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Title: SEASONAL PROPERTIES OF THE COYOTE SCENT STATION INDEX

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Dr. E. Charles Meslow

Six standard coyote scent station index lines and one scentless control line were repeatedly sampled from May through October, 1974, on a 400 square mile study area in Central Oregon. The scent station index remained relatively constant at a mean value of 0.025 from May through mid-August; increased to a mean value of 0.043 in September; then decreased to a mean of 0.038 in October. Reduced scent effectiveness due to weathering was not evident. Between-line and within-line variability of the index remained relatively constant throughout the study period. Between-line variability accounted for more of the total variation in indices than between-month variability. Up to four-fold, statistically significant, differences in index values between lines were evident throughout the study. The mean percent of coyotes that scored at a scent station, once they were on a segment of the road surface that extended 30 feet on each side of a scent post, was 28.8 percent over all lines and periods. There was statistically

significant variation in the percent scoring between lines and this variation partially explained the between-line differences for the scent station index. The percent scoring did not change significantly between months, however. An alternate index in which the stations read were 60 foot long segments of the road surface at 0.3 mile intervals was found to give an approximate four-fold increase in mean indices and a significant reduction in coefficient of variation compared to the standard scent station index. The relative merits of these two indices were compared. A functional relationship between coyote numbers, coyote activity and index values was proposed and evaluated in terms of observed index values. Seasonal capabilities of the index as a research tool were evaluated in terms of seasonal variability and the pattern of mean indices obtained throughout the study.

Seasonal Properties of the Coyote Scent Station Index

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SEASONAL PROPERTIES OF THE COYOTE SCENT STATION INDEX

I. INTRODUCTION

This paper reports the results of a 6-month field study of the scent station technique for indexing coyote (Canis latrans) populations. The objectives of this study were: 1) determine the seasonal mean and variance properties of the index; 2) give preliminary interpretations of the seasonal index values in terms of relative coyote numbers, relative coyote activity and coyote behavior; and 3) assess the seasonal capabilities of the index as a research tool.

Several techniques have been employed to estimate relative or absolute canid abundance. Bounty payment records were used as long term trend indices for coyotes by Gier (1968) and for red and gray foxes (Vulpes vulpes and Urocyon cinereoargenteus) by Lemke and Thompson (1960). Wagner (1972) employed federal catch records, in terms of coyotes taken per man-year, as long-term indicators of population trends; and Keith (1963) used fur return records as indicators of long-term population trends for foxes and coyotes.

Within shorter time frames, such techniques as catch per trap night for foxes (Wood 1959) and coyotes (Clark 1972) or kills per standard Humane Coyote-getter line (Knowlton 1972) were employed. Mech (1966) estimated the total number of timber wolves (Canis lupus) on Isle Royale by aerial census and Clark (1972) used the number of dens located per hour of flying time as an index to the post-breeding coyote population. A modified Peterson index was also used by Clark (1972) in an attempt to estimate the total number of coyotes on his study area.

Linhart and Knowlton (1975) noted that of the techniques currently available, the scent station index seemed to have the most promise for reliable, extensive and economical use. Their paper described the technique and presented preliminary results from the 1972 and 1973 fall samplings in the 17 Western states conducted by the U.S. Fish and Wildlife Service.

A standard Fish and Wildlife Service survey route consists of 50 scent stations placed at 0.3 mile intervals along a 14.7 mile section of secondary road. Each scent station is composed of a cleared circle, 3 feet in diameter, at the road edge covered with sifted soil. A perforated plastic tissue capsule, filled with about 0.035 ounces of granular fermented egg attractant, is supported 1 inch above the ground in the center of the circle. Each station is checked daily for 5 successive days and the number of stations visited (as evidenced by tracks) during each 24 hour period is recorded; the index value is the proportion of operational stations visited x 1000. No attempt is made to determine the number of animals that visit each station. Stations rendered unreadable by cattle, weather, or human activity are excluded from the calculations.

Hodges (1975) investigated the statistical properties of the scent station technique using the data collected by the U.S. Fish and Wildlife Service in the falls of 1972, 1973, and 1974. He found three characteristics of the data especially relevant to observer effects. First, observer to observer variability was very large as two different observers running the same survey line would be expected to obtain index values differing by more than 32 percent one-half of the time. Second, although there was little, if any, linear trend in the index through the standard 5 days of operation there was a significant increase on the fifth day of approximately 11 percent. Hodges suggested that observers got a better look at the stations on the fifth and last day as they picked up the station materials and recorded tracks they would have otherwise missed. Third, the ratio of the index for stations on the left-hand side of the road to the index for stations on the right-hand side was 0.95. Hodges suggested that some tracks in the left-hand side stations were missed when these stations were read from a vehicle.

Hodges (1975) also investigated the problems of: 1) more than one coyote visiting a single scent station in one night; 2) a single coyote visiting more than one station in a night; and 3) differential travel on roads by coyotes in a restricted (pine forest) habitat as opposed to a more open (sagebrush) habitat. He found that within the index range of 0-150, which included 74 percent of the index lines in the western states, the scent station index could be assumed to be proportional to the number of independent coyote visits. For higher index values, non-linearity became more of a problem and he presented an equation for converting scores to actual independent visits in the index range above 150. Hodges' results indicated that the average maximum estimate of the probability that a single coyote would visit more than one scent station, given that it had already visited a station, was 0.088 and a reasonable estimate of the actual probability was 0.046. The average distance a coyote could be expected to walk along a road, given it decided to walk along it at all, was about 0.2 miles for both the forest and the sagebrush habitats. In the forest, 12 percent of the coyotes walked at least 0.6 miles and in the sagebrush 7 percent walked at least 0.6 miles. Hodges (1975) noted that these percentages could be used as estimates of the proportion of coyotes which could be expected to encounter at least two regularly spaced scent stations.

Hodges (1975) found precipitation and wind to have noticeable effects on the scent station index. A change from clear or cloudy to showers caused an 8-10 percent decrease in the index. A change from showers to rain caused an additional reduction in the index of about 9 percent. When the wind changed from moderate or no wind to strong or gusty the index declined 8-14 percent. Results of his analysis of index values in relation to phase of the moon were generally inconclusive with no particular pattern evident.

Hodges (1975) investigated temporal variation of a single survey line based on averages of all survey lines in the western states. He considered the smallest measure of variability of interest to be the day to day variability over the normal 5-day period of operation and the largest measure of variability of interest to be the year to year variability of a given survey line. He presented equations for estimating the standard error of the mean index for the short term (5-day) and long term (3-year) time frames for a single survey line and emphasized that these measures of variability depended on the average index value.

Hodges (1975) was unable to make any seasonal interpretations since collection of the available data had been limited primarily to September in each year.

II. STUDY AREA

This study was conducted in Central Oregon on a roughly 400 square-mile tract of high desert within the Columbia Plateau centered approximately 7 miles south of Brothers (Figure 1). Of the potential study areas surveyed, this area provided the most uniform physiographic characteristics, vegetation patterns, land usage and coyote control. In addition, the road network allowed placement of the survey lines in close proximity to one another.

Terrain was gently undulating from 4500 feet to 4900 feet in elevation with buttes reaching 5650 feet. United States Department of Agriculture, Soil Conservation Service (1973) soil maps of the study area revealed that roughly 90 percent of the area was dominated by cold, well-drained gently sloping soils of the Floke-Olson association on tablelands. The remaining 10 percent, which included the western one-third of line 2 and the northern half of the control line (Figure 1), was an area dominated by cold, somewhat excessively to somewhat poorly drained ashy soils of the Kotzman association on nearly level terrain.

Primary sources of permanent water were privately owned wells in the northwestern three-quarters of the area and small lakes resulting from snow melt and blind drainage in the southeastern one-quarter. Average annual precipitation was approximately 11 inches

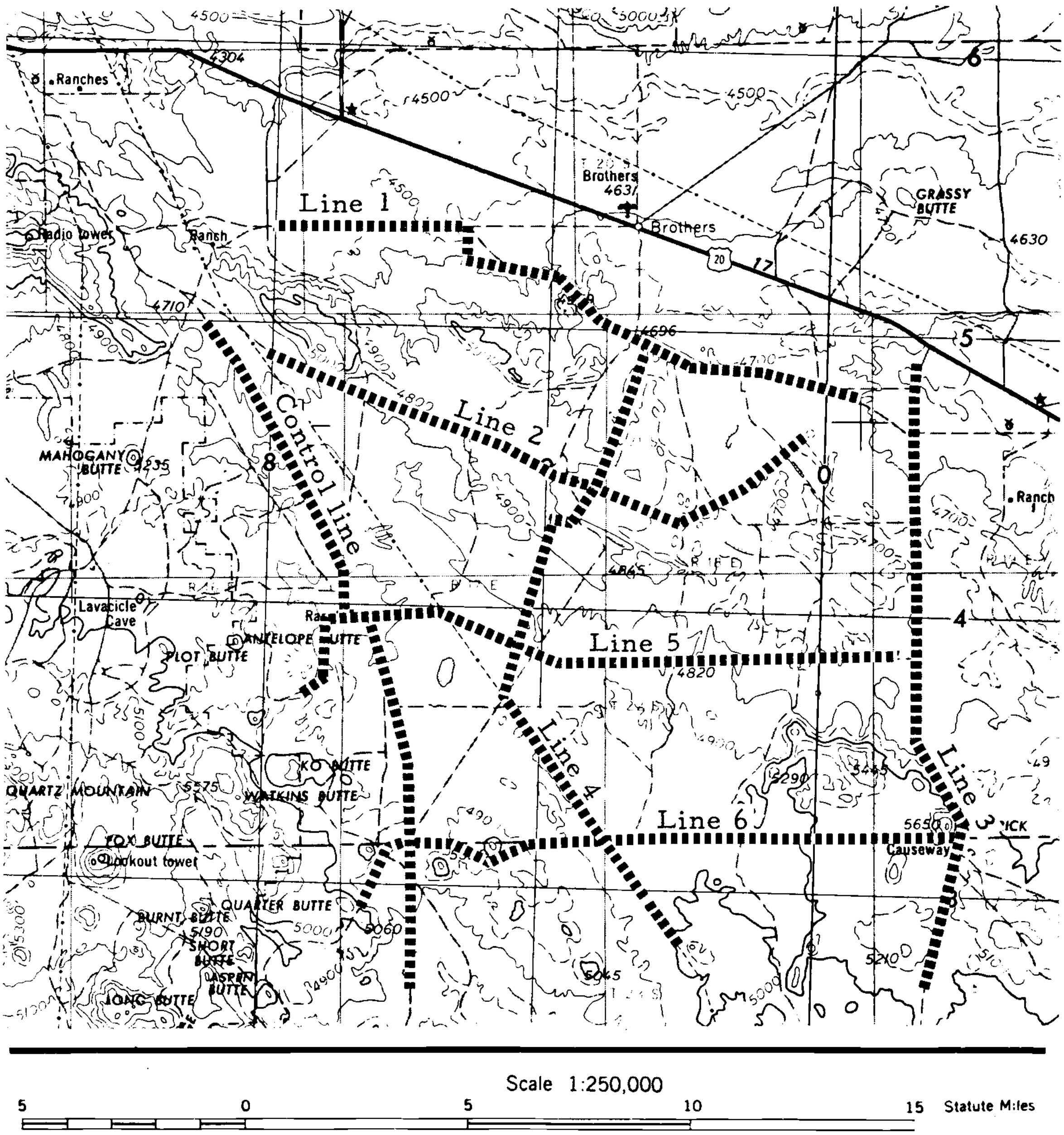

Figure 1. Map of Central Oregon study area.

with mean monthly temperatures ranging from a high of 62 F in July to a low of 28 F in December.

A review of the Bureau of Land Management (1974) range survey map of the study area, combined with aerial surveys and ground reconnaissance, revealed that vegetation was predominantly sagebrush (*Artemesia* spp.) and Idaho fescue (*Festuca idahoensis*) in the northwestern three-quarters of the study area with bitterbrush (*Purshia tridentata*) occurring on approximately 3 percent of the area along the west-central edge. In the southeastern one-quarter, open Western juniper (*Juniperus occidentalis*) stands with an understory of sagebrush and Idaho fescue predominated. Rabbitbrush (*Chrysothamnus* spp.) was prevalent along road edges throughout the area.

Land ownership was predominantly public and administered by the Bureau of Land Management. Human habitation was minimal. In addition to the five families at Brothers, there was only one seasonal cowboy camp on the west-central edge of the study area and one ranch adjacent to the northwestern corner. Primary land usage was cattle grazing.

Organized coyote control was limited to a single program on the northwestern one-quarter of the study area; one day of helicopter gunning was conducted in the vicinity of a calving ground. From January, 1974, until this study was initiated in May, 1974, approximately 60 coyotes were removed; 39 were taken by aerial gunning

(Roy McDonald personal communication), and, along the northwestern boundary of the area, another 15-20 were shot by ranchers (Ron Moffitt personal communication). There was little, if any, successful sport hunting or trapping on the study area.

III. METHODS

The experimental design was a randomized blocks two-way classification. Six standard scent station lines and one control line were established in the study area (Figure 1) and these lines were sampled in five replications from 6 May 1974 through 26 October 1974. The index routes chosen were essentially all of the consistently passable and continuous 14.7-mile segments of road available in the study area. Each time period (replication) was defined by the length of time it took to complete a sampling cycle of all index lines (Table 1). Within logistics, manpower and weather limitations, the time periods were a total sample of the periods available during the study. Starting dates for the periods were essentially random.

Table 1. Sampling periods.

Sampling Period	Inclusive Dates (1974)
A	6 May - 4 June
B	12 June - 23 July
C	28 July - 22 August
D	3-23 September
E	2-26 October

The randomized blocks design allowed the use of standard analysis of variance techniques to describe both temporal and spatial characteristics of the indices and provided seasonal estimates of variance which could be examined for temporal trends using standard regression procedures.

Stations for the control line were 50 segments of the road surface, 60-feet long and as wide as the road surface spaced at 0.3 mile intervals. There was a 1 mile break at station 25 on this route to avoid interference by dogs from the cowboy camp. Initially, tires were dragged behind a vehicle to daily clear this control route of animal tracks. Stations locations varied because the first station was read as the oddometer first turned a whole 0.1 mile after passing a fixed point. Then at 0.3-mile intervals, 60 feet of the road surface, measured by pacing, was examined for coyote tracks. Station locations did not vary by more than 600 feet however. This method of clearing tracks eventually proved unsatisfactory as the continual dragging caused the road surface to become severely washboarded. On 9 September 1974 this practice was discontinued and permanent stations were established. These stations were marked by red-tipped lathes placed along the edge of the road and tracks were daily cleared from the stations with a large push broom. There was never any fermented egg scent placed along the control route.

On the standard scent station routes the same scent post locations were used throughout the study. Scent posts were located approximately 2.5 feet from the road edge to minimize destruction by vehicles. To aid in scent station location a 6-inch piece of red flagging tape was tied to vegetation opposite the scent post and 30 feet away on each side of the scent post at the road edge. During periods of non-use, the flagging tape and stakes for securing the scent capsules were left in place.

Prior to study initiation criteria for line or station closure were established: 1) if over 50 percent of a station was unreadable, that station was closed; 2) if less than one-half of the scent stations were operational for a line on a day, data for that line were discarded and an additional day was run. Scent capsules destroyed by cattle, humans, weather or other causes were replaced with appropriately aged and weathered capsules.

During each standard 5-day sample, except period A when the control index was not run, the control line and two scent station lines were sampled on each day. The two scent station lines run on the same day were called a pair and they were, in order of first sampling, lines 1 and 2, lines 3 and 4, and lines 5 and 6. The same two lines were always run as a pair, and the same order of sampling was maintained throughout the study to insure that relatively equal amounts of time elapsed between the successivel samplings of a line. On all days the odd numbered scent station line was run first and the control line last.

In periods B and E the length of the sampling run was increased to 10 days per line. Data from the last 5 days of these samples were used in the following analyses only: 1) attractant attenuation, 2) near visit analysis of percent scoring by line and period, 3) multiple stations visited by a single coyote, and 4) effects of weather and phase of the moon (Appendix).

Due to bad weather only lines 1, 2, 3, and 4 were successfully sampled in period E. Low temperatures, rain and snow impaired tracking conditions during this period; six widely spaced days of data from a repeat sampling of lines 1 and 2 and two days of data from lines 5 and 6 were consequently excluded from the analyses.

The loss of lines 5 and 6 in period E produced incomplete blocks for two-way analyses of variance. The missing values were estimated by procedures outlined by Snedecor and Cochran (1967:317-321). The treatment sum of squares from the analysis of variance is biased upwards by this procedure and the total and error degrees of freedom are reduced by one for each estimated value. When applicable, this bias was calculated but was found to have no appreciable effect on the significance of the calculated F statistics. Uncorrected sums of squares are therefore reported in the two-way analysis of variance table. Procedures for calculating the standard error of the difference between treatments and between blocks with missing values (Cochran and Cox 1950:98) were utilized to determine specific differences between lines and between periods with missing values cited in the results and discussion section of this paper. The remaining specific between-line and between-period differences, for periods and lines without missing values, were determined using the revised least significant difference, LSD, test described by Snedecor and Cochran (1967:271-275).

When calculating the mean and variance for each 5-day or 10-day run of a line, the index for a day was considered to be a sample. Means were not weighted for differing numbers of station nights between days. In only 12 instances were there less than 40 station nights per day.

IV. DEFINITION OF TERMS USED

Repeated references to a number of indices are made throughout the results and discussion section of this paper. For simplicity, the definition of each index and, where appropriate, the justification for its use is presented:

1) CONTROL INDEX, I_c. In the 60-foot segments of road surface on the control line, the presence or absence of coyote tracks was recorded; the index, I_c, was the proportion of operational control stations with coyote tracks. This index was not taken in period A. No attempt was made to determine the number of coyotes which had left tracks on each station. This index was free of variation due to coyote response to the fermented egg scent and provided a basis for evaluation of scent effects.

2) VISIT INDEX, I_v. This was the standard scent station index described by Linheart and Knowlton (1975) except the proportion of operational scent stations with coyote tracks was not multiplied x 1000.

3) NEAR VISIT INDEX, I_n. The road surface for 30 feet on each side of each scent post was checked for coyote tracks daily. If tracks were found in this area, and the scent station had not been visited, the distance between the closest coyote track and the scent post was measured by pacing. All coyote tracks in the

60-foot segments of road were then cleared. The near visit index, I_n, was the proportion of operational road segment stations, opposite scent posts, with coyote tracks. As for I_c, no attempt was made to determine the number of coyotes which had left tracks on the road. These near visit data were used to describe coyote behavior toward the scent stations.

4) VISIT PLUS NEAR VISIT INDEX, I_s. For any day, $I_s = I_v + I_n$. At the outset of the study near visit data were not collected on 8 line days; I_s was not calculated for these days. Otherwise, except for five instances, station nights for I_v and I_n were the same for a line. On these five instances there were no scent station visits opposite closed road segment stations so no adjustment was made for differing numbers of station nights.

5) SMALL MAMMAL INDEX, I_m. At each scent station the presence or absence of small mammal tracks on the station was recorded concurrently with I_v. The small mammal index, I_m, was the proportion of operational stations with small mammal tracks. This index was not run in period A. No species larger than the black-tailed jackrabbit (Lepus californicus) was included in this index and neither individual species of small mammals, the number of species nor the number of individuals leaving tracks were recorded. Bider (1968) described the preparation of sand transects that allow the identification of small mammal species

by their tracks but his techniques were impractical to apply in this study. The commitment of sampling three coyote survey lines per day did not allow for the careful preparation and maintenance of scent station surfaces necessary to insure consistent identification of small mammal species by their tracks. A list of mammals whose known ranges overlapped this study area is given in the Appendix.

Dice (1938, 1941) emphasized that useful indices of abundance may be derived from the signs of presence of a given species on appropriately placed sample plots. Overton (1971) noted that methods involving signs or evidence of animal presence are widely used as indices to the relative abundance of game populations. The scent station index to small mammal populations was the only method that did not conflict with intensive sampling of the coyote scent station survey routes. Additionally, the method had certain advantages: 1) the collective small mammal population was not subjected to mortality as would have occurred through trapping; 2) the small mammal index could be directly compared to the coyote indices on a line for line and day for day basis; and 3) a large quantity (approximately 6000 station nights) of data could be accumulated with little extra expenditure of effort. The major limitation to the I_m technique was that individual species were not identified and thus relative indices were not available for each species. Therefore correlations between the coyote indices and the index for a specific small mammal species could not be determined.

6) PERCENT SCORING. For each scent station line in each period, except for lines 5 and 6 in period E, I have an estimate of the percent of coyotes that scored at a scent station once they were on a segment of the road surface that extended 30 feet on each side of a scent post. I used the raw numbers of scores and near visits to calculate the percent scoring as the ratio (scores/scores + near visits) x 100. By this convention I assumed a near visit each time there was a score. The 8 days at the beginning of the study when I_n data were not collected were excluded from these calculations.

V. RESULTS AND DISCUSSION

A. Inherent Properties of the Index

During the data collection portion of this study I closely examined each scent station on each day in view of Hodges' (1975) suggestion that, over the 17 Western states, stations were more closely examined on the last day of a sample and more coyote tracks were consequently recorded on that day. When all time periods for this study were combined, there were no significant differences between daily mean indices for days one through five for I_v, I_n, I_s or I_c. In addition, linear regressions of index value on day of sample for each of these four indices gave no consistent evidence of any trend in mean indices for days one through five.

The fact that the fifth day mean was higher than any other day for I_v (Table 2) may, however, indicate that my small sample in comparison to Hodges' (1975) sample (N = 28 vs. N = 521) limited my ability to detect a real, but small, fifth day effect related to some factor other than observer bias. An alternate hypothesis would suggest an initial 1 to 4 day period of avoidance of the scent stations by coyotes followed by a period of investigation resulting in the higher fifth day index. Since there were no scent stations on the control route I would expect a stable mean index through all 5 days for I_c if the latter hypothesis held, yet the fifth day mean was the highest

Table 2. Mean index by day of sample; all periods combined.

Index	Day 1	Day 2	Day 3	Day 4	Day 5	Grand Mean
Visit, I_v						
Mean	0.031	0.029	0.029	0.027	0.035	0.030
N (days)	28	28	28	28	28	
Standard error	0.008	0.005	0.005	0.007	0.008	
Deviation from grand mean	+0.001	-0.001	-0.001	-0.003	+0.005	
Near visit, I_n						
Mean	0.071	0.075	0.106	0.089	0.087	0.086
N (days)	22	26	28	28	28	
Standard error	0.012	0.013	0.018	0.015	0.011	
Deviation from grand mean	-0.015	-0.011	+0.020	+0.003	+0.001	
Visit plus near visit, I_s						
Mean	0.106	0.105	0.138	0.116	0.122	0.117
N (days)	22	26	28	28	28	
Standard error	0.018	0.014	0.023	0.018	0.015	
Deviation from grand mean	-0.011	-0.012	+0.021	-0.001	+0.005	
Control, I_c						
Mean	0.107	0.100	0.113	0.114	0.158	0.118
N (days)	11	11	11	12	12	
Standard error	0.023	0.028	0.020	0.022	0.036	
Deviation from grand mean	-0.011	-0.018	-0.005	-0.004	+0.040	

for this index also (Table 2). The fifth day mean was the highest for I_c even when those days when the control stations were marked by lathes were excluded from the calculations. The fact that the percent scoring for day one was higher than any other day (Table 3) detracts further from the avoidance-investigation hypothesis. The third day peak in daily mean indices for I_n and I_s (Table 2) confounds attempts to develop any other alternate hypothesis.

Table 3. Percent of coyotes that scored at a scent station, once they were on a segment of the road surface that extended 30 feet on each side of a scent post, by day of sample.

Day of Sample	1	2	3	4	5
Percent scoring	32.46	28.79	21.20	24.20	29.01

These results do not then strongly support Hodges' (1975) suggestion of observer bias as the cause for the fifth day rise in mean index he observed.

In an attempt to identify trends in coyote response to the scent stations over longer periods than the standard 5 days the sample period was increased to 10 consecutive days per line in periods B and E. Because weathering of scent could influence variability of coyote response to the scent stations, the standard scent replacement schedule was concurrently modified to test for this effect. On the odd numbered member of a pair of lines the scent was renewed daily; on the even numbered member the scent was renewed with an appropriately aged and weathered capsule only if it had been destroyed. A *t*-test for two population means showed no significant differences between the first and last 5 days for a line for either treatment in either period. Linear regression of index on day of sample failed to show significant correlations in either period or, when both periods were combined, for either treatment. I then calculated the percent scoring for each treatment and day of sample combination and conducted linear regression of percent scoring on day of sample. No significant correlation was found for either the renewed ($r^2 = 0.002$, 45 d.f.) or the non-renewed ($r^2 = 0.007$, 43 d.f.) treatments. The lack of evidence for a significant decreasing trend in mean indices or percent scoring through a sample period as long as 10 days does not prove that scent effectiveness remains constant. Once coyotes visit a scent station they might be more likely to visit again on subsequent nights and the effect would be to compensate for decreasing scent effectiveness. Alternatively, it may be that visual cues are important determinants of coyote response to the scent station.

Reading the near visit road segment stations necessitated my walking up to each scent station. In view of Hodges' (1975) suggestion that lower left-side of road indices were attributable to some left-side stations being read from a vehicle I reasoned that there should be no difference between left-side and right-side mean indices for this study. For each day I considered the indices for the left-side and right-side of the road to constitute a pair. A paired _t_-test, all lines and periods combined, did not show a significant difference between the indices for the two sides of the road Of 265 scent station visits recorded in this study, 129 (48.7 percent) were on the left side of the road and 136 (51.3 percent) were on the right side. The ratio of left-side to right-side visits was 0.95, exactly the same ratio as Hodges (1975) obtained. My data does not then clearly support his hypothesis of observer bias. The 0.95 ratio of left-side to right-side visits appears to be an anomaly as left and right sides of the road exist only in relation to the observer and are not related to prevailing winds or any other obvious variable that might influence coyote behavior.

B. Variance Properties of the Index

If the data obtained by the scent station technique were any less variable in one season than another the precision of an estimated index could be increased by sampling in that season. Of particular interest in this regard were the seasonal estimates of within-line and between-line variance. In this study the measures of within-line and between-line variance were expressed as the standard error of a 5-day mean index for a single survey line and the standard error of the difference between 5-day pair-mate indices respectively.

There was no significant relationship between the variance estimate and the sequential day of the study for either the within-line variance estimate ($r^2 = 0.047$, 26 d.f.) or the between-line variance estimate ($r^2 = 0.050$, 26 d.f.). Linear regression of standard deviation on mean five-day index revealed significant ($P < 0.01$) correlations between variance and mean for I_v (Figure 2), I_n ($r^2 = 0.665$, 26 d.f.), and I_s ($r^2 = 0.599$, 26 d.f.). Thses correlations imply constant coefficient of variation for each index. There is thus no evidence that a significant reduction in variance can be obtained by sampling in any particular season investigated in this study.

The significant relationship between standard deviation and mean index also implies heterogeneous variance. Bartlett (1947), Hartley et al. (1955), and Schultz and Muncy (1957) note that logarithmic transformation of data which exhibit a linear relationship between variance and mean gives a transformed variable with homogeneous variance. Such transformed data then satisfy the assumption of homogeneous variance for analysis of variance tests of treatment means. However, it is then not possible to talk of mean and variance properties of the data in the original scale.

Transformation of the data from this study, in the form $y = \log(x + a/b)$ (where a and b are the intercept and slope respectively of the regression equation relating standard deviation

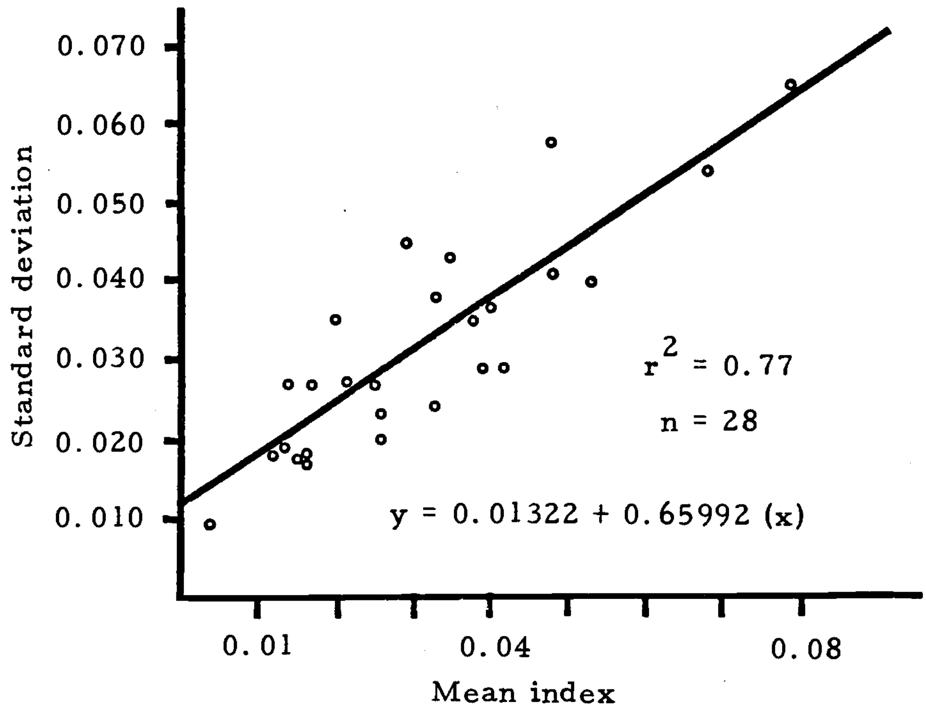

Figure 2. Standard deviation of five-day mean visit, I_v, indices.

(y) and mean (x)), gave results not materially different from those obtained using the untransformed data. The untransformed results were conservative in identifying significant F statistics and specific between-line and between-period differences. All results of this study are therefore based on analyses of the untransformed data.

Because the scent station lines established by the U.S. Fish and Wildlife Service were distributed over the 17 Western states and spaced a minimum of 20 miles apart (Linhart and Knowlton 1975), sources of between-line variability such as differences in habitat, land usage, coyote control, coyote density and coyote behavior undoubtedly varied widely between lines. Although this study area was not totally uniform in terms of the above mentioned sources of variability, it was more uniform in terms of physiography, vegetation patterns, land usage and coyote control than other potential study areas surveyed in Oregion and was certainly more uniform than the Western United States in terms of all the sources of variability. Observer to observer variability was eliminated in this study as I ran all the index lines. With the sources of between-line variation further reduced by close line spacing (5-8 miles separation) in a relatively uniform area, the estimates of between-line variance should have approached a minimum.

In this study the between line component of variance was approximately twice the between period component of variance for

I_v (Table 4). In other words, more of the total variation in I_v is accounted for by between line sources than is accounted for by between period sources such as seasonal fluctuations in coyote numbers, coyote activity and coyote behavior.

Table 4. Two-way analysis of variance of visit index, I_v, by line and period.

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Statistic
Total	0.0089789	27		
Lines	0.0045901	5	0.0009180	6.85**
Periods	0.0019771	4	0.0004842	3.69**
Error	0.0024116	18	0.0001340	

** Statistically significant at the 0.99 level.

The precision of an estimated index can be increased by increasing sample size in the area of greatest variability. Snedecor and Cochran (1967:279-282) outline procedures for quantifying the components of variance identified in analysis of variance techniques; in this study the components of interest are between-line and between-period variance. I have used Snedecor and Cochran's (1967) procedures to compare the efficiency of the sampling design of this study to other period and line combinations; a discussion of the procedure follows.

In the model used for the analyses of variance for this study the index for the ith line in the jth period, X_{ij}, is the sum of four parts: 1) an overall mean, μ; 2) a deviation due to line effect, A_i; 3) a deviation due to period effect, B_j; and 4) a random element from a normally distributed population with mean zero and deviation σ, ϵ_{ij}.

Mathematically the model may be written:

$$X_{ij} = \mu + A_i + B_j + \epsilon_{ij}$$

and the mean index, $\overline{X}..$, may be expressed as

$$\overline{X}.. = \mu + \overline{A}. + \overline{B}. + \overline{\epsilon}..$$

where $\overline{A}.$ is the mean of a independent values of A_i (one for each line), $\overline{B}.$ is the mean of b independent values of B_j (one for each period) and $\overline{\epsilon}..$ is the mean of ab independent ϵ_{ij}.

Then the variance of $\overline{X}..$ as an estimate of μ is

$$V(\overline{X}..) = \frac{\sigma_A^2}{a} + \frac{\sigma_B^2}{b} + \frac{\sigma^2}{ab} .$$

From Table 4, for I_v, where A represents lines and B represents periods the

Mean Square for lines estimates $\sigma^2 + 5\sigma_A^2$, the

Mean Square for periods estimates $\sigma^2 + 6\sigma_B^2$, and the

Mean Square for error estimates σ^2.

By rearranging terms the components of variance due to line, σ_A^2, effects and due to period, σ_B^2, effects can be estimated as:

$$\sigma_A^2 \triangleq (1/5) \quad (\text{MS for lines - MS for error}),$$

$$\sigma_B^2 \triangleq (1/6) \quad (\text{MS for periods - MS for error})$$

and $\sigma^2 \triangleq$ MS for error, where the sign $\triangleq$ means "is estimated by".

For I_v in this study, where $\overline{X}..$ equals 0.030, then

$$V(\overline{X}..) = \frac{\sigma_A^2}{a} + \frac{\sigma_B^2}{b} + \frac{\sigma^2}{ab} .$$

Replacing σ_A^2, σ_B^2 and σ^2 by the appropriate calculated values yields

$$V(\overline{X}..) = \frac{1.56810 \times 10^{-4}}{a} + \frac{6.00503 \times 10^{-5}}{b} + \frac{1.33981 \times 10^{-4}}{ab}$$

where a is the number of lines and b is the number of periods.

The standard error of $\overline{X}..$ is given as

$$s_{\overline{x}..} = \sqrt{V(\overline{X}..)}$$

and the approximate confidence interval on $\overline{X}..$ is then

$$\pm 2 s_{\overline{x}..} .$$

To estimate the relative precision of a sampling design, various values of a and b are inserted in the variance, $V(\overline{X}..)$, expression and the confidence intervals are subsequently calculated and compared.

Adding lines at the expense of periods increases the precision of the estimated index while adding periods at the expense of lines reduces precision of the estimated index (Table 5). The precision gained or lost by a particular sampling design must be weighed against the availability of time and suitable survey routes.

Table 5. Relative precision of various sampling designs for I_v.

Number of Lines	Number of Periods	Approximate 95 Percent Confidence Interval on I_v Mean of 0.030
6	5	$\pm 6.52772 \times 10^{-3}$ ($\pm$ 21.76 percent)
8	4	$\pm 6.22902 \times 10^{-3}$ ($\pm$ 20.76 percent)
10	3	$\pm 6.33749 \times 10^{-3}$ ($\pm$ 21.12 percent)
5	6	$\pm 6.77026 \times 10^{-3}$ ($\pm$ 22.57 percent)
4	8	$\pm 7.13412 \times 10^{-3}$ ($\pm$ 23.78 percent)
3	10	$\pm 7.92093 \times 10^{-3}$ ($\pm$ 26.40 percent)

C. Coyote Behavior in Relation to the Index

Specifying the effects of as many sources of variation as possible will aid interpretation of the index values obtained. One possible source of variation is coyote behavior toward the scent stations especially as behavior effects the probability that a single coyote will visit more than one scent station in one night. Hodges (1975) addressed this question and outlined procedures for estimating the maximum and actual adjacent station visitation rates. My estimates of 9.2 percent maximum and 5.5 percent actual adjacent station visitation rates for I_v (Table 6) agree remarkably well with Hodges' estimates of 8.8 percent and 4.6 percent respectively.

Table 6. Estimates of maximum and actual adjacent station visitation by a single coyote.

	Number of Visits Per Day		
	1	2	3
Observed frequency (N)	55	35	14
Probability of a neighboring visit occurring at random (P)		0.079[a]	0.216[a]
Observed number of neighboring visits (O)		9	5
Expected number of neighboring visits E = P(N-O)/(1-P)		2.23	3.04
Estimated number of neighboring visits due to same coyote		6.77	1.96
Maximum estimate = 14/(167-14) = 0.092; 9.2 percent			
Actual estimate = 8.73/(167-8.73) = 0.055; 5.5 percent			

[a]Hodges (1975).

The primary difference between I_s and I_c is the presence of the scent capsule in the former. If the scent draws coyotes onto the road in the vicinity of the scent stations I would expect I_s to be higher than I_c on the average. The effect of the scent, if any, might vary with season. There were no significant differences between the mean of I_s indices and the mean I_c index in any one period studied. Neither was there a significant difference between the mean of I_s lines and the mean of I_c repetitions ($d = 0.003 \pm 0.023$) when the data for the entire study season were combined. For these analyses I see no evidence that the fermented egg scent draws coyotes from a large area onto the road surface within 30 feet of a scent station. Further, it does not seem likely that the scent from adjacent stations draws coyotes down the road to subsequent stations. The adjacent station visitation rates for various habitat types may then best be considered as relative indices to the distance traveled on roads by coyotes.

The mean percent scoring over all lines and periods was 28.8 percent. A two-way analysis of variance disclosed significant ($P < 0.01$) differences in the percent scoring between lines but no evidence of significant differences between periods (Table 7). The significant between-line variation in percent scoring is cause for some concern as it effects the index values obtained on standard scent station lines.

The road surface characteristics of lines 1, 2, 4, 5, and 6 were similar. The roads averages 10-12 feet wide with no gravel. Line 3 was wider, approximately 15 feet, and had some gravel on the northern 12 miles. This gravel could have reduced track visibility and biased I_n downward and resulted in the exceptionally high (53.94) percent scoring for this line. I do not believe this was an important factor, however, as animal tracks were always readily visible on the road surface on line 3 and I could follow the route of a coyote on the road surface as easily on this line as any other.

Table 7. Mean indices and mean percent scoring by lines; all periods combined.

Line	Mean Value					
	I_v [a]	I_n	I_s	I_m	Percent Scoring	I_c
1	0.046 (2, $\underline{4}$)[c]	0.131 (2, $\underline{3}$, 6)	0.180 (2, $\underline{3}$, 4, 6)	0.308 ($\underline{3}$, 4, 5, 6)	29.10 ($\underline{3}$, $\underline{4}$)	0.117[b]
2	0.019 (1, 5)	0.076 (1)	0.096 (1, 5)	0.247 ($\underline{3}$, $\underline{4}$, $\underline{5}$, $\underline{6}$)	18.96 ($\underline{3}$)	-
3	0.034 (4)	0.029 ($\underline{1}$, 4, $\underline{5}$)	0.064 ($\underline{1}$, $\underline{5}$)	0.599 ($\underline{1}$, $\underline{2}$)	53.94 ($\underline{\text{all}}$)	-
4	0.012 ($\underline{1}$, 3, 5)	0.098 (3)	0.110 (1)	0.463 (1, $\underline{2}$)	12.84 ($\underline{1}$, $\underline{3}$, 5, 6)	-
5	0.045 (2, 4)	0.127 ($\underline{3}$, 6)	0.171 (2, $\underline{3}$, 6)	0.524 (1, $\underline{2}$)	27.56 ($\underline{3}$, 4)	-
6	0.030 (4)	0.067 (1, 5)	0.099 (1, 5)	0.513 (1, $\underline{2}$)	30.36 ($\underline{3}$, 4)	-

[a] See text for index definitions.

[b] Only one line sampled for control index, I_c.

[c] Numbers in parentheses refer to lines from which a line is statistically different; underscoring indicates significance at the 0.99 level, all others significant at the 0.95 level.

I believe the differences in percent scoring between lines are more likely related to the relative level of human activity associated with each line. Although vehicle traffic on all roads in the study area was low, there were marked differences in the relative amounts of traffic on the survey routes. Line 3 and the control route were used for access to recreation areas approximately 20 miles south of the study area; traffic along these two routes was noticeably greater than on any other line and was greatest on weekends during mid-summer. In contrast, on line 4 I rarely saw vehicle tracks other than my own or any other evidence of human presence. Traffic on the remaining survey routes fell between these extremes. Pair-mate lines 3 and 4 give the most interesting comparison (Table 7) as they were always sampled on the same dates, were dissimilar in road surface characteristics, typified the extremes of human activity along the routes in terms of traffic and had the high (53.94) and low (12.84) percent scoring respectively. The heavier traffic on line 3 could have obliterated some coyote tracks on the road thus biasing I_n downward and the percent scoring upward. It seems unlikely, however, that passing vehicles would eliminate all the coyote tracks in the 900 square-foot near visit stations on this route (only one coyote track is required for a score in the near visit stations). Although I cannot completely discount the effects of road surface characteristics and vehicle traffic, I believe a more important factor accounting for the variation in percent scoring was accimation to human activity on the more heavily traveled routes. There was far more roadside litter on line 3 than on line 4 and coyotes may have become used to investigating man-placed objects and have been less prone to avoid the quite unnatural looking scent posts.

The distance distribution of the nearest coyote approach to a scent post gives some insight into coyote behavior toward the scent stations (Figure 3). Some coyotes (12.1 percent) pass very close (1.5-4.5 feet) to the scent stations without scoring and a large portion (35.2 percent) appear to walk past the stations on the far side of the road (7.5-16.5 feet). At least 13.0 percent do not walk down the road past the scent stations (distances greater than 16.5 feet). It was obvious from sign at the stations that some coyotes definitely avoided the scent stations and the latter two categories undoubtedly reflect some of this behavior.

Since 25.8 percent of the measured tracks occurred in the scent stations (Figure 3), which comprised only 0.7 percent of the area read (Figure 4), it is obvious that coyote visits to the scent posts were not completely random. Although there is no evidence that the scent posts modify coyote behavior over a large area, they appear to be quite important in the vicinity of the scent stations.

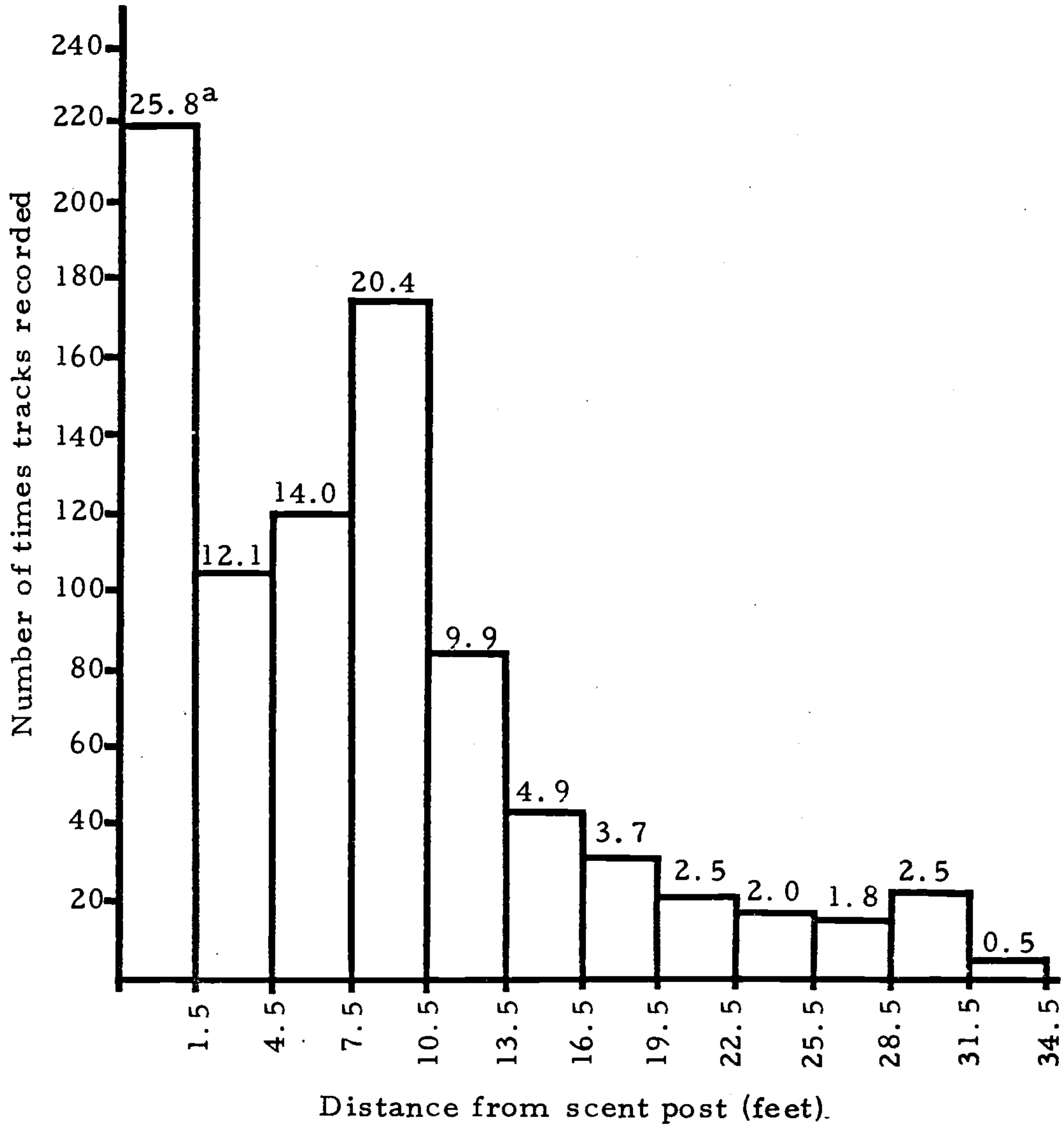

Figure 3. Distance distribution of nearest coyote approach to a scent post; all lines and all periods combined.

[a] Percent of total tracks in zone.

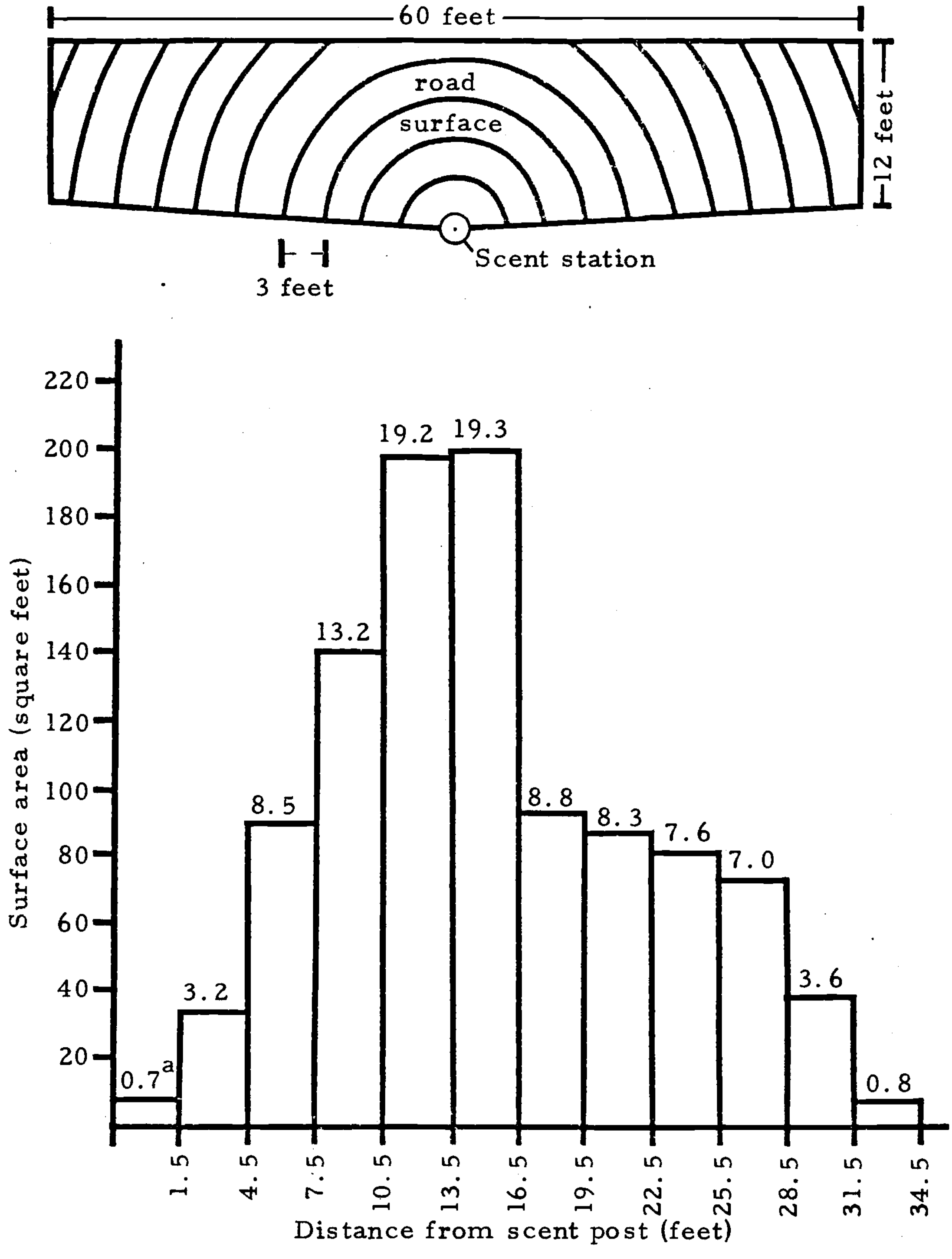

Figure 4. Near visit station schematic and surface area of zones in which near visits were recorded.

[a] Percent of total area in zone.

D. Spatial Properties of the Index

To use the scent station technique as an index to relative coyote densities it must be assumed, or demonstrated, that there is a definite relationship between index values and coyote density. This relationship must remain constant between years for year to year comparisons of index values for a given line to be valid indicators of relative densities; it must remain constant through space for valid area to area comparisons. It was not the purpose of this study to determine the relationship between index and density, but the mean indices for each line give a preliminary idea of the expected variation in index values for a relatively small geographical area.

In a relative sense the study area had advantages in reducing variation in factors that I would expect to affect patterns of coyote activity, distribution and behavior; these factors included the previously mentioned physiographic features, vegetation patterns, land usage and coyote control. As I ran all the survey lines, observer to observer variability was eliminated. Additionally the survey lines were spaced as closely as possible in a grid so local variations in coyote density, if they existed, should have been expressed in at least two survey lines.

I found it difficult to identify features of the environment which would suggest significant variation in coyote density, yet two-way analyses of variance revealed significant differences between lines for I_v (P < 0.01), I_n (P < 0.01), and I_s (P < 0.01).

Of particular interest are the specific between-line differences (Table 7) as they vary depending on the index in question. The mean coyote indices for line 1 are significantly (P < 0.05) higher than line 2 for all indices. Line 3 is significantly higher than line 4 for I_v (P < 0.05), but the order is reversed for I_n (P < 0.05) and the difference is not significant for I_s. The difference between lines 5 and 6 are significant (P < 0.05 for I_n and I_s but not for I_v. The differences in percent scoring (Table 7) explain part of the differences between the I_v index values for pair-mates 1 and 2 and pair-mates 3 and 4. In each pair the line with the higher I_v index has the higher percent scoring. However, this relationship does not hold for pair-mates 5 and 6 nor does it explain the rank of I_v indices (Table 7).

Since index lines 1, 3, and 5 were always run first in the day, and for I_v have higher indices than lines 2, 4, and 6 respectively (Table 7), the recency of human presence could be implicated as a factor in the index obtained. However, this pattern does not consistently hold for I_n or I_s and since the only time I touched a station with my hands was to replace a capsule the human scent left should have been minimal.

Clark (1972) has presented evidence for a temporal relationship between coyote density and black-tailed jackrabbit density. If the between-line variation in index values for this study reflected real differences in coyote density I would expect those density differences to be related to some relevant parameter such as prey density. The small mammal index for each scent station survey line is relevant in this regard. There were, however, no significant correlations between either I_v and I_m (r^2 = 0.006, 20 d.f.) or between I_s and I_m (r^2 = 0.020, 20 d.f.). This is not to say that no relationship existed between predator and prey densities however. Data presented by Clark (1972) and Keith (1963) suggest that predator densities may lag behind prey densities. Since this study was conducted during only one year, coyote and small mammal densities may have been out of phase and their relationship masked.

Other relationships between predator and prey density are also possible. Wagner and Stoddart (1972), referring primarily to coyotes and jackrabbits, suggest that conditions may exist such that prey density is so high by comparison that coyotes cannot make inroads into prey numbers. Black-tailed jackrabbits were extremely scarce on the study area (I saw less than 10 rabbits in the 6 months of field work) and I expect that coyotes made major use of prey populations other than rabbits. It seems unlikely that coyote populations which yield a relatively low index, as obtained in this study, would simultaneously depress several small mammal species as indexed by I_m. Alternatively, the lack of small mammal species identification may have made it impossible to identify an existing relationship between the coyote index and the index for a particular small mammal species.

Whatever the reasons for the significant spatial variation in coyote indices, the between-line variation has implications in terms of the usefulness of the coyote indices. For simplicity I will consider I_s and I_c since variation in coyote behavior toward the scent stations is minimized, if not eliminated, in these indices.

If the between line variation in indices reflects real density differences, then coyotes are finely tuned to habitat differences that I found difficult to identify, and the index is quite sensitive to variation in coyote density. Alternatively, the survey lines may have been placed such that they differentially sampled coyote travel routes or activity areas, which were just as difficult to identify, indicating sensitivity to a parameter other than density. An intermediate situation could very well exist between sensitivity to density and activity. In any case, the assumption that one given survey line is representative of a large area is questionable in view of the close line spacing and the significant between-line variation in index values observed in this study. The best approach may be to deal with a population of coyote scent station survey lines and realize that individual lines may deviate markedly from the average.

E. Relative Merits of the Standard Scent Station Index and the Visit Plus Near Visit Index

If the variation in I_v index values due to variation in percent scoring could be eliminated a better index would result. The most straightforward method for eliminating this variation is to remove the scent and use only the 60-foot road segments as stations. Comparisons of I_v and I_s (which includes the same spatial components of variation as I_v) show further advantages to be gained with the latter technique to include an approximately four-fold increase in mean indices (Table 7) and a significant $(P < 0.01)$ reduction in coefficient of variation (C.V., $I_v = 169.7$; C.V. $I_s = 57.2$; $n = 28$ in each case). These two factors greatly increase the precision of estimated I_s indices compared to I_v indices and increase the probability of detecting significant differences that do exist.

There are some limitations to the I_s index however. If the mean percent scoring of approximately 30 percent remains constant throughout the range of possible I_v indices, then for I_v indices of approximately 0.300 and higher I would expect an I_s index of 1.0. Sensitivity would thus be lost in the higher range. If employed on a wide geographical scale, variation in traffic density and road surface characteristics would probably have significant effects on track readability and the I_s indices. The standardized station preparation procedures for the scent station technique reduce these possible sources of variation.

I feel the most important limitation to the I_s technique as a western-states index to relative coyote numbers is the possibility for even larger observer to observer variability than has been reported by Hodges (1975) for the standard scent station technique. Much more attention is required to properly read a 720 square foot section of road surface than a 3-foot in diameter standard scent station and the ability to consistently detect tracks on the larger road segment stations may very markedly between observers.

In a small scale study area, where road surface characteristics and traffic density are relatively uniform, the best approach would be to combine both techniques. The I_v index would place the results in a western-states perspective and the I_s index would allow increased precision for index estimates related to the specific objectives of the study.

F. Seasonal Index Values in Terms of Relative Coyote Numbers and Relative Coyote Activity

Indices to relative abundance avoid some of the quantitative complications inherent in density estimates such as population mobility or difficulties in specifying the size of the area sampled. Indices are not, however, problem free. To properly evaluate the information derived from an indexing technique, it is necessary to relate population parameters to index values in meaningful terms. Modeling relevant population parameters can assist in identifying the relationship between index and population size.

A coyote must travel to and place a paw within a scent station to be scored. The average probability that a coyote will encounter a scent station should vary proportionately with the average distance traveled per 24 hours per coyote during the period of time an index line is in operation. The least complex hypothesis is that the index values obtained are a function of population size and activity, as the latter influences the probability that a coyote will encounter a scent station and score. As previously shown in Table 7, the probability of scoring once a scent station is encountered is not 1.0; but since this probability did not change significantly across the time frame of this study, it can be considered a constant term and dropped.

The population size of interest I call the effective population. This effective population is composed of those coyotes potentially capable of individually scoring at a scent station. Viewed in this manner, pups in the den are not members of the effective population and only one member of a group of coyotes traveling together is a member of the effective population. This approach is necessary because the number of individuals that may have contributed marks at each scent station is not recorded on a standard line.

I have synthesized coyote population models from the literature (Knowlton 1972, Gier 1968), adjusted these for the Oregon breeding season (Hamlett 1938) and constructed an annual curve of relative total population size (Figure 5, dashed line). The effective population curve (Figure 5, solid line) was derived by subtracting pups in the den, the effect of coyotes traveling in family groups after whelping and a minimal estimate of group travel throughout the year from the total population curve.

Seasonal estimates of relative activity are necessary to continue the model development. Robinson and Cummings (1951), Robinson and Grand (1958) and Hawthorne (1971) all noted increased coyote movement in the fall and winter periods compared to the remaining seasons. Knowlton (1972) noted that in Texas the fall and winter periods encompass litter break-up and dispersal of the young, breeding activities and the first half of gestation. He cited evidence suggesting that coyotes became more active in their home ranges in September and October and that infiltration into new areas became important in November, increased through January and then decreased through March. Based on the above mentioned sources, I constructed a hypothetical relative coyote activity curve (Figure 5, broken line) which reflects a conservative increase in winter activity compared

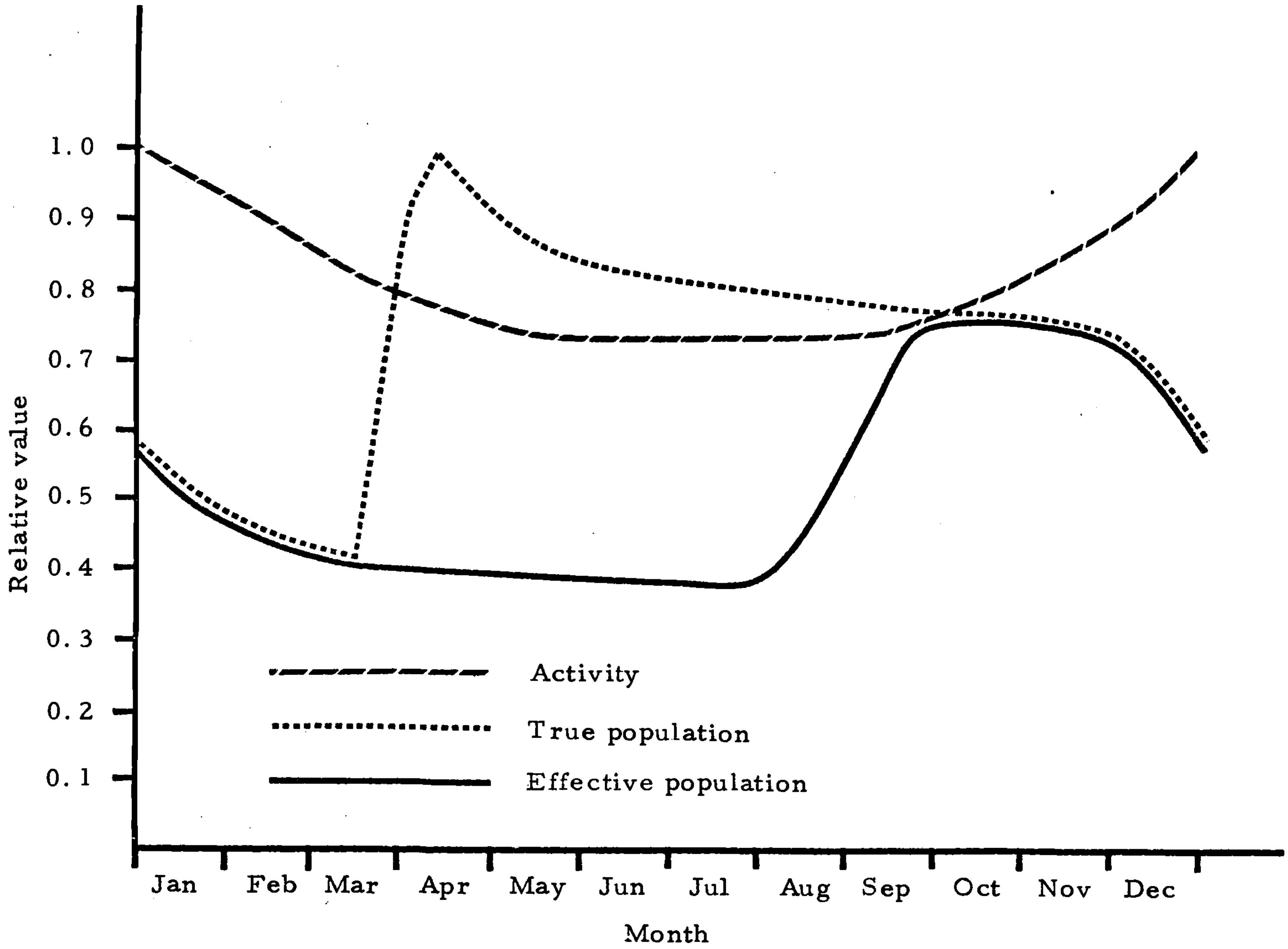

Figure 5. Hypothesized relative coyote population size and relative coyote activity through time.

to the remaining seasons.

After rescaling the effective population curve to a maximum value of 1.0, I multiplied monthly relative activity and relative effective population size values to yield monthly hypothetical index values. The resultant curve (Figure 6) was also rescaled to a maximum value of 1.0 making proportional changes were more readily visible.

This model suggests a marked departure of the hypothesized curve for the scent station index (Figure 6) from the expected total population curve (Figure 5, dashed line). Thus both the activity that influences the probability of a coyote encountering a scent station and the concept of an effective population size exert marked effects on the index obtained and have significant implications in interpreting the seasonal index values. If this relationship between effective population size, activity and index exists it should be evidenced in the seasonal index values obtained in this study.

Table 8 gives each individual coyote index by period and, in Figure 6, the relative (highest value set to 1.0) value of each coyote index is superimposed on the hypothesized relative index curve. Since the percent scoring is considered constant and the model is constructed in relative terms it is equally applicable to each coyote index. There is reasonably good agreement between the hypothesized relative index values and the observed relative index values from May

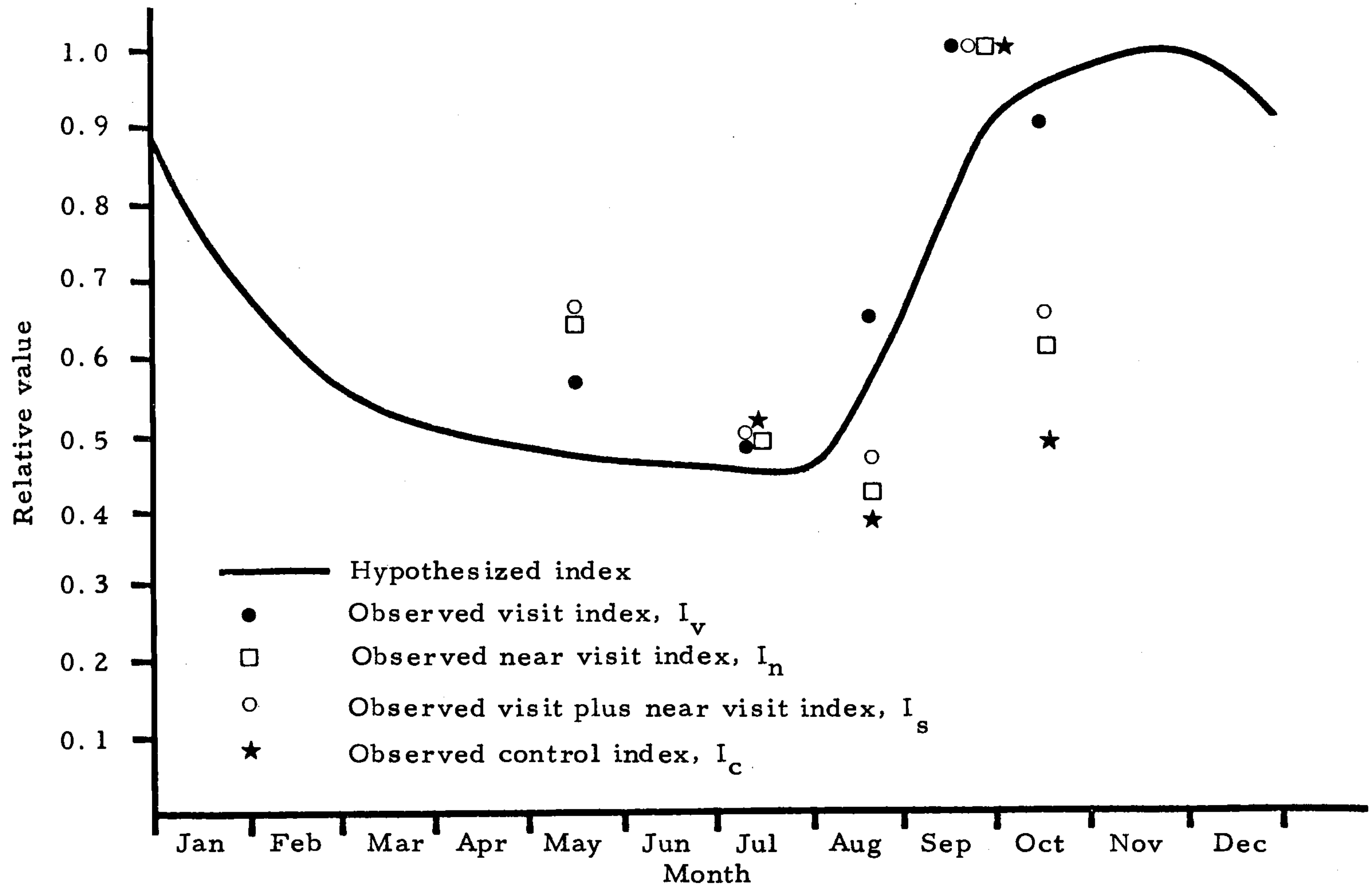

Figure 6. Hypothesized and observed relative index values through time.

Table 8. Mean indices and mean percent scoring by period; all lines combined.

Period	Mean Value					
	I_v [1]	I_n	I_s	I_m	Percent Scoring	I_c
A [2]	0.025 d [4]	0.092 d	0.122 d	[3]	26.6	[3]
B	0.021 D	0.070 D	0.091 D	0.608 d. C. E	26.3	0.100 D
C	0.028 d	0.057 D	0.085 D	0.397 B	36.7	0.074 D
D	0.043 a, B, c	0.139 a, B, C, e	0.181 a, B, C	0.448 b	25.4	0.199 B, C, E
E	0.038	0.083 d	0.121	0.316 B	28.9	0.091 D

1/ See text for index definitions.

2/ See Table 1 for period definitions.

3/ Index not run in this period.

4/ Letters refer to periods from which a period is statistically different; lower case letters indicate significance at the 0.95 significance level, upper case letters indicate significance at the 0.99 level.

through September (periods A-D). There were no significant differences between the mean monthly indices for May through August (periods A-C) for I_v, I_n, I_s or I_c. The index for September (period D) was significantly ($P < 0.05$) higher than the mean of May-August (periods A-C) for each of these indices. Additionally, the percent change for the mean index of May-August (periods A-C) to the mean index of September (period D) was 73.3 percent for I_v, 90.4 percent for I_n, 77.5 percent for I_s and 128.7 percent for I_c. These percentage changes are well within the neighborhood of the 90-100 percent change predicted by the model (Figure 6).

Since all the indices decrease from September to October (period D to period E) (Figures 6 and 7), significantly so for I_c ($P < 0.01$) and I_n ($P < 0.05$), the model inadequately explains the September to October trend. The prediction was that the index would continue to increase through this period.

A decrease in activity in October that would reduce the index is not consistent with the bulk of the literature available (Knowlton 1972, Robinson and Cummings 1951, Robinson and Grand 1958, Hawthorne 1971). Dispersal would not be expected to become important until November and then it is apparently related to density, being most pronounced in areas of high density (Knowlton 1972). If there are differences in the timing of dispersal in Oregon compared to Knowlton's (1972) evidence from Texas, dispersal still does not seem to be a

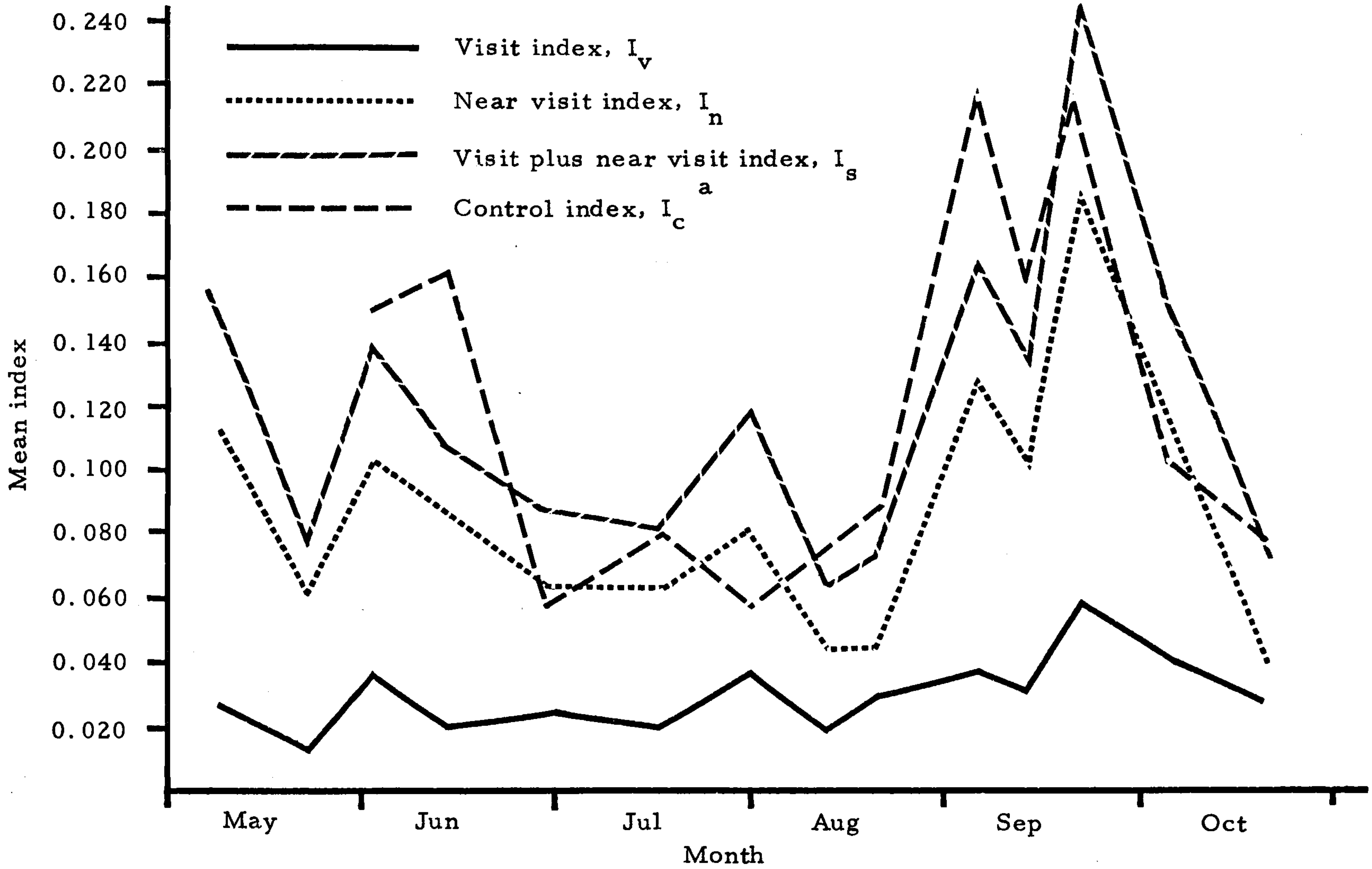

Figure 7. Mean of paired index lines through time. [a]Single line only for I_c.

reasonable explanation for the October decrease as my indices were quite low to begin with. Mortality in the relatively favorable period of October does not seem to be a plausible cause for the decrease in index from September to October either.

The October decrease in index may have been influenced by coyote behavior modification related to an amazing influx of hunters into the area as deer season opened on 5 October 1974. A large portion of these hunters drove the roads while hunting and as a result I saw vehicles on my survey routes in areas where I had never seen them before. I am sure that some coyotes were incidentally killed by these hunters, but I doubt that enough were killed to account for a 33 percent (I_s) to 56 percent (I_c) reduction in the indices. The sudden disturbance in the area and possible harrassment of coyotes by hunters could have caused coyotes to avoid the roads. Local residents of the area (Omar Moffitt personal communication) who make most of their coyote observations from roads note that coyotes are rarely seen for up to 6 weeks after deer season opens. They note a dramatic drop in sightings concurrent with the opening of deer season.

I have previously demonstrated (see behavioral aspects section) that coyote behavior is an important component of between line variation in the scent station index. If unusual seasonal usage of an area modifies coyote behavior in relation to the indexing technique then this phenomenon must be taken into account to properly explain temporal variation in indices. Although I feel the model of relative index values (Figure 6) is reasonable in a general sense, coyotes are extremely adaptable animals and models of their population processes must, in many cases, be area, time and condition specific.

G. Seasonal Capabilities of the Index as a Research Tool

In areas with temperature and precipitation regimes similar to those for this study area a researcher should not count on using any of the indices described in this paper from October through May as freezing and spring thaws hinder track reading during this period.

In terms of the normal 5-day sampling scheme there is no consistent evidence that the variance of one survey line changes markedly during the May-October period. Thus the September sampling period used throughout the Western states by the U.S. Fish and Wildlife Service is no more variable than any other period studied.

For I_v, between line variation accounts for more of the total variation than does between period variation (Table 4). Thus when attempting to estimate the index for an area more precision is gained by increasing the number of lines sampled than by increasing the number of repetitions for a line. There was no evidence that between-line variation was significantly greater in any period than another however.

The percent of coyotes that visited a scent station once they were on the road surface in the 60-foot long near visit stations varied significantly across lines but there were no significant differences in the percent scoring between the time periods of this study. The between-line variation in percent scoring is an important factor in determining I_v differences between lines and a measure of the percent scoring is essential to the proper interpretation of specific between-line differences for the scent station index. Increased knowledge of how the percent scoring varies across quite different habitats and across a broad range of index values will facilitate area to area comparisons. Knowledge of the year to year variation in percent scoring for a given line will facilitate year to year comparisons.

Since all coyote indices (I_v, I_n, I_s and I_c) follow the same general pattern from May through October (Figure 7), the scent stations do not appear to exert any seasonally differential effect on the indices obtained. The I_v indices were lower than any other coyote index across the periods studied but this was primarily related to the low percent scoring effect.

From May through mid-August the indices may only index an effective population equivalent to the adult segment of the total population minus the effects of group travel. After litter break-up, which presumably occurs during late August and early September, each individual in the total population should have the highest probability of being a member of the effective population. The August to September increase in indices may, however, be biased upward by increasing activity in early fall. The exact magnitude of this effect, if it exists, cannot be specified until more definitive information on seasonal relative coyote activity is obtained.

The marked fluctuations in the index values from August through October emphasize the fact that successive yearly samplings of an index line must be conducted on as near the same dates as practical considerations permit if yearly fluctuations in index are to be properly identified. Simiarly, emphasis should be placed on the reduction of within-year and between-year variation in sampling dates throughout the Western states. The August to September increases in index values further suggest that this is a poor period for using the index to measure the success of a control program conducted in early fall. The expected doubling of index values during this period would confound interpretations of control effectiveness.

Because coyote behavior is an important component of the indices any unusual seasonal human activity of large magnitude may alter coyote behavior and the relative indices.

H. Summary

The scent station technique for indexing relative coyote population levels is a relatively simple procedure which lends itself to employment over a wide geographical area. From May through October weather conditions, other than wind and rain as discussed by Hodges (1975), have little effect on the indices obtained. In other seasons freezing conditions impair track readability. The variability of the index remains relatively constant from May through October and no marked reduction in variance can be achieved by sampling in one season as opposed to another.

Since 25.8 percent of the recorded coyote tracks occurred in the scent stations, which comprised only 0.7 percent of the total area examined in this study, it is obvious that the scent stations are effective in drawing coyotes to the standardized scoring area. There was no evidence that the attractiveness of the scent stations declined through a period as long as 10 days.

Multiple station visitation by single coyotes is of relatively minor importance occurring only 5 percent to 10 percent of the time. As yet unexplained is an approximately 11 percent (Hodges 1975) higher index on the fifth day of operation and a 5 percent lower index for stations on the left side of the road.

The scent station technique does not appear to index the total coyote population from May through October, but rather indexes an effective population composed of individuals potentially capable of individually scoring at a scent station. The effective population is estimated by subtracting pups in the den and the effects of group travel from the total coyote population. After litter break-up, which presumably occurs from late August through early September, each member of the total population should have the highest probability of being a member of the effective population.

Coyote behavior is an important component of the index obtained. The percent of coyotes which scored at a scent station, once they were on the road surface within 30 feet of a scent post, varied widely between lines but did not change significantly with season. The between-line variation in percent scoring may be related to the relative levels of human activity associated with each line. A marked decrease in the October index, concurrent with increased human activity associated with the opening of deer season, suggests that marked changes in human activity on or near a scent station line may alter the indices obtained.

There was an approximate doubling of the index values in September compared to August. This was presumably caused by an increase in the effective population concurrent with pup independence and an as yet unquantified increase in relative coyote activity in the fall.

Significant between-line variation in the indices obtained from a relatively small and relatively uniform area suggests that the scent station technique is quite sensitive to variations in density, local activity patterns or a combination of these two factors. Sources of between-line variation in indices are difficult to identify and the most productive approach may be to consider populations of scent station survey lines and realize that individual lines may deviate markedly from the average.

The potential usefulness of the scent station technique is limited by the degree to which the sources of variation in the indices obtained can be identified and quantified. Further research to: 1) quantify the changes in relative coyote activity throughout the year, 2) determine if the percent scoring remains relatively constant from year to year for a line, and 3) quantify the relationship between human activity levels and the percent scoring will enhance the precision with which the data from the scent station technique can be employed. Until these data are available much can be done to improve the year to year comparability of the indices by reducing year to year variation in the sampling dates from each line, reducing variation in sampling dates for all lines within each year and, if possible, keying fall sampling dates for an area to the relevant whelping peaks and subsequent pup independence.

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APPENDIX

A. Introduction to Appendix

The appendix presents the data base for the major portion of the analyses of this study in the form of self-explanatory tables of mean five-day indices by line and period. Also included is a partial listing of mammals whose known ranges overlap the study area. In addition, a section on the analysis of visit index, I_v, data in relation to weather variables and phase of the moon is included as these analyses were not essential to the main body of the paper.

Table A. Visit index, I_v, five-day mean indices by line and period.

Period	Line 1	2	3	4	5	6
A						
Mean	0.038	0.016	0.013	0.014	0.042	0.029
Standard error	0.016	0.008	0.009	0.012	0.013	0.020
B						
Mean	0.022	0.017	0.035	0.012	0.026	0.013
Standard error	0.012	0.012	0.019	0.008	0.011	0.009
C						
Mean	0.048	0.025	0.033	0.004	0.026	0.033
Standard error	0.026	0.012	0.011	0.004	0.012	0.017
D						
Mean	0.053	0.020	0.048	0.016	0.079	0.039
Standard error	0.018	0.015	0.019	0.008	0.029	0.013
E						
Mean	0.068	0.016	0.040	0.016	0.052[a]	0.038[a]
Standard error	0.024	0.008	0.017	0.010	-	-

[a]Estimated value.

Table B. Near visit index, I_n, five-day mean indices by line and period.

Period	Line 1	2	3	4	5	6
A						
Mean	0.135	0.088	0.023	0.101	0.137	0.067
Standard error	0.060	0.025	0.017	0.018	0.030	0.015
B						
Mean	0.071	0.100	0.017	0.109	0.070	0.055
Standard error	0.013	0.015	0.004	0.016	0.017	0.027
C						
Mean	0.092	0.070	0.012	0.077	0.054	0.035
Standard error	0.010	0.023	0.005	0.020	0.022	0.014
D						
Mean	0.167	0.088	0.044	0.161	0.253	0.118
Standard error	0.026	0.024	0.026	0.026	0.068	0.032
E						
Mean	0.189	0.034	0.048	0.041	0.122[a]	0.062[a]
Standard error	0.046	0.017	0.016	0.011	-	-

[a]Estimated value.

Table C. Visit plus near visit index, I_s, five-day mean indices by line and period.

Period	Line 1	2	3	4	5	6
A						
Mean	0.191	0 109	0.040	0 116	0.174	0.103
Standard error	0.077	0.031	0.020	0.031	0.045	0.034
B						
Mean	0.093	0.117	0.052	0.121	0.096	0.068
Standard error	0.022	0.020	0.021	0.023	0.014	0.029
C						
Mean	0.140	0.095	0.046	0.081	0.080	0.068
Standard error	0.035	0.025	0.012	0.021	0.015	0.026
D						
Mean	0.220	0.108	0.092	0.177	0.332	0.157
Standard error	0.018	0.031	0.031	0.022	0.071	0.044
E						
Mean	0.257	0.050	0.088	0.057	0.171[a]	0.100[a]
Standard error	0.052	0.020	0.030	0.020	-	-

[a]Estimated value.

Table D. Control index, I_c, five-day mean index by replication and period.

Period	Replication 1	2	3
A			
Mean	0.150	-	-
Standard error	0.030		
B			
Mean	0.161	0.058	0.080
Standard error	0.036	0.021	0.024
C			
Mean	0.057	0.076	0.088
Standard error	0.018	0.025	0.044
D			
Mean	0.220	0.160	0.216
Standard error	0.042	0.051	0.028
E			
Mean	0.104	0.077	-
Standard error	0.035	0.035	-

Table E. Small mammal index, I_m, five-day mean index by line and period.

Period[a]	Line 1	2	3	4	5	6
B						
Mean	0.439	0.306	0.754	0.778	0.702	0.668
Standard error	0.054	0.052	0.029	0.044	0.034	0.025
C						
Mean	0.168	0.172	0.616	0.467	0.514	0.447
Standard error	0.029	0.050	0.032	0.021	0.055	0.069
D						
Mean	0.335	0.277	0.583	0.459	0.483	0.550
Standard error	0.027	0.030	0.035	0.050	0.024	0.057
E						
Mean	0.289	0.234	0.441	0.149	0.403[b]	0.391[b]
Standard error	0.028	0.035	0.030	0.048	-	-

[a]Index not run in period A.

[b]Estimated value.

Table F. Percent of coyotes scoring by line and period.

Period	Line 1	2	3	4	5	6
A	32.1	18.8	42.9	13.0	21.2	31.8
B	26.8	11.6	60.0	12.7	30.6	15.8
C	34.3	25.0	72.7	5.0	33.3	50.0
D	24.1	18.5	52.2	9.1	25.0	23.7
E	28.2	20.9	41.9	24.4	27.7[a]	30.5[a]

[a]Estimated value.

Table G. List of mammals whose known ranges overlapped the Central Oregon study area. [a]

Order Insectivora	
Family Scoricidae	
Sorex merriami	Merriam's shrew
Sorex vagrans	vagrant shrew
Order Lagomorpha	
Family Leporidae	
Sylvilagus idahoensis	pigmy rabbit
Sylvilagus nuttallii	mountain cottontail
Lepus californicus	black-tailed jackrabbit
Lepus townsendii	white-tailed jackrabbit
Order Rodentia	
Family Erethizontidae	
Erethizon dorsatum	porcupine
Family Sciuridae	
Marmota flaviventris	yellow-bellied marmot
Eutamias minimus	least chipmunk
Eutamias amoenus	yellow-pine chipmunk
Tamiasciurus douglasii	chickaree
Spermophilus lateralis	golden-mantled ground squirrel
Spermophilus townsendii	Townsend's ground squirrel
Spermophilus beldingi	Belding's ground squirrel
Family Geomyidae	
Thomomys talpoides	northern pocket gopher
Family Heteromyidae	
Dipodomys ordii	Ord's kangaroo rat
Perognathus parvus	Great Basin pocket mouse
Family Cricetidae	
Reithrodontomys megalotis	western harvest mouse
Onychomys leucogaster	northern grasshopper mouse
Neotoma cinerea	bushy-tailed wood rat
Peromyscus crinitus	canyon mouse
Peromyscus maniculatus	deer mouse
Peromyscus truei	piñon mouse
Lagurus curtatus	sagebrush vole
Microtus longicaudus	long-tailed vole
Microtus montanus	montane vole

Table G. Continued.

Family Zapodidae	
Zapus princeps	western jumping mouse
Order Carnivora	
Family Felidae	
Lynx rufus	bobcat
Family Canidae	
Canis latrans	coyote
Family Procyonidae	
Procyon lotor	raccoon
Family Mustelidae	
Mephitis mephitis	striped skunk
Spilogale putorius	spotted skunk
Taxidea taxus	badger
Mustela vison	mink
Mustela erminea	short-tailed weasel
Mustela frenata	long-tailed weasel
Order Artiodactyla	
Family Antilocapridae	
Antilocapra americana	pronghorn
Family Cervidae	
Odocoileus hemionus	mule deer

[a]Order Chiroptera not included in this listing; distributions obtained from Verts (1971).

B. Visit Index, I_V, Values in Relation to Weather and Phase of the Moon

Methods

Daily weather values recorded during this study were: 1) cloud cover; 2) temperature - high, low and mean; 3) relative humidity - high, low, and direction and magnitude of change; 5) wind speed; and 6) precipitation.

Clous cover classes were: 1) clear, less than 0.1 sky cover; 2) scattered, 0.1-0.6 sky cover ; 3) broken, 0.6-0.9 sky cover; and 4) overcast, greater than 0.9 sky cover.

Wind speed classes were: 1) none, 0-2 knots; 2) light, 2-10 knots; 3) moderate, 10-20 knots; 4) strong, greater than 20 knots; and 5) gusty, greater than 20 knots and gusting higher.

Precipitation classes were: 1) none, 2) rain, 3) snow, 4) fog, and 5) frost.

Temperature and relative humidity were measured on a recording hygrothermograph, and means were the averages of readings taken at two hour intervals. Barometric pressure records were obtained from the Redmond Flight Service Station located approximately 45 miles northwest of the study area. The class of weather variable recorded for cloud cover, wind speed and precipitation for each day was my best estimate of the prevailing condition during the preceding 24 hours.

The calendar dates of phases of the moon were designated the mid-points of the analyzed phases as I felt this made the phases more meaningful in terms of illumination. The data for all lines and periods were combined for the moon phase analyses. I made no adjustments for cloud cover in the analyses as each phase had a small (range of 1-5) number of days with overcast skies.

Results

Figure A gives a plot of three day running mean I_v indices in relation to phase of the moon. I see nothing in this plot that suggests significantly higher I_v indices under any phase of the moon. In addition, a one-way analysis of variance failed to show significant differences between the mean indices observed under each phase of the moon. These results are consistent with those of Hodges (1975).

Wind, precipitation and cloud cover were relatively uniform throughout this study; a typical day was clear with light wind and no precipitation. There were very few days when the weather changed from one condition to another; when this did happen the index changed to or from a zero value. Consequently, the median percent change in the index for a line when the weather changed from one condition to another on successive days could not be calculated or compared directly with Hodges' (1975) results. I did test for differences between mean indices obtained under the different classes of each

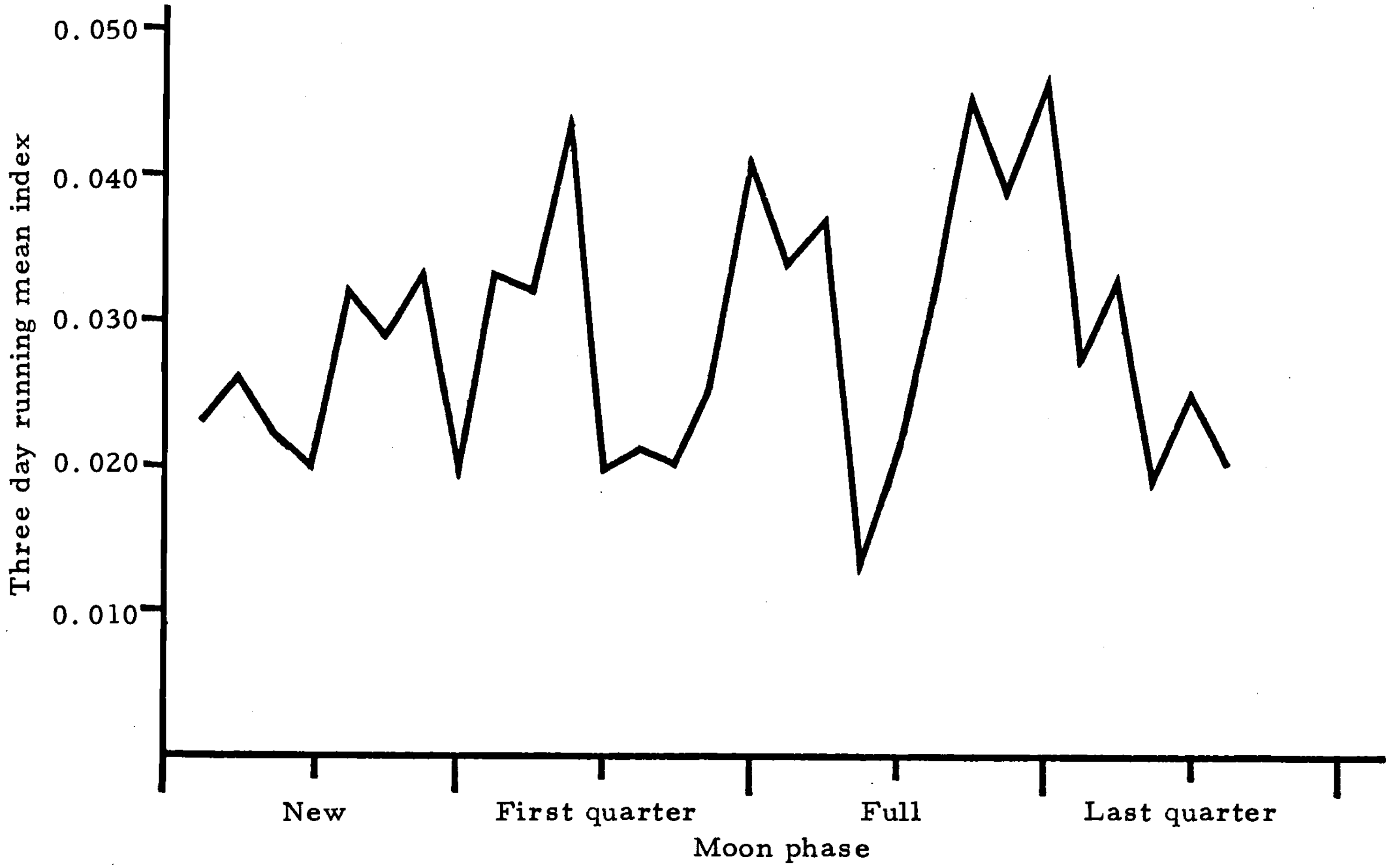

Figure A. Mean visit index, I_v, by day of moon phase.

weather factor and found that a moderate wind gave significantly ($P < 0.05$) lower indices ($d = 0.011 \pm 0.0049$) than a light wind; or, a 32.35 (± 14.41) percent decrease in mean index.

I had finer resolution of temperature data than Hodges (1975) and additionally collected relative humidity and barometric pressure data. For each factor, combining all lines and all periods, I conducted a linear regression of I_v index value on daily weather variable value. This procedure does not account for interaction among the weather variables or permit the detection of seasonal effects. The only significant correlation between weather variable and index at the 0.95 confidence level was for low relative humidity and index. Even then the variation in low relative humidity only accounted for 4 percent ($r^2 = 0.038$) of the variation in daily index (Table G). High and mean relative humidity were significant at the 0.90 level (Table G), but the relative humidity measures were significantly ($P < 0.05$) correlated among themselves. Very little of the variation in daily indices can be attributed to variation in weather variables other than precipitation and wind as described by Hodges (1975).

Table H. Correlation coefficients between daily I_V index and weather factor; all lines and all periods combined.

Weather Factor	Sample Size (days)	Correlation Coefficient	F Statistic
Increasing cloud cover	198	-0.0700	0.966
Increasing wind speed	198	-0.1264@	3.184@
High temperature	198	0.0652	0.836
Low temperature	198	-0.0642	0.812
Mean temperature	198	-0.0363	0.259
High barometric pressure	198	0.0603	0.714
Low barometric pressure	198	0.0698	0.935
Change in barometric pressure	198	0.0091	0.016
High relative humidity	98	-0.1733@	2.973@
Low relative humidity	98	-0.1963*	3.846*
Mean relative humidity	98	-0.1936@	3.739@

@ Statistically significant at the 0.90 level.

* Statistically significant at the 0.95 level.

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