morning. During that period the relatively low angle of the sun accentuates tracks by creating shadows within the track impressions. Similar light conditions exist later in the afternoon, but the light is scattered more by dust in the air; glare is greater, and the light is of poorer quality for tracking.

The shadows within a track can be seen best when the track is between the observer and the sun. To keep tracks between the rider and the sun, it is sometimes necessary to ride on a shoulder of the road. When the sun is behind the rider, it is often helpful to look back over a shoulder occasionally and to weave back and forth across the road to improve the angle toward the sun. During the mid-day period, careful observation is required because the high angle of the sun makes tracks difficult to see.

Besides shadows, other visual cues are flattening and color change. Flattening results from the animal compressing the soil so that the surface texture is different from the surrounding area. Color change occurs when dried surface soil is disturbed exposing moister, darker soil beneath or causing differential deposition of dew.

Lions sometimes cut corners as they travel along a road and tracks are often found on the insides of corners. Closely examine natural travelways such as ridge crests, drainage bottoms, and saddles between ridges. Slide marks on road-cut banks may indicate a lion crossing.

DATA ANALYSIS

Distinguishing Individual Lions

If a goal is to identify individual animals, a standard, accepted method of differentiating one lion from another is required. Such a method has not been developed, but it is possible to tell some tracks from others by comparing shape, size, angles, and patterns. An unusual gait may be detected by analysis of stride measurements and/or consistent unusual deviations of one print from the line of travel. A consistently different angle of the paw in relation to the line of travel may be meaningful if the gait is steady and straight. Different shapes or sizes of the heel pad may be diagnostic if the limits of observer differences are exceeded, and if the substrate is similar. There appears to be some difference between tracks in the placement of toes relative to the axis of the heel pad. Again, consistency is important. This is a difficult character to recognize in the field, and several tracings of the same paw at different locations help to document consistency in this characteristic. On-site evidence is important and should be noted on the field form, e.g., "track set B-3-85 crossed track set B-2-85, obliterating some prints. Right rear heel pad measurements were 35 mm and 42 mm in the same location."

When several tracings of track sets are obtained on a single route, a decision matrix helps identify different lions. When comparing tracings to one another, place signs for "equal", "not equal", or "questionable" in the cells of the matrix to identify relationships between track sets. In our hypothetical example (Figure 2) track set 1 is judged sufficiently different from sets 2-5 to be considered a separate lion, thus the "not equal" signs across the top row. Track set 2 is the same as track sets 3-5 and receives "equal" signs across the second row. Track set 3 is identical to set 4; the appropriate cell receives an "equal" sign. The relationships of sets 3 and 4 to set 5 are unclear; they receive question marks. Questionable ratings result from missing data (partial tracings of tracks, absence of tracings of one or more paws), substrate differences, observer error, and other factors. In our example then, we conservatively identify two individual lions, represented by track set 1 and track sets 2-5. Track set 5 is grouped with sets 3 and 4 based on the equal classification they all share with set 2.

Track set	1	2	3	4	5
1		≠	≠	≠	≠
2			=	=	=
3				=	?
4					?
5					

Figure 2. Example of a decision matrix helpful in classifying track sets from individual lions. Only cells to the right of the shaded area are needed for analysis. Symbols signifying that track sets are not from the same lion (≠), are made by the same lion (=), or the relationship cannot be determined (?).

Using Judgement in Interpretations

Two approaches to identifying individual lions are currently possible; each has its own utility. Both use the criteria already described, but vary in the reliance placed on judgemental factors like differences in size and shape. The standard, more scientific approach, used by Kutilek et al. (1981) requires the researcher to be very certain of any distinctions identified. Only tracings that are obviously different are classified as representing different animals. This approach is repeatable and tends to protect the scientist from having to defend statements that are subject to different interpretations. This method is thought to underestimate the lion population and has been called a "minimum" estimate.

The second approach requires the researcher to attempt to judge accurately, based on a synthesis of all available information, whether the tracings represent different animals. The decision matrix described earlier is helpful in this analysis. In this approach the researcher makes assumptions about observer and track variability (which are unquantified at present) and thus relies on the his/her experience and objectivity. For example, it is our opinion that the variability of heel pad width from different tracks of the same lion, traced by different trained trackers should not vary more than about 6 mm (0.25 in.). We believe this technique, employed in an objective manner by trained personnel, probably provides an answer closer to the real population values than does the more conservative method above. The numbers provided by the second approach still are likely to be conservative for two reasons. First, all tracks from different lions are not separable, and second, all lions whose home ranges cross the route will not have left tracks along the route. Van Dyke (1983) estimated that a lion crosses at least one unimproved dirt road within its home range every five to 12 days, but this conclusion depends upon road density.

The conservative nature of even the second approach was illustrated by our study in the Sierra National Forest. Of five radio-collared lions whose home ranges overlapped at the same point within our route area, four remained outside the route area during the five days we were there, and the other one was not detected, although present. (George Steger and Donald L. Neal, personal communications, July through November, 1984.) We did find eight sets of tracks representing two lions using the standard measure. Our best estimate of the actual number identified three lions from tracks during two good tracking days, while five other lions were known to use the same area. (Rain prevented work during one day and caused poor tracking conditions on two others.)

Sensitivity of the Index

An index to population changes can be made without reference to the absolute population number, although it may be insensitive to downward shifts in population. The conservative, first approach to estimating number of lions yields a low number, from one to four in the work completed to date, and these data were gathered during a period that probably represents normal to high population densities. Using this type of analysis it will be difficult to establish whether significant reductions in population have occurred because of the low estimates normally obtained. The less conservative approach to identifying lion numbers from tracks is a small improvement, but also involves greater inherent variability because of the lack of definitive guidelines. As discussed previously, recording the number of sets of tracks may or may not provide a better index.

Appropriate Comparisons

All of the measures discussed so far are collected along roads, so the sampling pattern is linear in nature. They may be expressed as a number per kilometer or per mile. An implicit assumption is that the probability of finding a number of different lions is proportional in some manner to the number of home ranges crossed by the linear route. The shape and location of these home ranges generally is unknown, and thus the probability of finding different lions is unknown. It may vary in different locations. Expressing results as number per kilometer obscures the lack of information about an "expected number" based on home range patterns. If the route is compared only with the same route from previous years, the only item of concern is whether the home range boundaries have changed. There is some indication that the do change periodically (Seidensticker et al. 1973).

In spite of these problems, Van Dyke (1983), using nonparametric analyses, stated that track frequency (sets of tracks) could provide reliable approximations of relative populations in different areas. We believe, without more testing and because of the unknown and, likely unequal, sampling probabilities, it would be invalid to compare results from different areas. Even comparing the same area to itself in different years requires the unsupported assumption that the probability of sampling animals that are present is the same in both years.

Statistical Analysis

Each survey period (five days in our research) constitutes one sample. Several years of data from one route are analyzed as paired samples, using the Fisher Randomization Test or the Wilcoxon Signed Rank Test. Roughton and Sweeny (1982) provide a description of the application of these tests to data like ours.

We caution against comparing different areas, but a number of different routes could be analyzed together to determine an area-wide trend if assumptions of randomness or proportionality are met by route locations. The Quade Test, The Friedman Two-Way Analysis of Variance by Ranks, or Kendall's Coefficient of Concordance could be used. If some data are missing, the Durbin Test may apply. All of the tests are found in Conover (1980).

Track Surveys and Radio Telemetry

If home range data are available from radio-tracking, the track data become more valuable, as pointed out from our experience in the Sierra National Forest. Combining radio tracking data with identification of individual lions from intensive track surveys probably can yield estimates of local population size.

RESEARCH AND MANAGEMENT NEEDS

An objective model is needed which quantifies the limits of observer error in tracings and the natural variability inherent in lion tracks. Such a model will allow more standardized determination of different lions from their tracks. The authors have initiated a pilot study to determine such variations. Existing tracings can be reevaluated once such a model exists.

Greater knowledge of the variability of track transect surveys can be gained by performing them in areas where lions are being followed with radios.

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