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Title: THE DEVELOPMENT AND EVALUATION OF AN AUDIO-INDEX TECHNIQUE FOR THE BAND-TAILED PIGEON

Abstract approved: Redacted for privacy
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A study of the calling activity of the band-tailed pigeon (Columba fasciata Say) was made between June, 1967, and June, 1969, in westcentral Oregon.[1] The objective of this research was to determine if an audio-index technique could be developed to detect fluctuations in populations of band-tails. Call-count routes and observations at a single location were conducted to study the calling by free-living pigeons.

The variability of the call was noted and the calling rate was studied. The rate of calling by band-tails increased as the number calling increased.

Calling activity by pigeons, along a call-count route in 1967,

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peaked in late-July. Mid-June to mid-July generally was the most favorable period in 1968 to hear pigeons call along three call-count routes.

The mean time of morning pigeons were first heard calling was 5.2 minutes prior to sunrise and 2.0 minutes after sunrise, 1967 and 1968, respectively. The time of morning that band-tails began to call was closely associated with the time of local sunrise in both years.

Approximately 64% of the calls heard on all-day point observations in 1967 occurred between 1/2 hour prior to sunrise and 1 1/2 hours after sunrise. Morning point observations in 1968 also demonstrated that calling was most frequent in the early-morning. Within the early-morning, the 1/2 hour beginning at the time of local sunrise was the period of greatest calling activity. Practically all afternoon calling was heard during the 4 hours prior to sunset, with more than three-fourths of the calls during this time occurring between 3 1/2 and 1 1/2 hours prior to sunset.

The influence of several weather factors on the calling of pigeons was studied. There was a definite relationship between a threshold of light intensity and the time of morning that pigeons began to call. These commencement times were modified slightly by the extent of cloud cover. A wind velocity greater than 7 miles per hour greatly reduced my ability to hear a pigeon call, because of noise produced in the tree-tops.

The suitability of summer habitat for band-tails was believed to be associated with the density and composition of the forest type.

An audio-index technique has been developed, and procedures for conducting call-counts are recommended. Estimates of route sample sizes are presented for the detection of various magnitudes of population fluctuations. A calibration technique, for the adjustment of call-count data for the influence of time-effect, is proposed.

The Development and Evaluation of an Audio-Index Technique for the Band-Tailed Pigeon

by

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THE DEVELOPMENT AND EVALUATION OF AN AUDIO-INDEX TECHNIQUE FOR THE BAND-TAILED PIGEON

I. INTRODUCTION

This Study

The purpose of this paper is to report on the development and evaluation of an audio-index technique for detecting fluctuations of populations of the band-tailed pigeon (Columba fasciata Say).

A knowledge of the status of a population of a species is essential for the proper management of that species. A census of a population was stated by Leopold (1933) to be the first step in the practice of game management.

In Washington, Oregon, and California the annual kill of band-tails is approximately one-half million (Sisson, 1968). This kill occurs without any concurrent knowledge of the extent of its impact upon the stability of band-tail populations. I believe this is sufficient reason for developing an effective method for detecting changes in the size of pigeon populations.

Concern for the welfare of pigeon populations was expressed by Chambers (1913), and several investigators since have discussed ways of censusing the populations of pigeons. Neff and Culbreath (1947) stated that an accurate census of the band-tail in Colorado was impossible due to the rugged terrain. These authors suggested two possible approaches for censusing the band-tail: (1) an extensive corps of observers to record pigeons when and wherever seen, and (2) an intensive study of late-summer concentrations at known feeding areas. Post-breeding season surveys to determine annual production were recommended by Glover (1953). The Oregon State Game Commission (Oregon, 1967) presently uses late-summer counts of pigeons at concentration-sites in an attempt to measure yearly population changes. Sisson (1968) stated that the results of his study, primarily with penned birds, indicated that call-counts had potential value for censusing pigeons during the breeding season.

The three general objectives of this study were as follows:

1. To measure the variation in the number of calls heard, and the number of pigeons calling on a census route that sampled a wild breeding population of band-tailed pigeons.
2. To determine the capability of the audio-index technique to detect population changes.
3. To relate forest successional stages and regrowth to breeding population densities.

It must be stressed that this study was aimed at an intensive investigation of the basic calling behavior of free-living band-tailed pigeons. This was necessary for an effective evaluation of an audio-index technique.

The Audio-Index Technique

In 1927, Cooke, as quoted by Kendeigh (1944: 89-90), stated, "a convenient way of taking a bird census is to count the singing males very early in the morning." This method would be termed a "census index" (Overton, 1969) as it is "a count or ratio which is relative in some sense to the total number of animals in a specified population." Generally, the objective of enumerating the singing activity of male birds has been to estimate relative levels of the breeding populations of various species and their yearly fluctuations.

Stoddard (1931), in reference to bobwhite quail (*Colinus virginianus*), was the first to propose the use of counts of singing male birds as a game management technique. Stoddard (1931: 339) stated, "the number of persistently whistling cock quail in early summer furnishes a key to the breeding population. . . ." McClure (1939) suggested the use of audio counts of singing male mourning doves (*Zenaidura macroura*) as a census method. McClure stated that there was a direct relation between the number of doves in an area and the number (of males) cooing, making it possible to determine the population on the basis of counting the cooing birds.

Those factors which have a major influence on the number of calls heard by an observer at a particular location were listed by Heath (1961) in a theoretical analysis of the audio-index. These factors are as follows: (1) The density of individuals (i. e., males) within the observer's hearing range and that are capable of sound production; (2) The average number of sounds produced per capable individual within the hearing range of the observer during the counting interval; (3) The observer's maximum hearing distance (transformed into area) under optimum listening conditions for the type of sound being produced; (4) the efficiency of the observer, determined by the extent of modification of his optimal hearing ability - a function of external factors (wind, traffic noise, etc.) and physiological factors (observer alertness, etc.).

To relate the numbers of calls heard to the level of the population (at least of males) the procedure has been to schedule the listening observations on a call-count route at a time of day and season when calling frequency is optimal, and when environmental conditions and observer efficiency the most favorable. In this manner, the number of calls heard should theoretically be proportional to the size of the population, assuming that a relatively constant proportion of the total population of males call, and that the average frequency of calling is reasonably independent of population density.

The audio-index technique, using the number of birds heard or the number of calls heard as an index, is extensively used to detect fluctuations of populations of five major game birds. The following investigators have provided major contributions to the initial development and the later refinement of this technique: the mourning dove coo-count (McClure, 1939; Duvall and Robbins, 1952; Kerley, 1952, Peters, 1952, Wagner, 1952; McGowan, 1953; Foote, Peters and Finkner, 1958; and Cohen, Peters and Foote, 1960); the ring-necked pheasant (*Phasianus colchicus*) crowing-count (Kimball, 1949; Kozicky, 1952; and Gates, 1966); the ruffed grouse (*Bonasa umbellus*) drumming-count (Petraborg, Wellein and Gunvalson, 1953; Dorney *et al.*, 1958; and Gullion, 1966); the woodcock (*Philohela minor*) singing ground count (Mendall and Aldous, 1943; Sheldon, 1953; Kozicky, Bancroft and Horneyer, 1954; Goudy, 1960; and Duke, 1966); and the bobwhite quail whistling-count (Stoddard, 1931; Bennitt, 1951; Rosene, 1957; Norton *et al.*, 1961; and Kabat and Thompson, 1963).

II. METHODS OF STUDY

Two general types of field observations, call-count routes and point observations, were used in this study. A summary of the field observations, specifying location, sample size, time of year, and time of day is presented in Table 1.

Call-Count Routes

To determine the extent of influence of those factors affecting the numbers of pigeons heard and calls heard on a census route, a single route - in the McDonald State Forest, Benton County, Oregon - was intensively studied in 1967. This area was chosen because it was known to be a band-tail breeding area, probably typical of that in western Oregon, and it was easily accessible.

It was anticipated that two factors were especially important in affecting the calling by pigeons, and their study was emphasized: (1) Time-effect, which is the influence of the time of day on the calling of pigeons; and (2) Station-effect, which is the influence of the "quality" of the station-location upon the number of pigeons calling - a result of the suitability of the habitat at that location for pigeons, and thus the number of pigeons present.

A unique route design in the McDonald Forest in 1967 permitted the study of time-effect and station-effect. A 5-mile route consisting

Table 1. A summary of location, sample size, time of year, and time of day of types of field observations used in this study.

Types of Observation	Year of Observation 1967	1968
Morning Call Count Routes		
Location and Number	McDonald Forest, 63 call-counts which produced 6 successive 10-count series	McDonald Forest, 19; Marys Peak, 16; Burnt Woods, 12; Cougar Ridge, 6; Blodgett, 6; Dawson, 6.
Time of Year	June 7 - August 17	May 14 - August 17
Time of Day	1/2 hour before sunrise to 1-1/2 hours after sunrise	18 minutes before sunrise to 102 minutes after sunrise
Afternoon Call-Counts		
Location and Number	Old Peak, 13; Burnt Woods, 3	*
Time of Year	July 16 - August 12	
Time of Day	3 to 1-1/2 hours before sunset	
All-Day Point Observations		
Location and Number	McDonald Forest, 3	*
Time of Year	July 17 - August 15	
Time of Day	1/2 hour before sunrise to sunset	
Morning Point Observations		
Location and Number	*	McDonald Forest, 29; Burnt Woods, 10
Time of Year		April 24 - August 18
Time of Day		1/2 hour before sunrise to 1-1/2 or 3 hours after sunrise
Afternoon Point Observations		
Location and Number	McDonald Forest, 9; Burnt Woods, 1	McDonald Forest, 10; Burnt Woods, 8
Time of Year	June 16 - August 13	June 14 - August 18
Time of Day	4 hours before sunset to sunset	4 hours before sunset to sunset

*These observations were not conducted in that respective year.

of ten stations 1/2 mile apart was established. The route was conducted in an "over-and-back" procedure, producing 20 listening intervals. On each successive observation the starting point was advanced six stations. In this manner, each station was sampled twice in a morning; and over a 10-day period each station was sampled once at each time interval. Thus, station-effect influences were assumed to be uniform at each time interval on the route, permitting the detection of time-effect on calling activity. Similarly, over the 10-day period the time-effect influences were assumed to be uniform in the total number of pigeons heard at each station, permitting the detection of station-effect on the number of pigeons heard. Numbers of pigeons heard and calls heard were directly comparable for each series of ten successive call-counts, but were not comparable between the individual call-counts within the series because each was started at a different station.

In 1968, routes were conducted in six areas (Appendix 1), selected on accessible roads through habitat that appeared favorable for band-tails. All routes were 10 miles in length (the 1967 McDonald Forest route was extended 5 miles) and consisted of 20 stations. All call-counts began at station no. 1 and proceeded through station no. 20, with each station sampled once in a morning. Therefore, numbers of pigeons heard and calls heard on successive call-counts in 1968 were directly comparable. I conducted the call-counts on the

McDonald Forest, Burnt Woods, and Marys Peak routes, Benton and Lincoln counties, Oregon. Two additional workers conducted the call-counts on the Cougar Ridge, Dawson, and Blodgett routes, Linn and Benton counties, Oregon.

The numbers of pigeons heard and calls heard at each station were recorded. A 3-minute listening interval at each station was used both years. In 1968, the calling heard was recorded as occurring during the first 2 minutes, or as occurring during the third minute. In both years a 3-minute interval was allotted for traveling the 1/2 mile between stations.

Air temperature, cloud cover (on an ascending scale of cloudiness of 0/10 to 10/10), wind direction and velocity (using the Beaufort scale of estimation, see Appendix 3) were recorded at the start and finish of all routes. Additional notes on weather factors were recorded whenever observed to change markedly, along with the occurrence of rain and fog. Incident light intensity, measured in foot-candles, was recorded at the start and finish of each route, at the time the first pigeon was heard, and at sunrise. Light intensity was measured with a Model 8DW (in 1967) and a Type DW-68 (in 1968) General Electric exposure meter. Barometric pressure records, for the periods of study in 1967 and 1968 were obtained from the Agricultural Service Weather Bureau on the Oregon State University campus.

A hand-held anemometer was used on serval occasions in 1967 and proved to be less efficient than the Beaufort scale of wind velocity estimation. This was because the anemometer measured the velocity only several feet above the ground, which was much less than the velocity in the tree-tops - where the calling pigeons were located.

Point Observations

A point observation was a continuous listening observation, through an extended length of time, at a single location. Therefore, point observations provided an accurate evaluation of the distribution of calling by band-tails by time of day.

On all point observations the numbers of pigeons heard and calls heard were recorded at consecutive 1-minute intervals. An estimate of the number of different pigeons calling was made on each point observation on the basis of sightings, mapping of the location of the calling pigeons, and peculiarities of the pigeon's call. Air temperature, cloud cover, wind direction and velocity, and incident light intensity were recorded at the beginning and end of each point observation and at 1-hour intervals. Light intensity was also recorded when the first pigeon was heard in the morning, at sunrise, when the last pigeon was heard in the evening, and at sunset.

The time of all calling on routes and point observations was recorded and plotted by Pacific Standard Time. The time the first pigeon was heard in the morning was plotted in relation to the time of sunrise and civil twilight. Sunrise tables used in this study were those of the U. S. Naval Observatory for Eugene and Salem, Oregon. Civil twilight in the morning is that time when the center of the sun is 6^{o} below the horizon until the upper limb of the sun attains the horizon (Kimball, 1916).

Relation of Habitat to Calling Pigeons

Daily call-counts on a single route in 1967 made it impossible to adequately sample different forest types in the morning for calling band-tails. Therefore, the Old Peak and Burnt Woods areas were selected for conducting afternoon call-count routes. There was a variety of forest types along the road system of each route. An over-and-back technique was used to sample the 6-12 stations per route. A 3-minute listening interval per station was used.

A greater sampling of different forest types was possible in 1968 because call-counts were conducted in six areas. A subjective description of the vegetation type was made at all stations on each of the six routes. An increment borer was used to obtain the approximate ages of trees at selected stations.

III. RESULTS AND DISCUSSION

Characteristics of the Call

The song of the band-tailed pigeon (hereafter termed "call") has been well-described phonetically (particularly by Sisson, 1968), but its variability needs to be emphasized. In 1968, characteristics of 584 calls were recorded. There was a range of 1 to 12 audible notes per call, and a four-note call was heard most frequently. The frequency distribution is listed below.

Notes per call:	1	2	3	4	5	6	7	8	9	10	11	12
Number of calls:	5	18	48	173	134	91	61	28	14	4	6	2

The preliminary "ooh" was frequently audible under normal listening conditions, somewhat contrary to a statement by Wales (1926). A two-syllable note was characteristic, although a one-syllable note was frequently heard. Whether a single one-syllable note was heard or a series of 12 two-syllable notes was heard, each was considered to be a single call and was recorded as such.

The call was of low intensity, and was audible only a short distance even during favorable listening conditions. Even slight environmental disturbances reduced its audibility. Wind was the greatest disturbing factor to the audibility of the call. Sounds of song birds and flying insects also interfered with hearing a pigeon call.

In four instances in 1968, distances to the calling pigeon were obtained. During good listening conditions pigeons could be heard for a maximum of 300, 250, and 175 yards. During a light drizzle and a very dense fog a pigeon was heard at 225 yards. I believe the maximum distance a band-tailed pigeon call is audible is approximately 300 yards.

Calling Rates

Calling rate is defined as the average number of calls per calling pigeon per 3-minute listening interval. The rate is computed by dividing the total number of calls heard during a listening interval by the total number of pigeons calling.

The mean rates of calling, derived from all completed routes in 1967 and 1968 respectively, were 1.97 and 1.85. Although a low rate was characteristic, one pigeon was heard to call three times per minute for 3 consecutive minutes.

The highest rate of calling on call-count routes in 1967 and 1968 occurred during the 1/2 hour beginning at the time of sunrise (Table 2).

Although there was no apparent trend of calling rate through the season in 1967, the calling rate steadily increased as the time of season in 1968 progressed (Table 3).

An attempt was made to determine if the calling of one band-tail

Table 2. Mean calling rates of band-tailed pigeons on call-count routes, related to time of morning. McDonald Forest, Marys Peak, Burnt Woods, Cougar Ridge, Dawson, and Blodgett routes; Benton, Lincoln, and Linn counties, Oregon; June 12-August 17, 1967, and May 14-August 17, 1968.

Time of morning	Mean calling rate	
	1967, McDonald Forest (n=60 call-counts)	1968, all routes (n=65 call-counts)
Prior to sunrise		
1/2 hour	2.05	- -
18 min.	- -	1.59
Following sunrise		
First 1/2 hr.	2.06	2.02
Second 1/2 hr.	1.84	1.74
Third 1/2 hr.	1.72	1.74
Last 12 min.	- -	1.60
Overall	1.97	1.85

Table 3. Mean calling rates of band-tailed pigeons on call-count routes, related to time of season. McDonald Forest, Marys Peak, Burnt Woods, Cougar Ridge, Dawson, and Blodgett routes; Benton, Lincoln, and Linn counties, Oregon; June 12-August 17, 1967, and May 14-August 11, 1968.

1967, McDonald Forest (n=60 call-counts)		1968, All routes (n=65 call-counts)	
Time of season	Mean calling rate	Time of season	Mean calling rate
June 12-21	2.11	May 14-28	1.50
June 23-July 3	1.94	May 29-June 12	1.71
July 4-15	2.15	June 13-27	1.74
July 16-27	1.91	June 28-July 12	1.86
July 28-August 6	1.97	July 13-27	1.89
August 7-17	1.60	July 28-August 11	2.02
Overall	1.97	Overall	1.85

influenced the calling of other nearby pigeons. Calling rates were calculated for all call-count stations in which pigeons were heard (five pigeons was the maximum number heard at a station) (Table 4). I assumed that the calling of pigeons at one station was independent of calling at adjacent stations. This procedure provided for a greater sample size than would have been possible by using the calling heard per route, a method used with mourning doves by Duvall and Robbins (1952). There was a 27.7% increase (significant at $P < 0.05$, z distribution) and a 17.2% increase (not significant at $P < 0.10$, z distribution) in the calling rate, 1967 and 1968, respectively, when two or more pigeons were calling at a station than when a single pigeon was calling. Thus, there may have been a contagious influence present.

Table 4. Mean calling rates of band-tailed pigeons at call-count stations, related to the number of pigeons heard calling. McDonald Forest, Marys Peak, Burnt Woods, Cougar Ridge, Dawson, and Blodgett routes; Benton, Lincoln and Linn counties, Oregon; June 12-August 17, 1967, and May 14-August 17, 1968.

Number of calling pigeons per station	Number of stations (1967, 1968)	Mean calling rate	
		1967, McDonald Forest	1968, all routes
1	(274, 174)	1.66	1.74
2	(118, 42)	2.11	1.87
3	(56, 11)	2.11	2.58
4	(13, 1)	2.17	1.25
5	(3, 0)	2.22	- -
2 or more		2.12	2.04

A basic assumption for the use of an audio-index based on the number of calls heard is that the average calling rate is independent of the number of calling birds. Heath (1961) believed this assumption to be reasonable in his theoretical analysis of an audio-index. The study of Dorney et al. (1958) indicated an independent relationship for ruffed grouse. However, the studies of Kimball (1949) and Gates (1966) with ring-necked pheasants, Duke (1966) with woodcock, and Duvall and Robbins (1952) with mourning doves indicated this independent relationship was not present. Data from the present study (Table 4) demonstrated that there was an increased rate of calling as the number of pigeons calling increased, thus, not fulfilling a basic assumption for an audio-index based on the numbers of calls heard.

To further study the relation of calling rate and numbers of calls heard, linear regression analyses were made between the number of pigeons heard and the number of calls heard at the call-count stations. Coefficients of determination, r^2, were 0.706 and 0.550 for 1967 and 1968 respectively. Thus, 71% and 55% of the influence upon the number of calls heard was accounted for by the number of pigeons calling. A variable calling rate and sampling error (including all factors that may have reduced my hearing ability) would have accounted for the residual variance in the number of calls heard (29% and 45%).

Seasonal Distribution of Calling

Glover (1953) and Houston (1963) reported a late-June to early-July peak in calling of pigeons in Humboldt County, California. A June and early-July peak in the calling of pigeons at Berkeley, California, was illustrated by Peeters (1962). Sisson (1968), at Oregon State University, found no definite seasonal pattern in the calling of captive and free-living pigeons.

The greatest level of calling activity in 1967 occurred in July. The interval of July 16-27, 1967, was the period of the greatest numbers of pigeons calling and the period of the lowest coefficient of variation in the numbers of pigeons calling on successive call-counts (Figure 1, Tables 5 and 6).

In 1968, the seasonal pattern of numbers of pigeons heard and calls heard (Figure 2) was not similar to the pattern in 1967 (Figure 1). Calling was quite variable on successive observations on the same area, and between areas through the 1968 season.

Mid-June to mid-July was the best time of 1968 for hearing calling pigeons. For each of the three routes conducted through the 1968 season, the 15-day period with a high mean number of pigeons heard and a low coefficient of variation of numbers of pigeons heard on successive call-counts (Table 7) was: McDonald Forest, July 28-August 11; Marys Peak, June 13-27; and Burnt Woods, June 28-July 12.

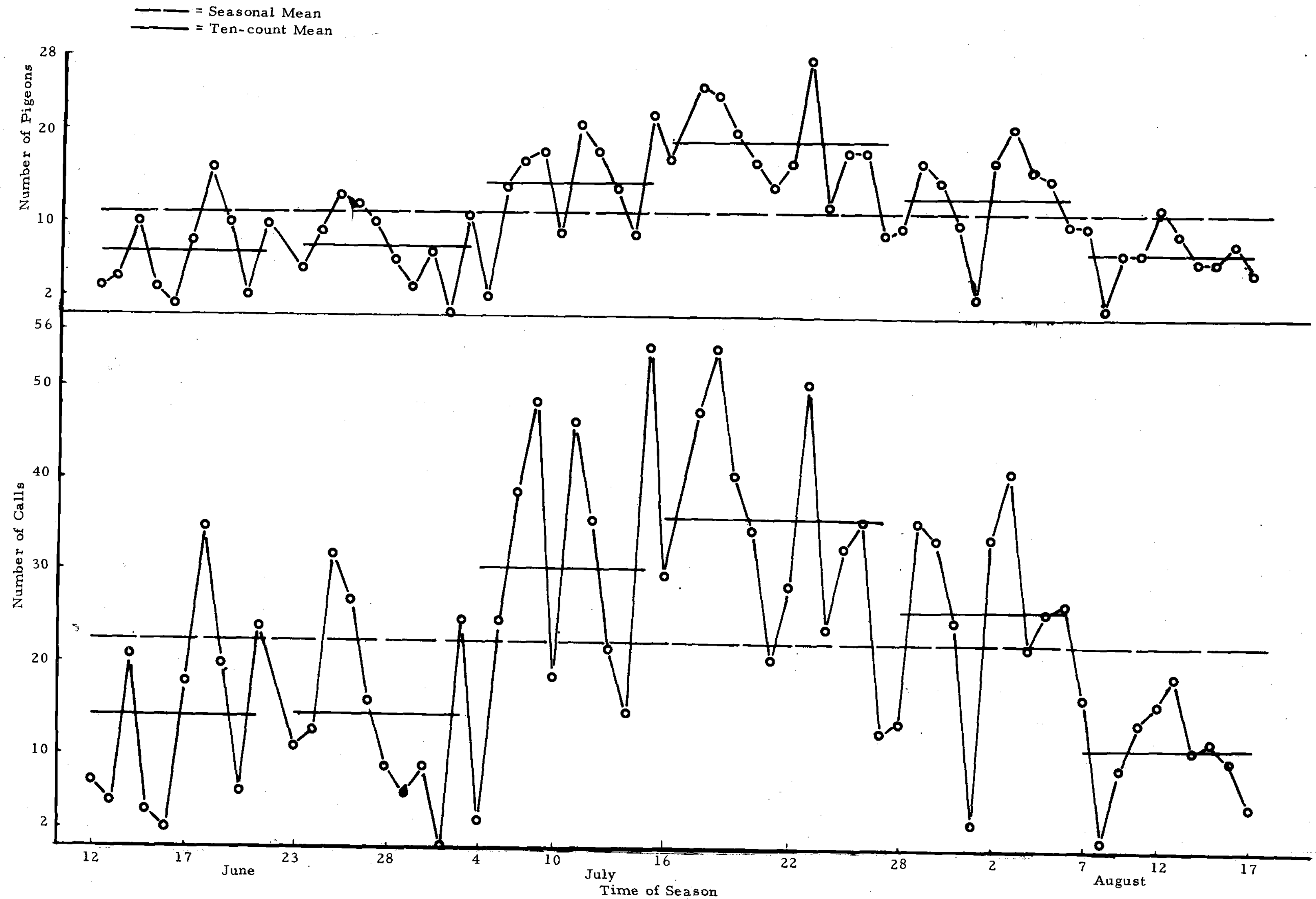

Figure 1. Seasonal distribution of numbers of band-tailed pigeons heard and calls heard on daily call-counts. McDonald Forest route, Benton county, Oregon; June 12 - August 17, 1967.

Table 5. Seasonal distribution of calling activity of band-tailed pigeons, by 10-count periods. McDonald Forest route, Benton County, Oregon; June 12-August 17, 1967. Analyses of data presented in Figure 1.

Ten-count period number	Time of season	Mean no. calls per route	Mean no. pigeons heard per route	Coefficient of Variation (%) calls heard	Coefficient of Variation (%) pigeons calling	Probability of hearing a pigeon call
1	June 12-21	14.2	6.7	77.11	72.08	0.239
2	June 23-July 3	14.8	7.6	68.71	54.73	.291
3	July 4-15	31.0	14.4	54.22	43.05	.426
4	July 16-27	36.3	19.0	36.19	28.94	.545
5	July 28-Aug. 6	26.3	13.3	43.42	40.45	.361
6	Aug. 7-17	11.4	7.1	48.42	42.11	.230
	Entire season	22.3	11.4	65.51	57.79	.349

Table 6. Seasonal distribution of numbers of band-tailed pigeons heard at each station, by 10-count periods. McDonald Forest route, Benton County, Oregon; June 12-August 17, 1967. This illustrates the influence of station-effect on the number of pigeons heard.

Period	Dates	Station 1	2	3	4	5	6	7	8	9	10	Total
1	June 12-21	3	14	8	13	8	6	1	6	5	3	67
2	June 23-July 3	2	13	2	17	8	12	7	4	6	5	76
3	July 4-15	8	27	27	21	30	16	4	3	2	6	144
4	July 16-27	11	31	23	28	32	26	10	8	10	11	190
5	July 28-Aug. 6	9	15	27	21	29	19	1	0	7	5	133
6	Aug. 7-17	6	18	16	13	9	6	1	0	2	0	71
Total		39	118	103	113	116	85	24	21	32	30	681
			78.6% (stations 2–6)									

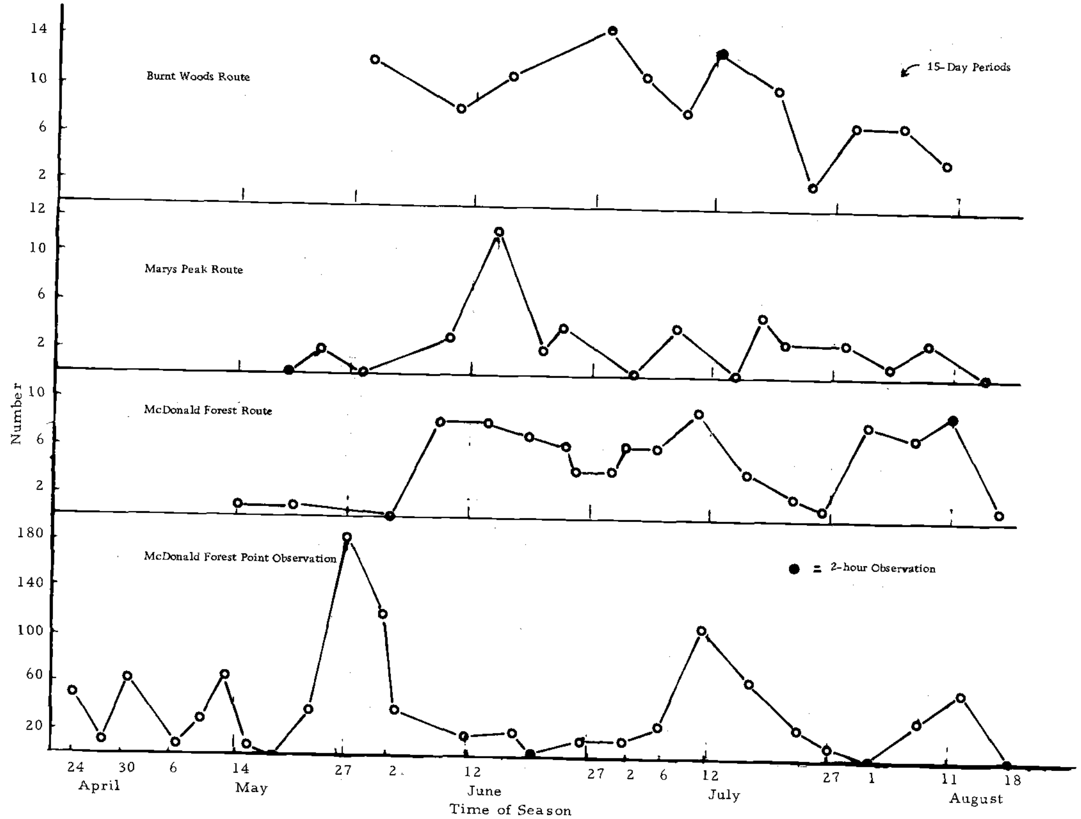

Figure 2. Seasonal distribution of numbers of band-tailed pigeons heard (routes) and calls heard (point observations). McDonald Forest, Marys Peak, and Burnt Woods routes; Benton and Lincoln counties, Oregon; April 24 - August 18, 1968.

Table 7. Seasonal distribution of calling activity of band-tailed pigeons, by 15-day periods. McDonald Forest, Marys Peak, and Burnt Woods routes; Benton and Lincoln counties, Oregon; May 14-August 11, 1968. Analyses of numbers of pigeons heard on routes in Figure 2.

Route	15-Day Periods						
	May 14-28	May 29-June 12	June 13-27	June 28-July 12	July 13-27	July 28-Aug. 11	Entire season
McDonald Forest							
no. call-counts	2	2	4	4	3	3	19
s^2	0	32.00	2.92	4.25	2.34	1.00	9.47
s	0	5.65	1.70	2.06	1.52	1.00	3.07
$\bar{x}$	1.0	4.0	6.25	6.25	2.33	8.00	4.84
C. V. (%)	0.0	141.25	27.20	32.96	65.27	12.50	63.43
Marys Peak							
no. call-counts	2	2	3	2	3	3	16
s^2	2.00	4.50	28.00	8.00	6.34	1.34	9.05
s	1.41	2.12	5.29	2.82	2.51	1.15	3.00
$\bar{x}$	100	1.50	6.00	2.00	2.67	2.33	2.63
C. V. (%)	141.00	141.33	88.17	141.00	94.01	49.36	114.07
Burnt Woods							
no. call-counts	0	2	1	3	3	3	12
s^2	-	8.00	-	12.34	23.34	3.00	14.00
s	-	2.82	-	3.51	5.68	1.73	3.74
$\bar{x}$	-	10.00	11.0	11.33	8.33	6.00	9.00
C. V. (%)	-	28.20	-	30.98	68.19	28.83	41.56

The periods of June 13-27 and June 28-July 12 also were favorable on the McDonald Forest route.

The greatest number of pigeons heard calling on a McDonald Forest point observation in 1968 was on May 28. This coincided with observations of high numbers of band-tails at a trap-site on the east edge of Corvallis, Oregon. Pigeons frequently have been heard calling at this trap-site, an area not used for breeding activities. Band recoveries of pigeons trapped on May 28, 1968, indicate that northward-migrating birds were in the area at that time, and may have accounted for the large number of pigeons and calls heard in the McDonald Forest.

I anticipate that the first half of July would be the best time of summer to observe band-tailed pigeons calling. This prediction is based on data of 1967 which demonstrated that July 4-27 was a favorable time of season for numbers of calling pigeons, and on data of 1968 which indicated that mid-June to mid-July was generally the best time of season to hear calling pigeons.

Diurnal Pattern of Calling

All-Day Point Observations

Of the 448 calls heard on all-day point observations in 1967, 288 (64.3%) occurred between 1/2 hour prior to sunrise and 1 1/2 hours following sunrise (Figure 3). Calling was relatively infrequent

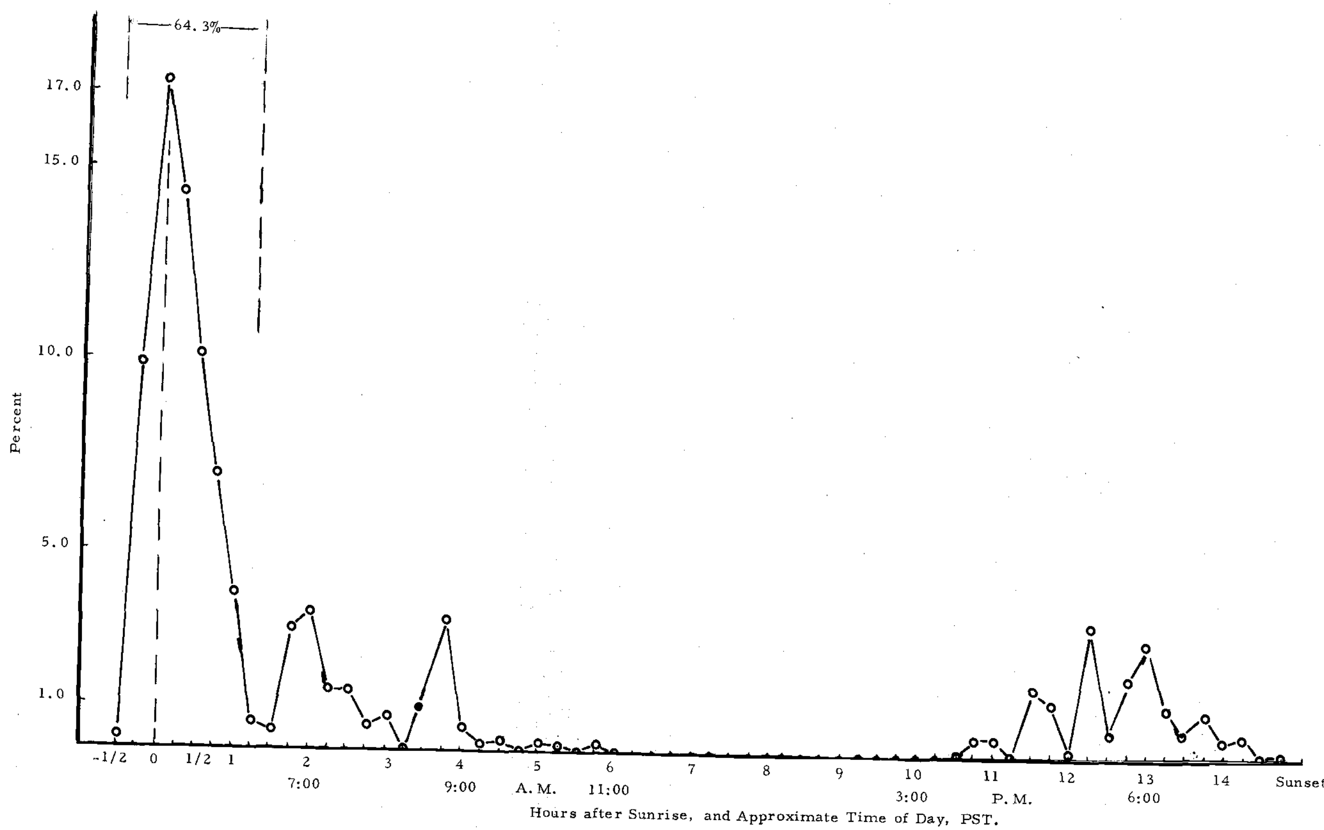

Figure 3. Percent distribution of band-tailed pigeon calls heard, by 15-minute intervals, in the period of 1/2 hour prior to sunrise to sunset. Three all-day point observations, McDonald Forest route, Benton county, Oregon; July 17 - August 15, 1967.

in the morning following the first 2 hours of listening on all-day point observations (18.5% of the total calls) and in the late-afternoon (17.2%), and completely absent during the mid-day (approximately 11 a.m. to 3 p.m., PST). Numbers of calls heard also declined after 1 1/2 hours after sunrise on the morning point observations in 1968 (Figures 4-7).

The early-morning peak of calling observed in this study is completely different from that reported by three other investigators. Glover (1953) and Houston (1963) reported that the greatest calling activity of pigeons, in Humboldt County, California, occurred in the late-morning. Peeters (1962) stated that pigeons called most frequently about 5-6 p.m. at Berkeley, California. I cannot place any confidence in their findings for the following reasons: Houston and Peeters did not mention the duration of their listening through the day; Glover apparently did not listen prior to 7 a.m.; all three related calling to the actual time of day rather than time from sunrise or sunset; and the time of day was not indicated as Standard Time or Daylight Saving Time by any of these authors.

From his study of captive band-tails, Sisson (1968) concluded that the 2-hour period from 1/2 hour prior to sunrise to 1 1/2 hours following sunrise was the time of greatest calling activity in the morning.

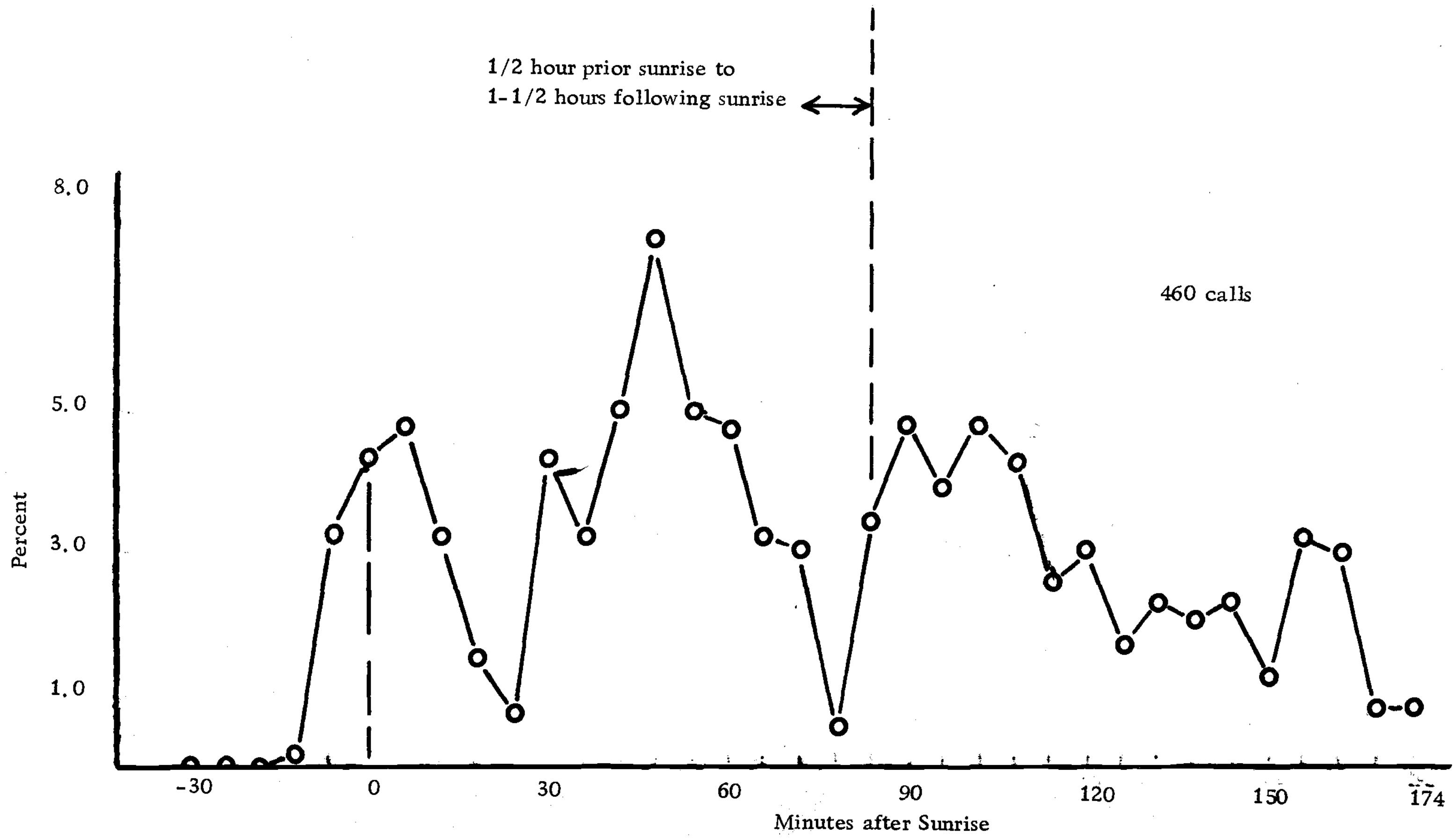

Figure 4. Percent distribution of band-tailed pigeon calls heard, by 6-minute intervals, in the period of 1/2 hour prior to sunrise to 3 hours after sunrise. Nine point observations, McDonald Forest route, Benton county, Oregon; April 24 - May 28, 1968.

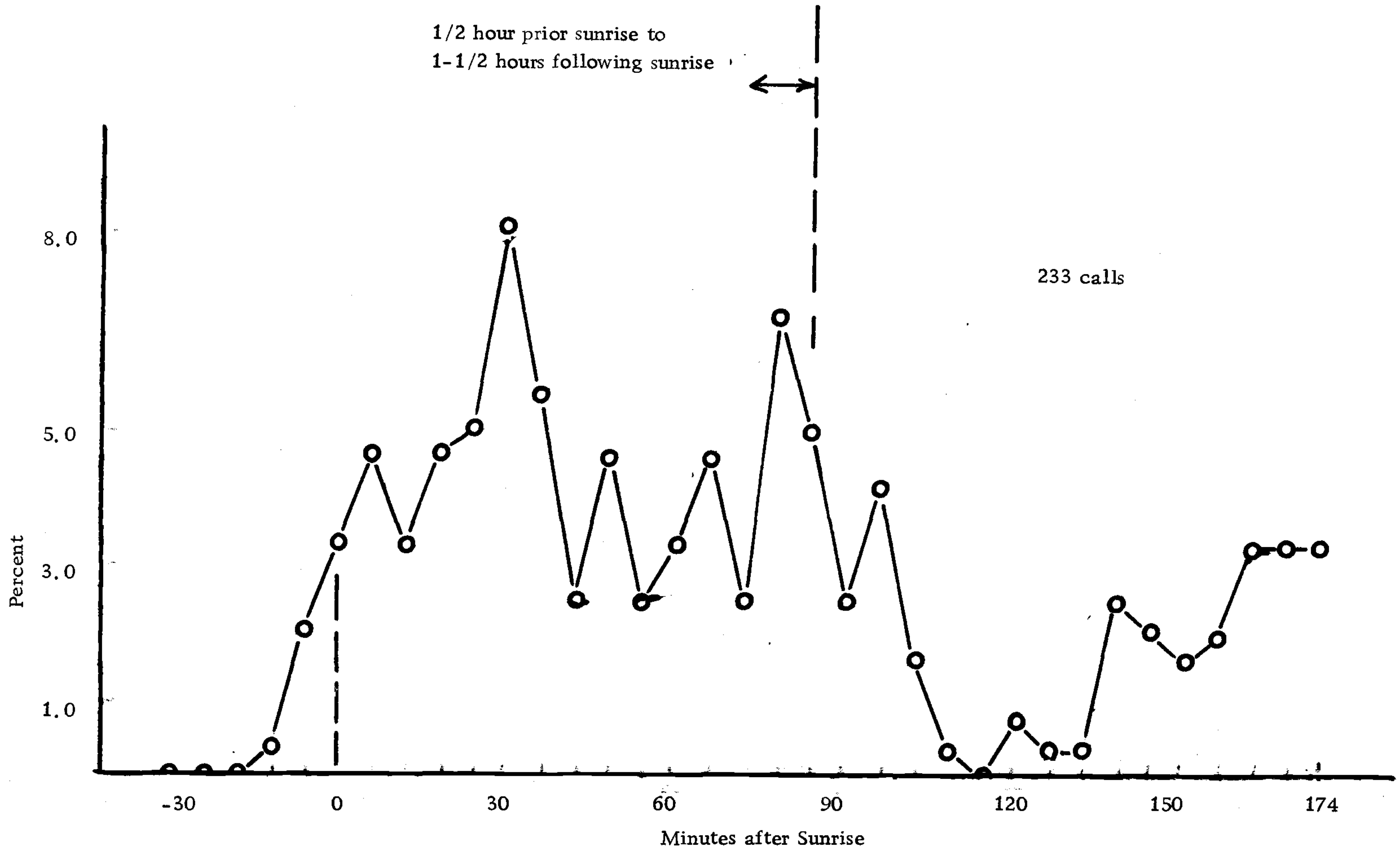

Figure 5. Percent distribution of band-tailed pigeon calls heard, by 6-minute intervals, in the period of 1/2 hour prior to sunrise to 3 hours after sunrise. Six point observations, McDonald Forest and Burnt Woods routes, Benton and Lincoln counties, Oregon; June 1-26, 1968.

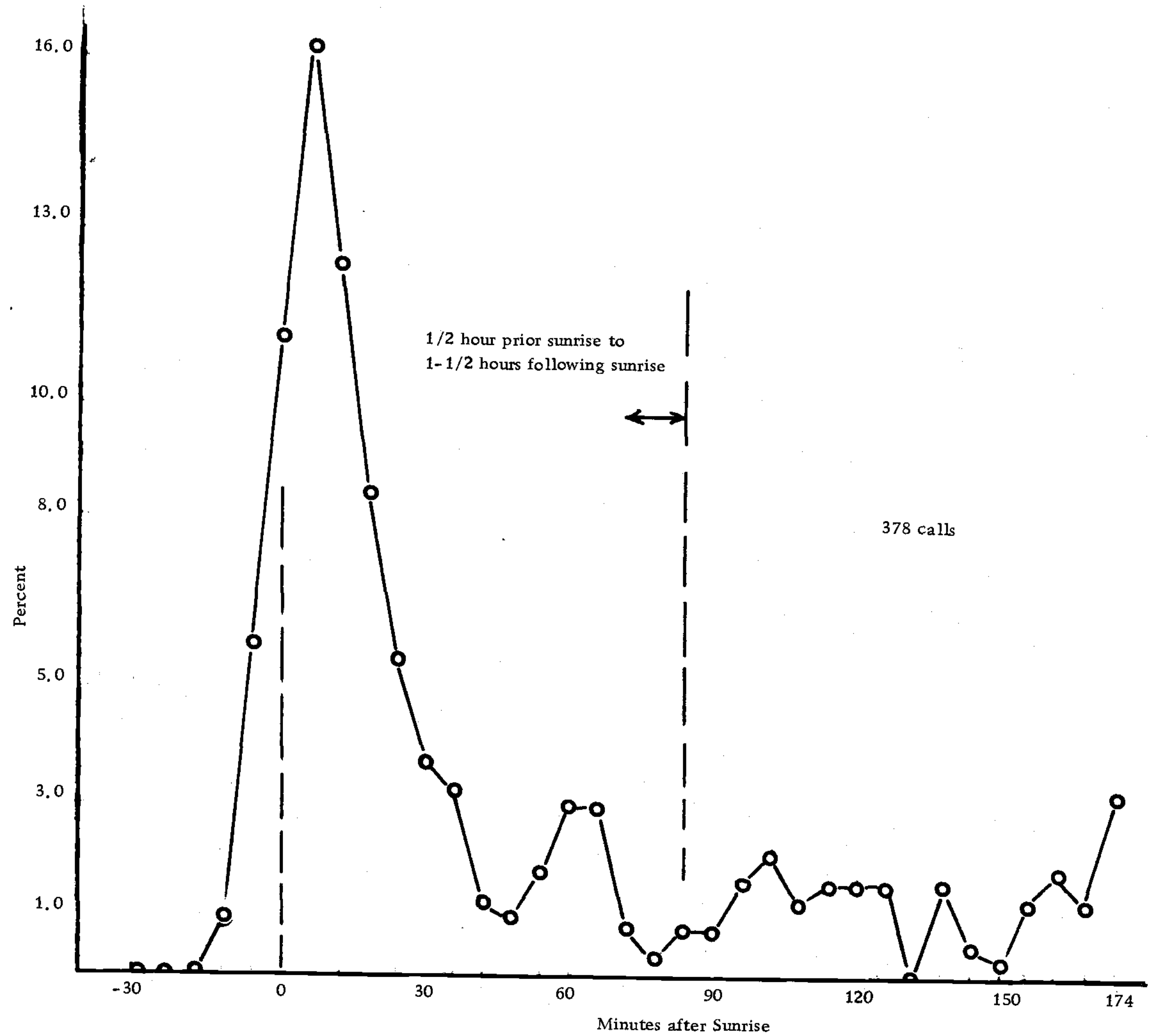

Figure 6. Percent distribution of band-tailed pigeon calls heard, by 6-minute intervals, in the period of 1/2 hour prior to sunrise to 3 hours after sunrise. Ten point observations, McDonald Forest and Burnt Woods routes, Benton and Lincoln counties, Oregon; July 1-30, 1968.

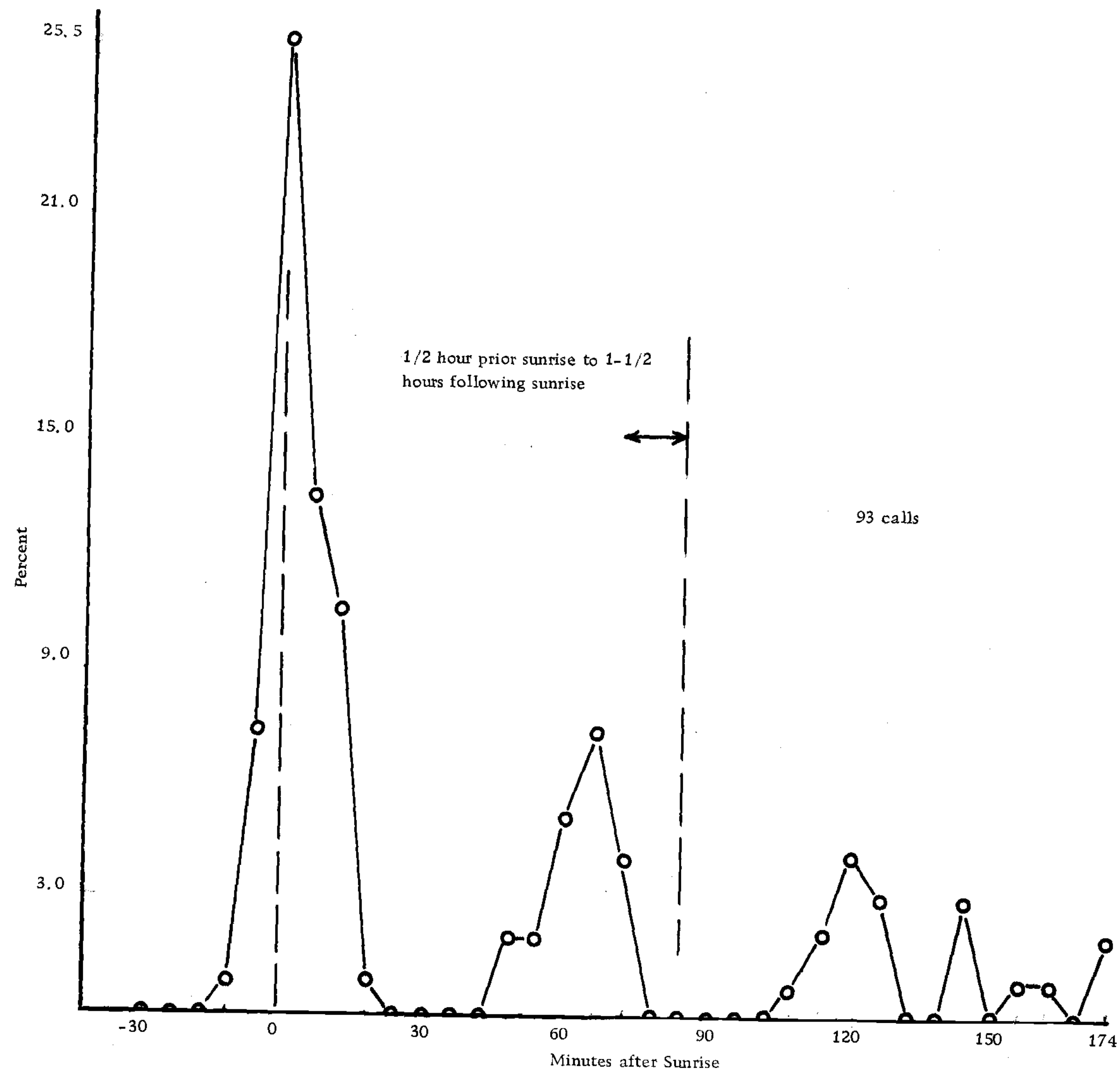

Figure 7. Percent distribution of band-tailed pigeon calls heard, by 6-minute intervals, in the period of 1/2 hour prior to sunrise to 3 hours after sunrise. Two point observations, McDonald Forest route, Benton county, Oregon; August 7 and 12, 1968.

Morning Calling

It has been demonstrated that the early-morning was the most favorable time of day to hear band-tailed pigeons call. In this section I will discuss the data relating to the time of morning pigeons began to call and the distribution of calling during the early morning hours.

Time of Morning Pigeons Began to Call

The time of morning that band-tailed pigeons began to call was closely associated with the time of local sunrise (Figures 8 and 9). Linear regression analyses were made between the time of morning that the first pigeon was heard and the time of sunrise. The resulting coefficients of determination were 0.557 and 0.729 (1967 and 1968, respectively).

The mean time of morning pigeons were first heard calling in 1967 was 5.2 minutes prior to sunrise (Figure 8). The mean time of morning pigeons were first heard calling in 1968 was 2.0 minutes after sunrise (Figure 9). Although the earliest calling heard on point observations in 1968 (Figure 9) was 11 minutes prior to sunrise (July 27), pigeons were heard at 18 minutes prior to sunrise on two call-counts.

The general maxim that birds begin singing in the morning at or

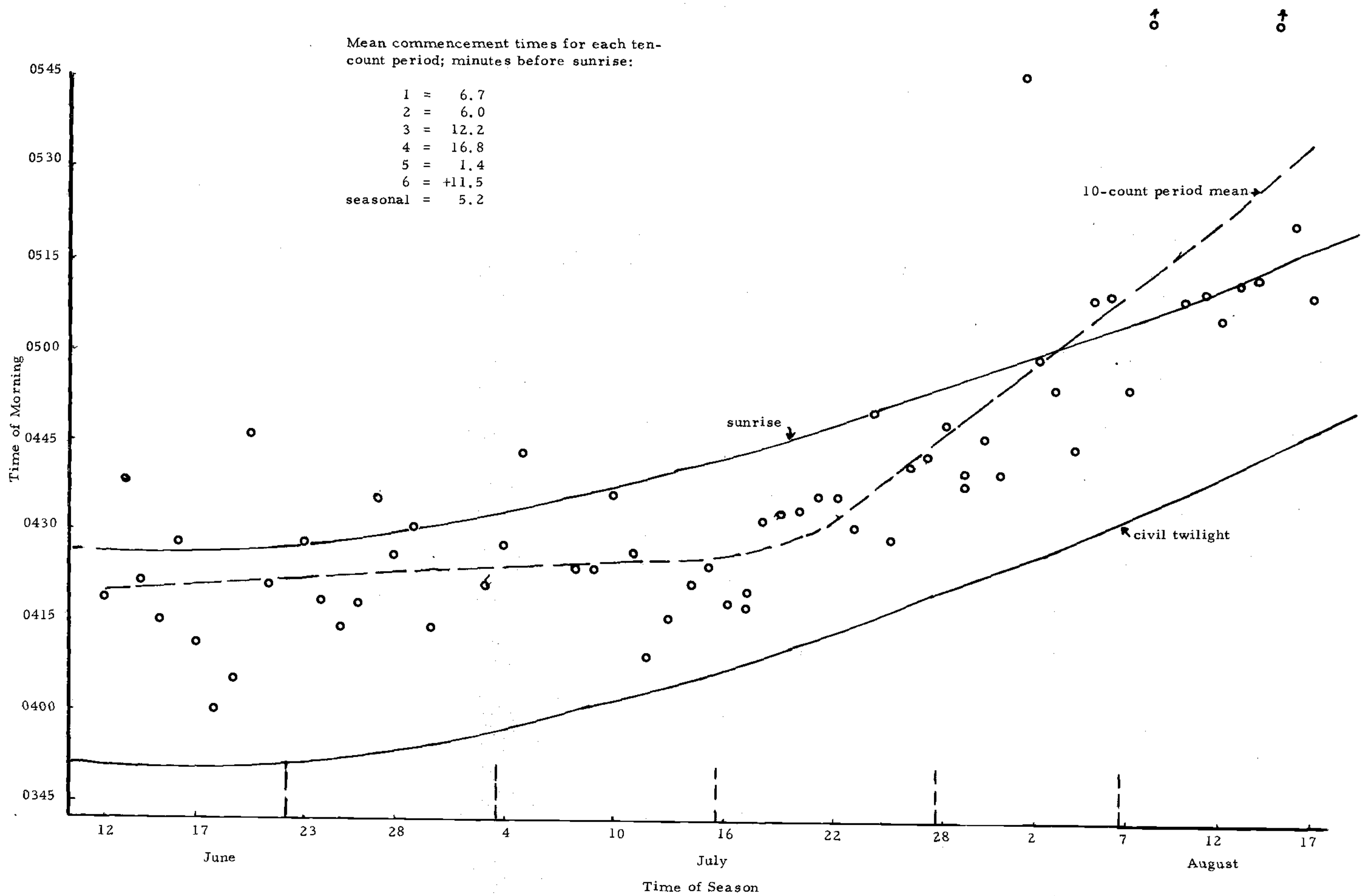

Figure 8. The time of morning band-tailed pigeons were first heard calling, by time of season. Commencement times of calling are plotted by Pacific Standard Time in relation to the time of local sunrise and civil twilight. Sixty call-counts and three morning point observations, McDonald Forest route, Benton County, Oregon; June 12 - August 17, 1967.

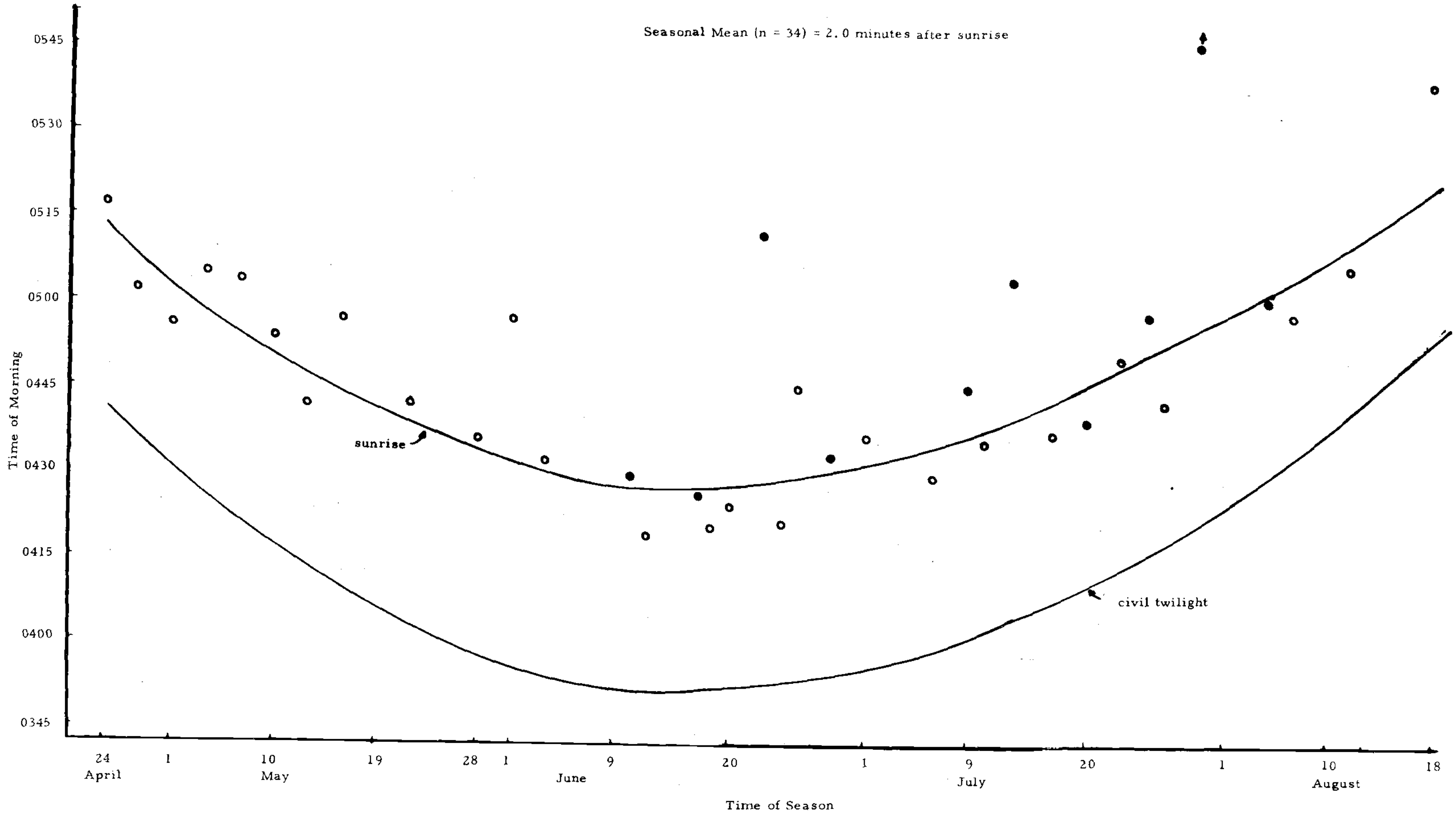

Figure 9. The time of morning band-tailed pigeons were first heard calling, by time of season. Commencement times of calling are plotted by Pacific Standard Time in relation to the time of local sunrise and civil twilight. Twenty-six point observations, McDonald Forest route (o), and ten point observations, Burnt Woods route (•); Benton and Lincoln counties, Oregon; April 24 - August 18, 1968.

prior to the beginning of civil twilight (see Allard, 1930, and Leopold and Eynon, 1961) apparently is not true for the band-tailed pigeon. With the possible exception of the house wren (Troglodytes aedon) (Allard, 1930), the band-tailed pigeon begins its calling in the morning later than any other species of which I am aware.

The earliest calling of pigeons in the morning in 1967 occurred during July 16-27, when the greatest numbers of pigeons were calling. It is generally believed that the singing of male birds is a courtship activity, usually indicative of the breeding season of that species. The intensity of singing and/or the time of morning singing began has been associated directly with the level of breeding condition of the ring-necked pheasant (Kimball, 1949; Taber, 1949; and Leopold and Eynon, 1961) and of the rufous-sided towhee (Pipilo erythrophthalmus) (Davis, 1958). It is possible that the earlier calling in the morning of greater numbers of pigeons in late-July, 1967, reflected the time of season of greatest breeding activity. Observations in 1968 of the time of morning pigeons began to call and the number of pigeons calling, related to time of season, did not agree with the observations in 1967.

Distribution of Calling

During the 2 years of this research, 164 observations were conducted to study the distribution of calling by pigeons through the early-morning. All resulting patterns demonstrated that the 1/2 hour beginning at the time of sunrise was the period of greatest calling activity in the early-morning (Figures 10-14, Tables 2 and 8).

Although different types of field observations were used in 1967 and 1968, the patterns of this time-effect (Figures 10-13) were very similar. Point observations occurred at a single station and thus were not affected by a varying station-effect (Figures 10 and 13). The over-and-back route design in 1967 made the station-effects uniform at each time interval for each ten-count period (Figure 11). All call-counts in 1968 began at station no. 1 and proceeded through station no. 20, yet increasing the number of routes to six provided for detection of time-effect by making the influence of station-effect more uniform at each time interval (Figure 12).

An example of the interaction of time-effect and station-effect upon the calling heard is presented in Figure 15. This pattern illustrates the results of conducting call-counts on a single route such that the number of pigeons heard at a particular time is greatly influenced by the station-effect at that time; in contrast to those time-effect patterns in which influences of station-effect were assumed to be uniform at each time interval (Figures 11 and 12).

The probability of hearing a pigeon call (Figure 14) has relevance to a call-count route system. The 0.165 value for routes over the entire 1968 season indicated that pigeons were heard at an average of 3.3 of the 20 stations (16.5%) on a route during <u>that</u> 2-hour period.

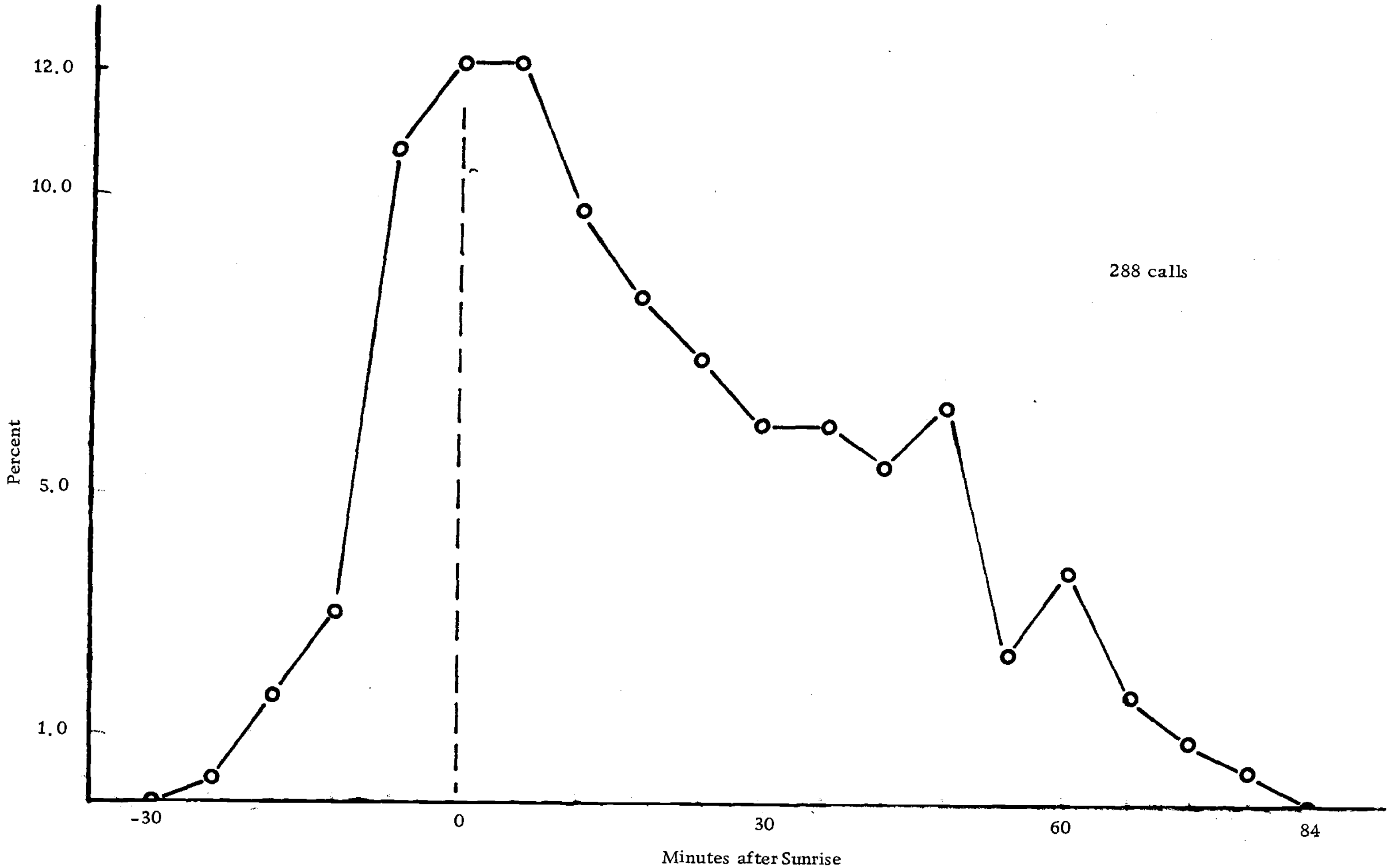

Figure 10. Percent distribution of band-tailed pigeon calls heard, by 6-minute intervals, in the period of 1/2 hour prior to sunrise to 1-1/2 hours after sunrise. Extracted from three all-day point observations, McDonald Forest route, Benton county, Oregon; July 17 - August 15, 1967.

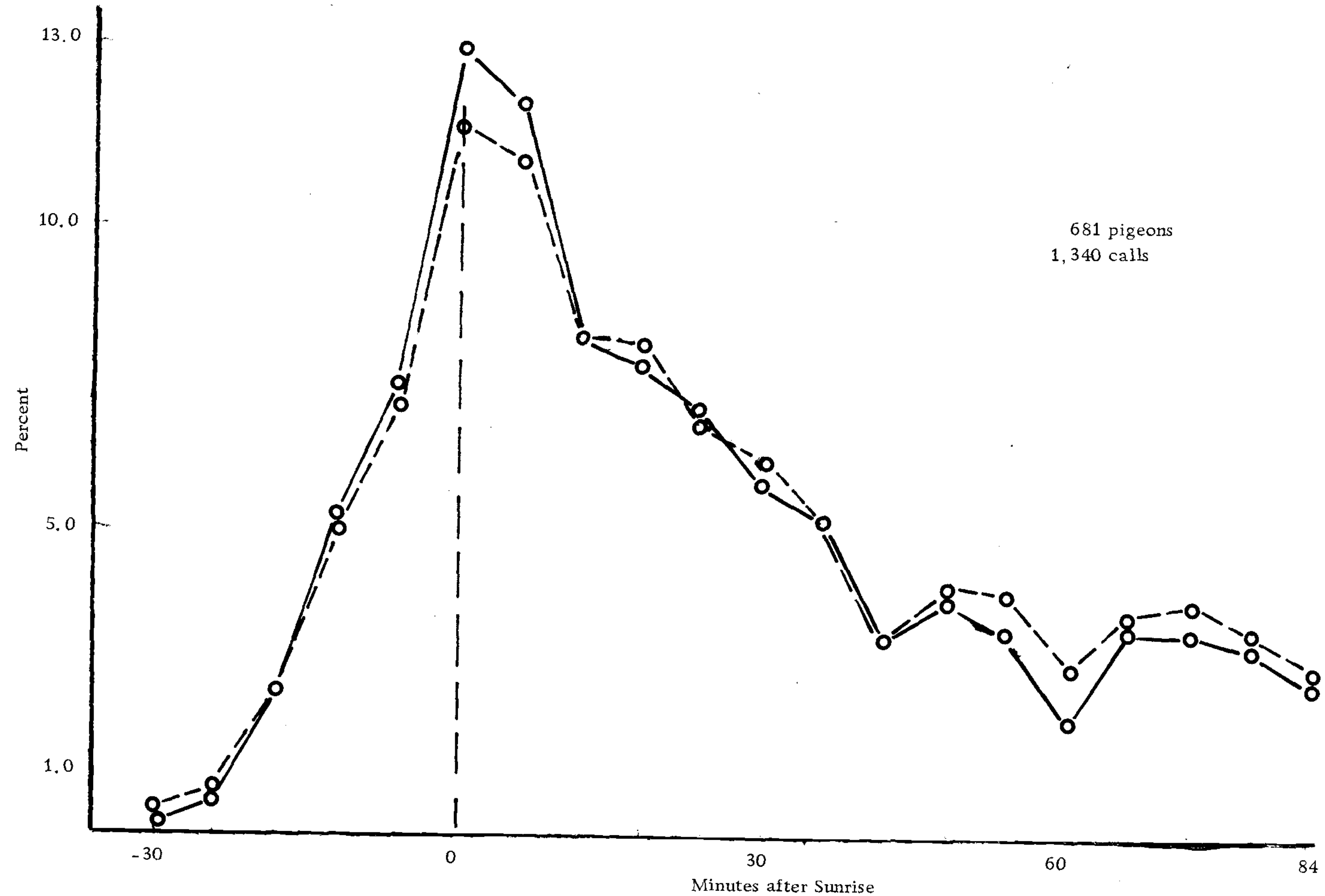

Figure 11. Percent distribution of band-tailed pigeons heard (--) and calls heard (—), for 3-minute listening intervals, in the period of 1/2 hour prior to sunrise to 1-1/2 hours after sunrise. Sixty call-counts, McDonald Forest route, Benton county, Oregon; June 12 - August 17, 1967.

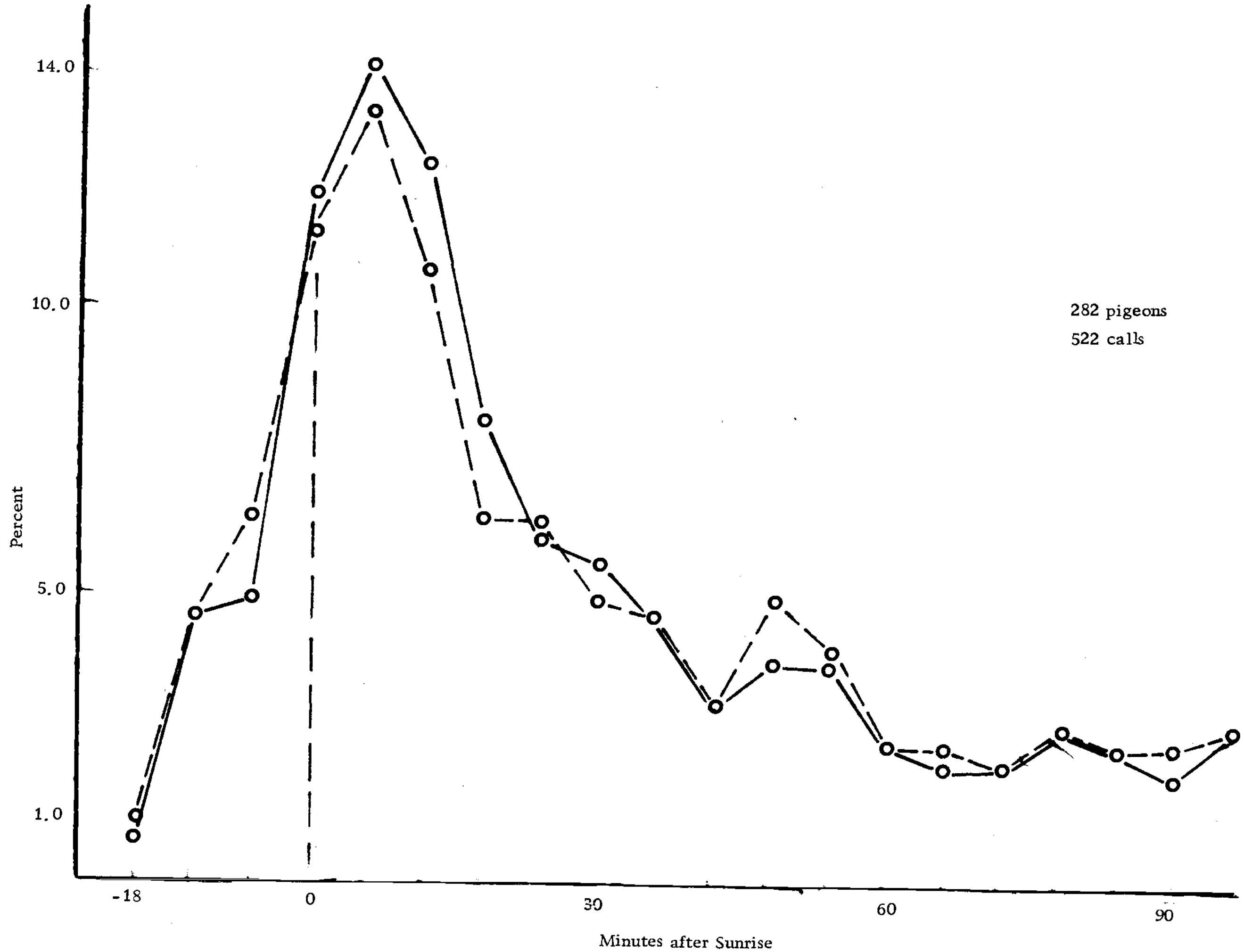

Figure 12. Percent distribution of band-tailed pigeons heard (--) and calls heard (—), for 3-minute listening intervals, in the period of 18 minutes prior to sunrise to 102 minutes after sunrise. Sixty-five call-counts on the McDonald Forest, Burnt Woods, Marys Peak, Cougar Ridge, Dawson, and Blodgett routes, Benton, Lincoln, and Linn counties, Oregon; May 14 - August 17, 1968.

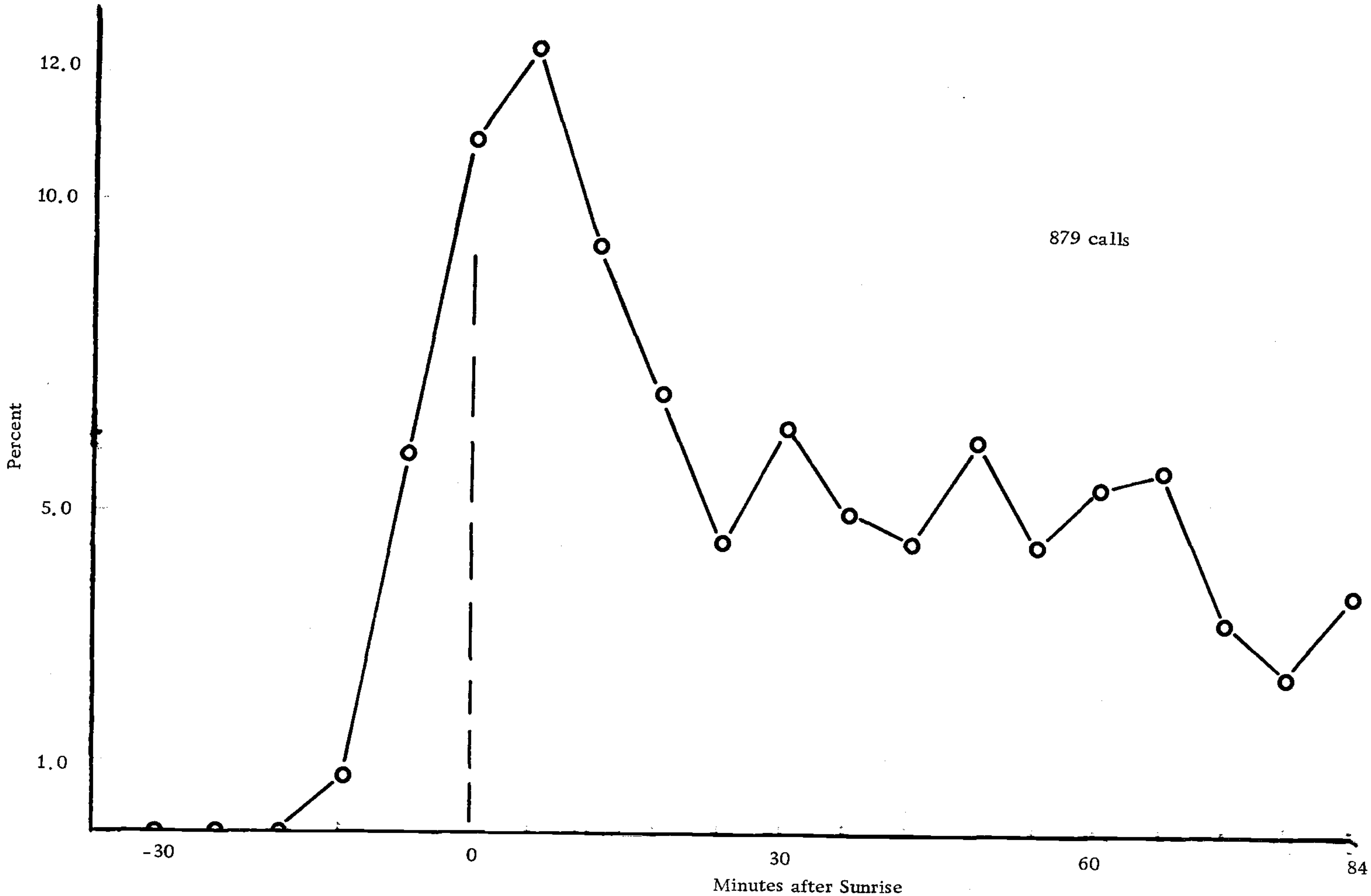

Figure 13. Percent distribution of band-tailed pigeon calls heard, by 6-minute intervals, in the period of 1/2 hour prior to sunrise to 1-1/2 hours after sunrise. Thirty-six point observations, McDonald Forest and Burnt Woods routes, Benton and Lincoln counties, Oregon; April 24 - August 18, 1968.

1/2 Hour Mean Probabilities

						Overall:
1967 route:	0.236	0.556	0.320	0.283	---	0.349
1968 routes:	0.144	0.276	0.158	0.095	0.091	0.165
1968 point obs.:	0.064	0.379	0.314	0.245	0.201	---

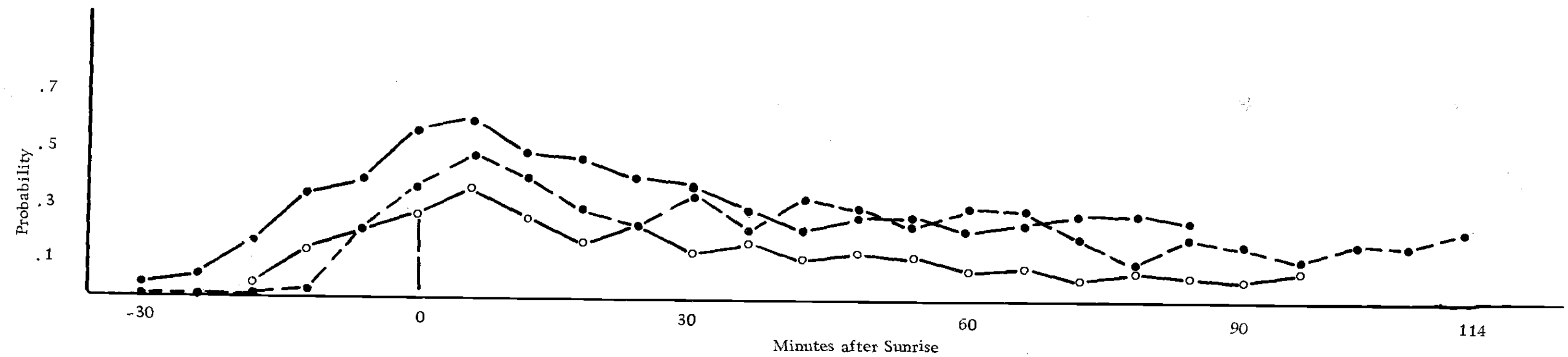

Figure 14. Probabilities of hearing a band-tailed pigeon call (the number of times at least one pigeon was heard during a 3-minute listening interval divided by the number of times that interval was sampled) on 60 call counts in 1967 (•—•), 65 call-counts in 1968 (o—o), and 38 point observations in 1968 (•---•). McDonald Forest, Marys Peak, Burnt Woods, Cougar Ridge, Dawson, and Blodgett routes, Benton, Lincoln, and Linn counties, Oregon; June 3 - August 17, 1967, and April 24 - August 18, 1968.

Table 8. Percent distribution of band-tailed pigeons heard and calls heard in the period of 18 minutes prior to sunrise to 1 1/2 hours after sunrise on routes and point observations in this study. McDonald Forest, Marys Peak, Burnt Woods, Cougar Ridge, Dawson, and Blodgett routes; Benton, Lincoln, and Linn counties, Oregon; June 12-August 17, 1967, and April 24-August 18, 1968

Distribution	1967 McDonald Forest Route (n=60 call-counts)	1967 McDonald Forest Point observations (n=3)	1968 Routes (n=65 call-counts)	1968 Point observations (n=36)
Percent of total calls, occurring during				
18 min. prior sunrise	15.41	15.68	10.80	7.05
1st 1/2 hr. after sunrise	48.49	49.83	55.00	44.60
2nd 1/2 hr. after sunrise	21.75	27.18	21.60	27.19
3rd 1/2 hr. after sunrise	14.35	7.32	12.20	21.16
Percent of total pigeons calling, occurring during				
18 min. prior sunrise	14.46	- -	12.69	- -
1st 1/2 hr. after sunrise	46.35	- -	50.75	- -
2nd 1/2 hr. after sunrise	22.80	- -	23.13	- -
3rd 1/2 hr. after sunrise	16.39	- -	13.06	- -

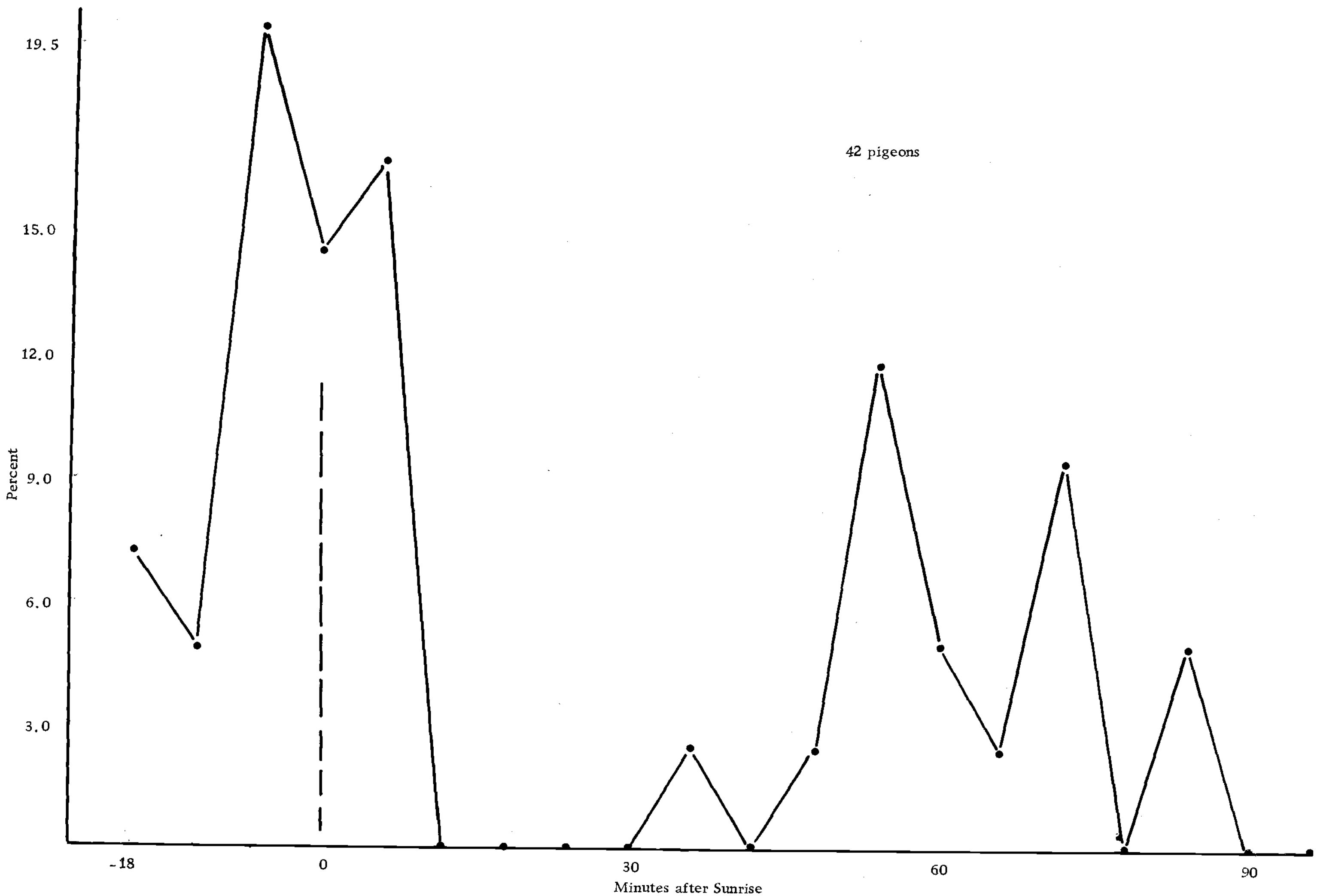

Figure 15. Percent distribution of band-tailed pigeons heard, for 3-minute listening intervals, in the period of 18 minutes prior to sunrise to 102 minutes after sunrise. Sixteen call-counts on the Marys Peak route, Benton county, Oregon; May 20 - August 15, 1968. An illustration of time-effect and station-effect on the calling heard.

The pattern of calling during the early-morning (Figures 10-13), as well as the illustrations of the time of morning pigeons were first heard calling (Figures 8 and 9), substantially demonstrated the relation of calling by pigeons in the morning to the time of sunrise. It is suggested that figures illustrating the calling of pigeons by time of morning have "minutes or hours from the time of sunrise" as the abscissa label. Between April 24 and August 18, 1968, the time of sunrise changed as much as 51 minutes. Thus, if calling were expressed relative to the actual time of day of observation, the resulting interpretation would have been greatly in error. The use of a uniform time standard should also be stressed, preferably Standard Time rather than Daylight Saving Time.

There was a marked influence of time of season on the distribution of calls heard during the early-morning on point observations in 1968 (Figures 4-7). As the time of season progressed, the peak interval of number of calls heard occurred earlier in relation to time of sunrise. This situation did not occur in 1967.

An attempt was made in 1968 to find a more efficient 2-hour period for conducting call-counts. The analysis of data collected in 1967 demonstrated that there was very little calling between 30 and 19 minutes prior to sunrise (Table 9), and, as a result, the start of routes in 1968 was delayed until 18 minutes prior to sunrise. It was anticipated that this change would increase the probability that

Table 9. Relative intensities* of band-tailed pigeon calls heard for each 3-minute listening interval on 60 call-counts, McDonald Forest route, Benton County, Oregon; June 12-August 17, 1967.

3-Minute listening interval, beginning at minutes after sunrise	Relative intensity
-30	0.0183
-24	.0549
-18	.2012
-12	.4207
- 6	.6707
0	1.0000
+ 6	.9939
12	.6585
18	.6585
24	.5793
30	.4512
36	.4512
42	.2317
48	.3171
54	.2805
60	.1463
66	.3171
72	.2378
78	.2683
84	.2134

*Computed by dividing the total number of calls heard, throughout the season, at each time interval by the total number of calls heard, throughout the season, at the best interval (sunrise).

observations at the first two stations on a route would contribute calling activity. This change was worthwhile, as evidenced by the following comparison. In 1967, only 0.82% of the total calls heard on call-counts were heard during the 12-minute interval of 30-19 minutes prior to sunrise, whereas 4.60% of the total calls heard on routes in 1968 were heard during the final 12 minutes (relative to sunrise).

Afternoon Calling

Practically all calling by pigeons in the afternoon was heard during the 4 hours prior to sunset (Figure 3). More than three-fourths of all the calls during this 4-hour period were heard between 3 1/2 and 1 1/2 hours prior to sunset (Figure 16).

The mean time of evening the last pigeon was heard was 65.5 and 89.4 minutes prior to sunset (14 observations in 1967 and 15 observations in 1968, respectively). Seven minutes prior to the time of sunset was the latest time of evening a pigeon was heard to call on any observation in this study.

Relation of Weather Factors to Calling

In this study, linear regression analyses were made between individual weather factors and the calling of pigeons on call-counts and point observations over the entire season. This procedure has

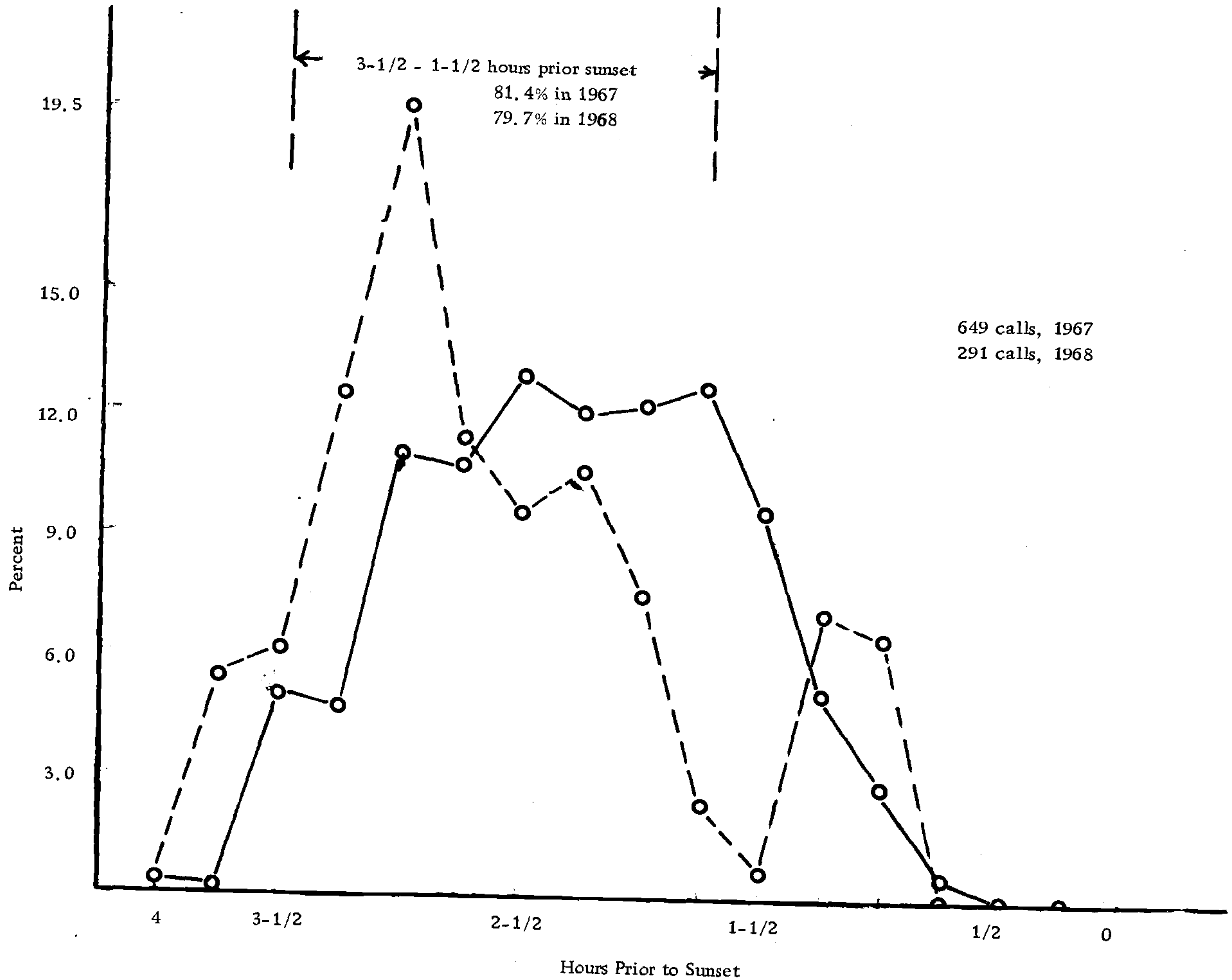

Figure 16. Percent distribution of band-tailed pigeon calls heard, by 15-minute intervals, during the four hours prior to the time of sunset. Thirteen point observations, June 16 - August 15, 1967 (—), and 18 point observations, June 14 - August 18, 1968 (--); McDonald Forest and Burnt Woods routes, Benton and Lincoln counties, Oregon.

limitations in that it will not demonstrate any influence from the interaction of two or more weather factors nor any influence of time of season on the affect of a weather factor.

The discussion by Stone (1966) provided an extensive review of previous studies attempting to analyze the affect of weather factors upon singing activities of birds.

Incident Light Intensity and Cloud Cover

There was a definite relationship between light intensity and the time of morning that pigeons began to call (Table 10, rows 1-3). A seasonal mean incident light intensity of approximately 25 foot-candles was registered at that time of morning pigeons were first heard to call (Table 10, row 1; Tables 11 and 12). The time of morning pigeons began to call was generally later under increasing cloud cover (Table 10, row 3; Table 13); as the increasing cloudiness delayed the time the threshold of light intensity was reached.

The relationship between light intensity, cloud cover, and the time of morning pigeons began to call substantiates the relationships long-recognized for birds in general (see Allard, 1930).

In late-July, 1967, pigeons began calling in the morning at the lowest light intensities of the season (Table 11), which coincided with that time of season the greatest number of pigeons were calling (Tables 5 and 6). I speculate that in 1967, the greater sensitivity of band-tails

Table 10. Coefficients of determination, r^2, from linear regression analyses between various individual weather factors and calling activity of band-tailed pigeons from call-count routes and point observations, 1967 and 1968.

Relationship	1967 McDonald Forest Route	1968 McDonald Forest Route	1968 Burnt Woods Route	1968 Marys Peak Route	1968 All Routes Combined	1968 All Point Observa-ions Combined
Light intensity and the time of morning pigeons began to call	0.7838[3] (41)	----	----	----	0.6717[3] (29)	0.9481[3] (17)
Increasing cloud cover and the light intensity at the time of morning pigeons began to call	0.0001 (41)	----	----	----	0.0010 (28)	0.0237 (17)
Increasing cloud cover and the time of morning pigeons began to call	0.0120 (54)	----	----	----	0.0962[2] (42)	0.1123[1] (34)
Cloud cover and the number of pigeons heard	A)	0.00002 (19)	0.0032 (12)	0.1875[1] (16)	----	----
Barometric pressure and the number of pigeons or calls heard	B): 0.2301 0.4400 0.5386[1] 0.3115	0.0391 (18)	0.2540 (11)	0.1578 (15)	----	0.00008 (26)
Median temperature and the number of pigeons or calls heard	A)	0.1012 (18)	0.1090 (12)	0.0094 (16)	----	0.0531 (25)
Temperature at start of observation and the number of pigeons or calls heard	A)	0.0394 (18)	0.0983 (12)	0.0077 (16)	----	0.0284 (25)
Increasing wind velocity and number of pigeons heard	----	0.0726 C)	----	----	----	0.0629[1] D)

Analyses of route observations used numbers of pigeons heard; analyses of point observations used numbers of calls heard.

Numbers in parentheses show sample size of observations.

[1] The r^2 value is significantly different from zero at $P < 0.10$.

[2] The r^2 value is significantly different from zero at $P < 0.05$.

[3] The r^2 value is significantly different from zero at $P < 0.001$.

A) Scatter diagrams were drawn for the six call-counts begun at each of the ten stations; no pattern showed a possible significant relationship.

B) Scatter diagrams were drawn for the six call-counts begun at each of the ten stations; four patterns showed a possible significant relationship and their r^2 values are presented.

C) Derived from 18 observations at station no. 5 at the same time of morning.

D) Derived from 18 route observations and 28 point observations at station no. 4, McDonald Forest route, at sunrise.

Table 11. Mean incident light intensity* at the time of morning that band-tailed pigeons were first heard calling, related to time of season, and at the time of sunrise. Call-counts and point observations on the McDonald Forest, Marys Peak, and Burnt Woods routes, Benton and Lincoln counties, Oregon; 1967 and 1968.

Time of season	1967	1968	
	McDonald Forest call-counts (n=41)	All routes (n=29)	McDonald Forest and Burnt Woods, point observations (n=16)
June 23-July 3	31.0		
July 4-15	33.0		
July 16-27	13.8		
July 28-August 6	28.9		
August 7-17	51.0		
May 29-June 12		10.0	--
June 13-27		19.1	38.8
June 28-July 12		19.6	33.2
July 13-27		22.8	13.8
July 28-August 11		26.1	11.0
Seasonal mean	29.9	18.8	25.7
Seasonal mean light intensity at the time of sunrise	50.7 (n=9)	23.1 (n=34)	24.3 (n=22)

*Measured and recorded in foot-candles.

Table 12. Mean incident light intensity* at the time of morning that band-tailed pigeons were first heard calling, related to the extent of cloud cover. Call-counts and point observations on the McDonald Forest, Marys Peak, and Burnt Woods routes, Benton and Lincoln counties, Oregon; 1967 and 1968.

Cloud cover	1967 McDonald Forest call-counts (n=41)	1968 All routes (n=28)	1968 McDonald Forest and Burnt Woods, point observations (n=17)
0/10	28.7	18.4	18.2
1-3/10	33.1	- -	- -
4-6/10	44.0	- -	- -
1-6/10	- -	20.2	31.5
7-10/10	27.5	17.8	25.0

*Measured and recorded in foot-candles.

Table 13. The time of morning, relative to the time of sunrise, that band-tailed pigeons were first heard calling, related to the extent of cloud cover. Call-counts and point observations on the McDonald Forest, Marys Peak, and Burnt Woods routes, Benton and Lincoln counties, Oregon; 1967 and 1968.

	Cloud cover		
	0/10	1-6/10	7-10/10
McDonald Forest route, 1967 (n=57)			
June 12-21	- 9.8	- -	- 2.8
June 23-July 3	- 8.8	0	+ 5.0
July 4-15	-11.1	-14.7	- -
July 16-27	-22.7	-14.3	-14.3
July 28-August 6	- 1.3	+ 6.0	- 5.5
August 7-17	+15.8	- -	- 5.5
Overall	- 4.0	-10.1	- 6.5
All routes, 1968 (n=42)	- 6.8	0	+ 1.2
Point observations, McDonald Forest and Burnt Woods, 1968 (n=34)	- 2.5	+ 4.1	+ 4.8

Mean commencement times listed as minutes prior to (-) or after (+) the time of sunrise.

to light in late-July may have been indicative of the major breeding period. Leopold and Eynon (1961) stated, "Seasonal shifts in the mean value of this light intensity seem to be due to the reproductive status and a changing hormonal balance." There was no similar relationship observed in 1968.

The use of a different exposure meter in each year probably accounted for the light intensity differences at sunrise (Table 11), and probably accounted for the fact that pigeons were first heard in the morning at slightly lower light intensities in 1968, but at a later time of morning, than in 1967 (Table 11, Figures 8 and 9). I believe that the exposure meter used in 1967 slightly over-registered the actual light intensity.

I do not believe the one significant relationship ($P < 0.10$) between cloud cover and the number of pigeons heard is particularly meaningful in view of the other 12 non-significant relationships ($P > 0.10$) (Table 10).

Barometric Pressure

The range of barometric pressure readings during the period of study in 1967 and 1968 were 29.53-29.98 inches and 29.47-30.21 inches, respectively. These narrow ranges of barometric pressure made it difficult to ascribe its influence to the wide range of numbers of pigeons heard and calls heard. Only 1 of the 14 linear regressions between barometric pressure and the calling heard provided a significant ($P < 0.10$) coefficient of determination (Table 10).

Air Temperature

There was no apparent influence of temperature on the number of pigeons heard or calls heard (Table 10).

Wind

I believe that wind velocity was a major influence on the numbers of pigeons heard and calls heard. This was caused by the noise created by wind passing through the trees. A wind velocity greater than 7 miles per hour (greater than Beaufort 2) seriously reduced my ability to hear a band-tailed pigeon call.

Wind velocity varied greatly between stations on a route, in contrast to air temperature, cloud cover, and barometric pressure, and as a result, its analysis was done on the basis of individual stations. Only those stations were used in which a sufficient range of number of pigeons were heard in a sufficient range of wind velocities at the same time of morning. At one station, the number of pigeons heard decreased significantly (at $P < 0.10$) when wind velocities increased (Table 10). However, on one occasion a pigeon was heard calling at the time of a 13-18 mile per hour wind velocity.

I definitely believe that the importance of an increasing wind velocity to the numbers of pigeons heard and calls heard is much greater than the analyses in Table 10 suggested. From an operational point of view, the most direct influence of wind velocity is its affect on the ability of an observer to hear a pigeon's call; and in this respect, I believe a wind velocity greater than 7 miles per hour is a very disturbing factor.

Fog and Rain

Glover (1953) and Houston (1963) suggested that fog disturbed the normal distribution of calling of pigeons through the day.

In general, I do not believe fog markedly inhibited the calling of pigeons or my ability to hear the call. I have frequently heard pigeons call in a very dense fog (visibility to 100 yards) and have heard pigeons in display flights (indicated by the "chirping"sound, Peeters, 1962) in very dense fog. Although, in contrast, a very dense fog cover was probably the cause for the delay in commencement of calling and the low number of pigeons heard on three observations in 1968.

Rain, of any intensity, may adversely affect the calling of band-tails. On three occasions, heavy overnight rain and light drizzle during the morning observation probably were factors in the delayed, and low level, of calling activity. In contrast, however, I have heard pigeons call in a light drizzle and heavy rain.

Of primary importance is the fact that rain very definitely interfered with my ability to hear a pigeon call, because of the noise produced by the rain falling through the trees.

Relation of Habitat to Calling Pigeons

One of the objectives of this study was to relate forest types to populations of band-tails. Such a knowledge of the presence of calling pigeons will have value in apportioning call-count routes among the various habitat types.

An attempt was made to sample various forest types for calling pigeons by conducting afternoon call-counts on the Burnt Woods and Old Peak routes in 1967. These call-counts were completely worthless for relating calling activity to forest type because of excessive noise disturbance from high wind velocities. Therefore, my comments on forest type are the result of subjective observations in 1967 and 1968.

I believe the density and composition of the forest type are important factors in governing the suitability of habitats for band-tails. Douglas fir (*Pseudotsuga menziesii*) was the dominant tree species in the foothill and mountainous study areas of this project. The greatest numbers of pigeons were observed and heard calling in two forest types: (1) mixed-species composition of light to medium density Douglas fir, Oregon white oak (*Quercus garryana*), and red alder (Alnus rubra); and (2) stands of densely-stocked, pure, young Douglas fir (as young as 15 years of age) with scattered, taller individuals.

Dense, mature stands of Douglas fir were poor band-tail habitat. Five consecutive stations on the Marys Peak route were located in a block of medium-dense, pure, 110 to 120-year old Douglas fir. On only 2 of the 80 observations at these stations were calling pigeons heard. In contrast, pigeons frequently were heard calling in the densely-stocked, young, pure Douglas fir stands, and in the lightly-stocked, mixed-aged stands of Douglas fir adjacent to this block of pure, mature Douglas fir.

Pigeons commonly were observed calling from lightly-stocked, 100+-year old Douglas fir. These trees invariably were located in stands of mixed-species composition, or located as scattered individuals in a densely-stocked stand of pure, young Douglas fir.

I believe the above observations indicate that large blocks of pure, mature Douglas fir may not be a favorable habitat for band-tailed pigeons in the summer. Young stands of Douglas fir regrowth, 15-20 years of age, provided suitable habitat for calling pigeons, when scattered, taller trees were present. Because of the clear-cut logging practices and the fast growth of Douglas fir, which quickly change the forest type over large areas, this information may prove valuable in establishing and maintaining call-count routes for band-tails.

IV. RECOMMENDATIONS FOR AN AUDIO-INDEX TECHNIQUE

I believe that an audio-index is a promising method for detecting fluctuations in populations of band-tailed pigeons. Males of this species produce a recognizable call, and an index method can be developed to conform to the characteristics of the pigeon's calling.

However, I do not know to what degree the calling by pigeons can index the level of the "breeding population". This situation results from the following observations. (1) Sporadic calling was heard (and subsequently recorded) from pigeons as they fed on red elderberry (Sambucus racemosa), during morning call-counts on the Burnt Woods route. The disturbing point was that I observed these concentrated flocks (up to 100 birds, including many males) actively feeding at that time of morning when these birds theoretically should have been dispersed and actively calling. (2) During the early-morning, actively calling males have been observed to stop calling and fly completely out of sight. In addition, males heard at a station on one day were not heard (or sighted) at the same time of morning on the following day. Apparently, some male pigeons are not closely associated with a specific area for calling activity even in the early-morning. (3) Pigeons, presumably still in northward migration, have been heard calling in the spring at a trap-site - an area devoid of any summer residents. This problem can be rectified by conducting call-counts after northward migration has terminated.

It may be more appropriate to interpret the calling heard on call-counts as an index to the population of band-tails residing in a particular summer habitat.

The capability of the audio-index technique to detect fluctuations in populations of pigeons, suggested procedures for conducting call-count routes, and a proposed calibration scheme for the analysis of call-count data are presented in this section.

Precision of the Audio-Index and Estimates of Sample Sizes of Routes

One objective of this study was, "to determine the capability of the audio-index technique to measure population changes."

The precision of the audio-index technique is related to the inherent variability of the numbers of pigeons heard on call-counts and the number of routes to be used. That is, the greater the variance in numbers of pigeons heard on call-counts, the lower the precision for a specified sample size of routes, or the greater the route sample size required for a certain precision.

The choice of a route sample size is based on a specified, true population difference of magnitude δ, such that an estimate of this difference will be significantly different from zero, according to a specified test, at the $1-\alpha$ level, $1-\beta$ % of the time.

Reference was made to Snedecor and Cochran (1967:111-114) for a general model of sample size determination, $n = (Z_\alpha + Z_\beta)^2 \sigma^2_D / \delta^2$.

The specific model used in this study for estimation of route sample sizes was provided by the assumption $\sigma^2_D = \frac{2}{n}\left[\frac{s^2_d}{k} + s^2ry\right]$, for each route conducted k times each (Table 14). This model refers to paired samples. That is, the same n routes conducted k times each in 2 different years. Data of numbers of calling pigeons in this study were essentially from a single "region", and comparison of population differences between regions in the same year would require different variances than defined in this section.

The variance, σ^2_D, of numbers of band-tails heard on call-counts between years was broken down into two components: s^2_d, that variance between runs on the same route (i.e., day-effect) in the same year; and s^2ry, that variance attributable to route-year-interaction.

Analyses of variance were conducted on numbers of pigeons heard at stations no. 1-10 on the McDonald Forest route in 1967 and 1968 (Table 15) and on numbers of pigeons heard on the McDonald Forest, Marys Peak and Burnt Woods routes in 1968 (Table 16). The resulting estimates of s^2_d were 11.08 and 10.46, respectively.

Analyses of variance could not be used to directly estimate s^2ry because only one route was conducted in the two years, 1967 and 1968. The following procedure was used to obtain a crude estimate of s^2ry .

Table 14. Estimates of the number of routes, n, required to detect various percentage differences, δ, of the number of pigeons heard on call-counts between years, at 1-β probability levels.[1] The same routes are conducted k times each in each year (paired samples).

1-β Level	δ =	10%	15%	20%	25%	30%	40%
		n, for a specified δ					
.90							
k = 1		526	234	131	84	58	33
k = 2		361	161	90	58	40	23
.50							
k = 1		192	85	48	31	21	12
k = 2		132	59	33	21	15	8

[1]Reference was made to Snedecor and Cochran (1967:111-114) for a general model of sample size determination. For this specific case, $V(\hat{D}) = \delta^2/(Z_\alpha + Z_\beta)^2$, where $\hat{D}$ is an estimate of the true mean difference of the populations. The form,

$$\hat{V}(\hat{D}) = \frac{2}{n}\left[\frac{s^2_d}{k} + s^2_{ry}\right]$$

was used. Solving for n,

$$n = \frac{2(Z_\alpha + Z_\beta)^2}{\delta^2}\left[\frac{s^2_d}{k} + s^2_{ry}\right] .$$

Z_α = 1.96, the appropriate normal deviate for a two-tailed test at α = 0.05 level of significance.

Z_β = 1.28 or 0.0, the appropriate normal deviate for a one-tailed test at the level β; where 1-β = 0.90 or 0.50 respectively, the selected probability of detecting a true population difference of level δ.

s^2_d = 10, an estimate of the variance attributable to day-effect.

s^2_{ry} = 6, an estimate of the variance attributable to route-year-interaction.

δ = the percentage change of the mean number of pigeons heard on the routes, based on a mean of 8.0 band-tails heard per route (the overall mean from call-counts in 1967 and 1968).

Table 15. Analysis of variance of numbers of band-tailed pigeons heard at stations no. 1-10 on six call-counts on the McDonald Forest route, Benton County, Oregon, 1967 and 1968.[1)]

Source of variation	d.f.	SS	MS
Total	11	158.92	
Between years (blocks)	1	52.09	52.09
Periods, within years (treatments)	5	51.42	10.28
Error (day-effect)	5	55.41	11.08

[1)]Analysis of the number of pigeons heard on the six call-counts in 1967 that began at station no. 2; so that station no. 1 was surveyed at 18 minutes prior to sunrise in order to conform to the time of day of observations in 1968. Analysis of the number of pigeons heard on the six call-counts in 1968 that were conducted at approximately the same time of season as those counts of 1967.

Table 16. Analysis of variance of the numbers of band-tailed pigeons heard on the 47 call-counts on the McDonald Forest, Marys Peak, and Burnt Woods routes, Benton and Lincoln counties, Oregon, 1968.

Source of variation	d.f.	SS	MS	F
Total	46	741.958		
Between routes	2	281.682	140.841	13.46[1)]
Within routes (error)	44	460.276	10.461	

[1)]Significant at $P < 0.005$.

$$s^2ry = \frac{MS_{1_{(68)}} - MS_{2_{(68)}}}{k} = \frac{\left[\frac{MS_{1_{(67,68)}}}{MS_{2_{(67,68)}}} (MS_{2_{(68)}})\right] - MS_{2_{(68)}}}{k}$$

where, $MS_{1_{(67,68)}} = 52.09$, $MS_{2_{(67,68)}} = 11.08$, $MS_{2_{(68)}} = 10.46$, and $k = 6$.

Therefore, $$s^2ry = \frac{\left[\frac{52.09}{11.08} (10.46)\right] - 10.46}{6} = 6.45$$

Values of $s^2_d = 10$ and $s^2ry = 6$ were used to estimate route sample sizes (Table 14). These variance estimates were not derived from enough data to justify the use of precise values of s^2_d and s^2ry. Although data available for estimates of sample sizes were somewhat insufficient, the estimates presented herein are the best available.

The most efficient procedure is to conduct each route once per year. An analysis of variance of numbers of band-tails heard on call-counts in 1968 (Table 16) demonstrated that there was a greater mean square for "between routes" (140.841) than for "within routes" (10.461). Thus, the allocation of call-counts should be put toward reducing the "between route" variance by conducting each route only once. Additionally, in reference to mourning dove coo-counts, "... a more efficient sampling design would result from doubling the number of routes and censusing each route only once. Variation was greatest between routes, rather than between censuses on the same route"(Southeastern Assoc. ..., 1957: 15). From an analysis of numbers of pigeons heard and calls heard on 31 call-counts on 7 routes in western Oregon in 1966, Sisson (1968) concluded that "... one count per route results in the highest precision for a fixed sample size."

The following example, in reference to the most efficient allocation of call-counts based on a fixed cost (or number of man-hours), demonstrates that one count per route is the most favorable allocation. I have assumed that it would require the same effort and cost to set up all routes the first year and to conduct the same routes in 2 consecutive years. Over a 2-year period (in reference to a 20% δ at $1-\beta = .90$, Table 14) conducting each route once would require 393 (3 x 131) units of effort or cost, whereas conducting each route twice per year would require 450 (5 x 90) units.

There is value though in considering running each route twice per year. It may be impossible to locate the required number of routes if each is to be conducted once per year. It also appears that it will be relatively costly to conduct the large number of routes required to detect a certain population fluctuation of level δ. Thus it may be worthwhile to put some of the effort into the development of more efficient methods of analysis of the call-count data, such as calibration techniques.

Route sample sizes were estimated for $1-\beta$ levels of .90 and .50. The .90 power is a commonly used probability level. Sample sizes estimated for a .50 power represent the minimal estimates possible for a specified precision, that is, there is only a 50% probability of detecting a population fluctuation of level δ when it is true.

Estimates of route sample size were computed by using a Z_{α} for a two-tailed test, that is, for the detection of a population fluctuation of either direction.

Certain considerations should be given to procedures for selection of call-count routes for band-tails. There may be the practical problem of locating enough accessible roads through pigeon habitat. Extensive, purely-agricultural areas, such as the central Willamette Valley, Oregon, should be completely excluded from any sampling design. Likewise, valleys within the Coast Range and Cascade-Sierra Nevada Mountains that are devoted to agriculture (including orchard crops) should be omitted from the sampling design.

Randomly-chosen routes, within the acceptable major sampling regions, should be confined to extremely narrow valleys (probably no more than 1-2 miles in width), foothill, and mountainous areas, where coniferous trees or coniferous-hardwood mixed composition types predominate. Randomly-chosen routes in which all stations are situated in crop-land will be useless.

Until additional information is available concerning the eastward distribution of the band-tail (with respect to Oregon), the most practical eastern boundary for call-count sampling would probably be the summit of the Cascade Mountains. There is information regarding the band-tail's presence east of the summit, but the extent of the distribution and the magnitude of numbers is not known.

In future years it may be desirable to stratify the allocation of call-count routes on the basis of forest type, in an attempt to increase the precision of the technique. I believe that the composition and density of the forest type would be valid guidelines.

Procedures for Conducting Call-Count Routes

A suggested call-count route form is presented in Appendix 2. The route form that is actually used should contain at least the information in this suggested form. An instruction sheet for conducting the call-count route is presented (Appendix 3), and this should be furnished to all cooperators conducting the routes.

A very important consideration is that cooperators realize the necessity of conducting the call-count according to the recommended procedures and of filling in the route form completely. Precision will be lost if the route is not conducted according to the recommended time schedule. A completely recorded route form will greatly facilitate the analysis of call-count data.

It has been proposed that standard call-count routes, consisting of 20 stations, be set up. If it is impossible to locate a sufficient number of 20-station routes consideration could be given to using routes of fewer stations. The calibration technique, for the adjustment of call-count data for time-effect, would facilitate this flexibility in the route design.

I believe it will take considerable experience for a new observer to become efficient at hearing a band-tail call. This is partially due to the variation in the number of notes per call and the low audibility of the call. It may be desirable to require new observers to gain experience by conducting two call-counts prior to the one that is formally submitted.

The principal recommendations for conducting call-counts for band-tails are further discussed below.

Time of Year

Call-count routes for band-tails should be conducted between July 1 and July 15.

The first half of July was a favorable time of season for numbers of calling pigeons and uniformity in numbers of calling pigeons on successive observations in both years of this study (Tables 5-7). A 15-day period should be sufficient for a person to complete the route(s) assigned to him, and yet be short enough so any inherent variance of calling due to time of season is acceptable.

Time of Day

The starting time for conducting band-tailed pigeon routes should be 6 minutes before the time of local sunrise.

It was evident in this study that there was little value in listening for calling band-tails prior to 12 minutes before sunrise (Figures 10-13). Two hours after sunrise was approximately the latest time of morning it was practical to listen for calling band-tails (Figures 3-7). The interval of 6 minutes prior to sunrise to 114 minutes after sunrise was the 2-hour time span in the early morning that generally contained the greatest calling activity (Table 17)

Table 17. The mean number of calls heard and the mean probabilities of hearing a pigeon call for every other 3-minute listening interval (i.e., a simulated route) for various 2-hour time spans of the early-morning. McDonald Forest and Burnt Woods point observations, Benton and Lincoln counties, Oregon; July 17-August 15, 1967, and July, 1968.

2-hr. time span, min. after sunrise	Mean no. calls/ 3-min. interval		Mean probability/ 3-min. interval
	1967	July, 1968	July, 1968
-18 to 102	7.50	8.60	0.2603
-12 to 108	7.50	8.80	.2706
- 6 to 114	7.45	8.85	.2719
0 to 120	6.85	8.65	.2685
6 to 126	6.05	7.85	.2512

A standard call-count route for band-tailed pigeons should be 2 hours duration, conducted between 6 minutes prior to sunrise and 114 minutes after sunrise. I suggest that cooperators consult the same source for a table of times of local sunrise, such as the U. S. Naval Observatory.

It must be stressed that cooperators make every attempt possible to start the call-count route at the recommended time, 6 minutes prior to sunrise. Cooperators should realize that delays in starting the route, after this prescribed time, will reduce the number of calls heard and the probabilities of hearing a pigeon call for a standard 2-hour route (Table 17).

Weather Guidelines

The call-count route should not be conducted when the wind velocity on the route is greater than 7 miles per hour (greater than Beaufort 2). The Beaufort scale should be used to estimate wind velocity.

The call-count route should not be conducted during rain of any intensity.

Light intensity and cloud cover have no practical importance in the conduct of a call-count, even though they affected the time of morning pigeons began to call (Table 10). Air temperature, barometric pressure, and the presence of fog should not affect the decision to conduct a call-count route.

Index to the Status of the Population

The number of pigeons heard on a call-count route should be used as the index to the status of the population.

During both years of study the coefficient of variation of numbers of pigeons heard was less than the coefficient of variation of numbers of calls heard on routes (Table 18). There will also probably be less confusion in recognizing the number of pigeons calling than the actual number of calls produced. This situation became evident in 1968 when several cooperators for the Washington Game Department apparently counted, and recorded, the number of notes per call rather than the number of complete calls heard (Swanson, 1968).

In addition to the number of pigeons heard per listening interval, the number of calls heard (not the number of notes) should be recorded on the route form.

Table 18. Coefficients of variation for numbers of band-tailed pigeons heard and numbers of calls heard on call-count routes. McDonald Forest, Burnt Woods, Marys Peak, Cougar Ridge, Blodgett, and Dawson routes; Benton, Lincoln, and Linn counties, Oregon; 1967 and 1968.

Coefficient of Variation (%)	Route 1967 McDonald Forest	1968 McDonald Forest	Burnt Woods	Marys Peak	Cougar Ridge	Blodgett	Dawson
Pigeons heard	57.79	63.43	41.56	114.07	180.60	59.11	100.67
Calls heard	65.51	70.48	44.88	122.57	187.33	62.24	121.31

Listening Interval

The listening interval at a call-count station should be 3 minutes. Advantages of a 2-minute interval and a 3-minute interval were compared. Of the number of pigeons heard in a 3-minute interval on routes and point observations, 77.0-79.3% were heard in the first 2 minutes (Table 19). Thus, listening a third minute did not proportionately increase the number of new pigeons heard in the first 2 minutes (i.e., at least a 50% increase). A main advantage of the 2-minute listening interval would be that it would permit observations at five additional stations during approximately the same 2-hour time span of the morning.

The results of an analysis presented below, in which a 79% value was used to adjust the number of pigeons heard in every other

Table 19. The distribution of calling by band-tailed pigeons during a 3-minute listening interval on point observations and call-counts. McDonald Forest, Marys Peak, Burnt Woods, Cougar Ridge, Dawson, and Blodgett routes; Benton, Lincoln, and Linn counties, Oregon; 1967 and 1968.

Calling heard	Percent distribution of calling heard		
	1967 point observations[1] (n=288 calls and 139 pigeons heard)	1968 routes (n=287 pigeons heard)	1968 point observations[2] (n=677 pigeons heard)
Calls			
First minute	33.7	--	--
Second minute	32.3	--	--
Third minute	34.0	--	--
First two minutes	66.0	--	--
Pigeons			
First minute	54.0	--	49.0
Second minute	52.5	--	--
Third minute	57.6	--	--
First two minutes	77.0	79.1	79.3

[1] First 2 hours of all-day point observations, McDonald Forest; consecutive 3-minute intervals.

[2] Consecutive 3-minute intervals during the morning 3 1/2 hour observations; McDonald Forest and Burnt Woods.

3-minute interval (i.e., a simulated route) on ten point observations in July, 1968, demonstrated that the addition of five stations does not regain the number of pigeons "lost" by listening only 2 minutes at the first 20 stations. Thus, a 3-minute interval is preferred.

Sum of pigeons heard at first 20 stations, in 3 minutes listening at each = 66.0

Sum of pigeons heard at first 20 stations, in 2 minutes listening at each = 52.1

Sum of pigeons heard at 25 stations, in 2 minutes listening at each = 57.7 (a 40.5% recovery).

A 3-minute listening interval is also preferred to a 4-minute interval (Table 20). In the first 3 minutes of a 5-minute interval there was a greater percent of pigeons heard (82.2) than proportional for the time spent (60.0). Also, I believe it is very difficult to maintain the proper concentration necessary for hearing pigeon calls for any longer than 3 minutes.

Table 20. The distribution of calling by band-tailed pigeons during a 5-minute listening interval. Point observations, McDonald Forest route, Benton County, Oregon; 1967.

Calling Heard	Cumulative percent distribution of calling heard by consecutive minutes				
	1	1-2	1-3	1-4	1-5
Calls: (n=288)	19.0	44.7	65.2	83.6	100.0
Pigeons: (n=107)	39.3	63.6	82.2	92.5	100.0

Record those pigeons that begin to call within the 3-minute interval and those calls that are definitely heard.

Distance Between Stations and Time Interval for Travel

The standard distance between stations on a call-count route should be 1/2 mile.

If there is interfering noise at this 1/2 mile distance (noise from nearby streams, etc.) the station-location should be moved to where the interference is not noticeable. Any change from the 1/2 mile distance between stations should be noted on the route form.

A 3-minute time interval should be allotted for traveling between stations.

A Calibration Technique for Analysis Of Call-Count Route Data

It has been suggested by Overton (1969) that the full value of audio-indices could be better realized by the development of refined calibration techniques for adjusting the various influences on a call-count index. Such a calibration technique, for adjusting call-count data of band-tails for the influence of time-effect, is herein proposed.

On a call-count, the number of pigeons heard is, in part, a function of time of day (time-effect). The usual practice of audio-indices has been to fix the times of day the station-observations are made. As a result, time-effect is still present in the index, but it is standardized to the extent that the same time functions are acting on the observations. This paper proposes an alternative method, that of measuring the function of time of day on the calling of pigeons so that an adjustment can be made for this time-effect at each observation. It is desirable that the index to numbers of pigeons on a route be a reflection of that habitat or geographic region, which is expressed through a "sum of station-effects". This goal can be achieved by the use of the proposed calibration scheme, in which freedom from time-effect is obtained.

Development of the Calibration Technique

It is postulated that the expectation of number of pigeons heard at a location is proportional to a function of time of day.

That is, $E(X_t) \propto g(t)$.

Where X_t = the number of pigeons heard at the t^{th} 3-minute time interval of the day beginning at -30, -24, ..., 0, +6, +12, ... minutes from sunrise.

At this time it is assumed that the function, $g(t)$, of time of day is known for all t. The problem of estimating $g(t)$ will be presented later.

A calibration ratio, A_t, can be defined for each t.

Let, $$A_t = \frac{g(t^*)}{g(t)}$$

Where t^* is some t selected as the "standard interval."

The number of pigeons heard, X_t, at each station on a call-count route can be multiplied by the calibration ratio, A_t, for the respective t. This will provide an adjusted index, Y_t, of pigeons heard at each station. That is,

$$Y_t = X_t A_t .$$

Now, $E(Y_t) \propto g(t^*)$ for all t and $V(Y_t) = A_t^2 V(X_t)$.

As a result, the expectation of the adjusted count at each station, Y_t, equals the expected number of pigeons that would have been heard if that station had been sampled at the standard time, t^*. Therefore, the expectation of the sum of all adjusted counts of calling pigeons on a route, $\sum_{t=1}^{n} E(Y_t)$, will equal the expected total number of pigeons that would have been heard if all stations had been sampled at the same time, t^*.

In order to develop the best (i.e., minimum variance) estimator of $E(Y_t)$ it is necessary to give the most weight, W_t, to those observations in which the variance of the adjusted count, $V(Y_t)$, is smallest; therefore, $W_t \propto 1/V(Y_t)$. These observations occur at the time of morning of greatest calling activity (generally at and shortly after sunrise) and have the lowest A_t values.

The resulting index, I, of the mean number of pigeons heard per station is the weighted, adjusted number of pigeons heard averaged over all stations, and will be of the form,

$$I = \sum W_t Y_t = \sum W_t A_t X_t, \quad \text{with} \sum W_t = 1 .$$

Now, $V(I) = \sum W_t^2 V(Y_t)$, and $V(I)$ will be minimized by $W_t = C/V(Y_t)$, from which we determine $C = 1/\sum(1/V(Y_t))$ under the constraint $\sum W_t = 1$.

Therefore, the index, I, of the mean number of pigeons heard at a station will be independent of the time of day influence, provided that the calibration function, $g(t)$, is truly proportional to the expectation of number of pigeons heard, $E(X_t)$, and I will have minimum variance of all indices of this form.

An index to the total number of pigeons heard on a route can be obtained by multiplying I by the number of stations in the route.

Estimation of Calibration Ratios and Weight Values

Calibration ratios, A_t, and estimates, $1/V(Y_t)$, of weights, W_t, from the numbers of pigeons and calls heard on routes and point observations are presented in Table 21. Estimates of the variance, $V(X_t)$, of the actual calling heard at each t also are presented in Table 21 to illustrate their change through time of morning in relation to A_t and $1/V(Y_t)$.

Data of calling pigeons from point observations, an aggregate of several call-count routes, and an "over-and-back" design on a single route can be used to estimate A_t and W_t values. Data on numbers of calls heard on point observations can be used to estimate A_t and W_t values for use in an audio-index based on the numbers of pigeons heard. This is possible because of the close similarity of the patterns of numbers of calls heard and pigeons heard on routes (Figures 11 and 12).

A "running mean of 3" procedure has been employed when necessary to estimate A_t and W_t. In order to estimate A_t, the number of pigeons heard or calls heard, X_t, at each time interval, t, must first be transformed into a "running mean of 3" value for each t. This procedure will correct for an irregular pattern of A_t values, if present, and reduce the number of time intervals in which no calling was heard. If, after transformation of the original data, there is still a "0" value recorded for a particular t, that interval can be given an A_t value in relation to the values for the adjoining t's. There must be a positive A_t value available for each t that pigeons are heard on a call-count route in order to calibrate to t^*.

After transformation of the actual number of pigeons or calls heard into a "running mean of 3" value for each t, that t with the greatest value, or a specific t such as sunrise, is selected as the "standard interval", t^*. Transformed values of X_t at all other t are calibrated in relation to t^*. Thus,

$$A_t = \frac{g(t^*)}{g(t)} \hat{=} \frac{X_{t^*}}{X_t} \quad ,$$

in which $A_{t^*} = \dfrac{X_{t^*}}{X_{t^*}} = 1.0$. In this study, t^* was the time interval with the maximum transformed value of X_t.

A "running mean of 3" manipulation has been used twice on the W_t estimates presented for point observations (Table 21) in order to achieve a more consistent pattern.

Calibration ratios and weight estimates, suggested for use in a calibration scheme in the analysis of call-count data of pigeons, are presented in Table 22. These proposed values were manipulated, according to procedures in the table, from the data in Table 21.

There is a very intriguing aspect to the weight estimates, $1/V(Y_t)$, of Table 22. Each value is actually an "information index". By examination of the values relative to each other, one can determine at what time intervals of the day the weighted call-count data will yield the greatest information.

Table 21. Estimates of the variance, $V(X_t)$, of the actual calling heard, calibration ratios, A_t, and weights, $1/V(Y_t)$, for 3-minute listening intervals, t, in the early-morning. The values are estimated from data of calling band-tailed pigeons on routes and point observations, 1967 and 1968.

t, Beginning at Minutes after Sunrise	$V(X_t)$			A_t			$1/V(Y_t)$		
	(A)	(B)	(C)	(A)	(B)	(C)	(A)	(B)	(C)[1]
-30	0.0475	--	0	26.22	--	283.82	0.0304	--	0
-24	0.0764	--	0	9.13	--	46.83	0.0524	--	0
-18	0.3208	0.0440	0	3.89	6.25	13.38	0.1124	0.5818	0
-12	0.7122	0.2523	4.683	2.17	2.94	3.51	0.2600	0.4585	0.0442
- 6	1.1933	0.2618	41.579	1.30	1.59	1.72	0.3093	1.5110	0.0659
0	1.6163	0.6500	41.252	1.04	1.14	1.09	0.6187	1.1839	0.0666
6	1.3875	0.6736	51.184	1.00	1.00	1.00	0.6500	1.4846	0.0643
12	1.3622	0.7101	39.484	1.12	1.16	1.05	0.3687	1.0466	0.0724
18	1.2430	0.4464	24.049	1.34	1.52	1.30	0.3901	0.9696	0.0742
24	1.2455	0.3233	23.270	1.47	2.00	1.51	0.2723	0.7733	0.0708
30	0.9433	0.2921	17.721	1.72	2.22	1.77	0.2996	0.6947	0.0630
36	0.8788	0.1600	13.135	2.14	2.78	2.08	0.2107	0.8087	0.0642
42	0.5322	0.1501	5.694	2.50	2.78	2.34	0.1457	0.8621	0.0703
48	0.6822	0.2613	5.153	2.72	2.86	2.96	0.1842	0.4679	0.0626
54	0.6142	0.2428	3.237	2.83	3.03	2.99	0.1902	0.4486	0.0519
60	0.3832	0.1269	10.237	3.00	3.76	3.12	0.1509	0.5574	0.0503
66	0.5007	0.0961	6.266	3.04	5.00	3.43	0.1843	0.4162	0.0586
72	0.5455	0.1146	1.099	2.92	4.76	4.02	0.1986	0.3851	0.0689
78	0.4988	0.1387	5.051	3.14	4.76	5.32	0.1555	0.3182	0.0528
84	0.3163	0.1269	2.949	4.90	4.55	5.41	0.1829	0.3806	0.0366
90	--	0.1576	2.381	--	4.55	5.75	--	0.3065	0.0206
96	--	0.1387	2.803	--	4.44	6.12	--	0.3657	0.0228
102	--	--	1.769	--	--	7.04	--	--	0.0267
108	--	--	0.696	--	--	7.43	--	--	0.0290
114	--	--	2.607	--	--	7.81	--	--	0.0246
120	--	--	1.687	--	--	6.42	--	--	0.0224
126	--	--	9.655	--	--	8.84	--	--	0.0263
132	--	--	1.056	--	--	7.81	--	--	0.0338
138	--	--	2.978	--	--	9.37	--	--	0.0357
144	--	--	1.856	--	--	8.51	--	--	0.0286
150	--	--	1.144	--	--	8.84	--	--	0.0228
156	--	--	1.799	--	--	7.43	--	--	0.0203
162	--	--	1.997	--	--	6.12	--	--	0.0228
168	--	--	1.633	--	--	5.51	--	--	0.0237
174	--	--	2.652	--	--	5.35	--	--	0.0228

(A) Data from numbers of pigeons heard on 60 call-counts, McDonald Forest route, 1967.

(B) Data from numbers of pigeons heard on 65 call-counts, McDonald Forest, Burnt Woods, Marys Peak, Cougar Ridge, Blodgett, and Dawson routes, 1968.

(C) Data from numbers of calls heard on 3 point observations, McDonald Forest, 1967; and 21 point observations, McDonald Forest and Burnt Woods, June and July, 1968.

[1] The values for point observations have been smoothed twice with a "running mean of 3" procedure.

Table 22. Calibration ratios, A_t, and estimates of weights, $1/V(Y_t)$, for 3-minute listening intervals, t, in the early-morning. These values are suggested for use in a calibration scheme in the analysis of call-count data of band-tailed pigeons. The values are estimated from data of calling pigeons on routes and point observations, 1967 and 1968.

t, Beginning at Minutes after Sunrise	A_t [1]	$1/V(Y_t)$ [2]
-30	155.02	0.0064
-24	27.98	0.0110
-18	7.84	0.0346
-12	2.87	0.0443
- 6	1.54	0.0822
0	1.09	0.0955
+ 6	1.00	0.1048
12	1.11	0.0764
18	1.39	0.0764
24	1.66	0.0620
30	1.90	0.0593
36	2.33	0.0565
42	2.54	0.0553
48	2.85	0.0452
54	2.95	0.0417
60	3.29	0.0413
66	3.82	0.0426
72	3.90	0.0461
78	4.41	0.0361
84	4.95	0.0345
90	5.15	0.0220
96	5.28	0.0253
102	7.04	0.0257
108	7.43	0.0279
114	7.81	0.0237
120	6.42	0.0216
126	8.84	0.0253
132	7.81	0.0326
138	9.37	0.0344
144	8.51	0.0276
150	8.84	0.0220
156	7.43	0.0196
162	6.12	0.0220
168	5.51	0.0228
174	5.35	0.0220

[1] Each A_t is a mean of the calibration ratios of that specific t listed in Table 21.

[2] Each $1/V(Y_t)$ is an estimate from the $1/V(Y_t)$ values of that specific t listed in Table 21 by the following procedure. For each column of $1/V(Y_t)$, all values over the 17t of -12 through 84 were summed; a "standardized" $1/V(Y_t)$ was obtained by dividing each $1/V(Y_t)$ by the summation of $1/V(Y_t)$ over these 17t; a mean of the now "standardized" $1/V(Y_t)$ was derived for each t across the three columns.

Discussion

Calibration ratios and weight estimates presented in this paper should be sufficient to initially support a calibration scheme for call-count routes of band-tails. Perhaps 3-5 years after an extensive band-tailed pigeon route program has been in effect, calibration ratios and weight values can be estimated from those data. Beginning at that time, judgement will be needed to determine how much weight to give A_t and W_t values presented in this paper and for those values estimated from the more-contemporary studies, for different geographical areas.

It must be realized that this calibration technique has not been used. It is being proposed in this paper as a method of analysis of call-count data of band-tailed pigeons. The use of the calibration scheme is believed to be a logical approach for the proper interpretation of call-count route data in relation to the habitat or geographical area. It will be necessary for future investigators to use data available to them from call-count routes to improve upon the calibration scheme.

V. BIBLIOGRAPHY

Allard, H. A. 1930. The first morning song of some birds of Washington, D. C.; its relation to light. American Naturalist 64:436-469.

Bennitt, R. 1951. Some aspects of Missouri quail and quail hunting, 1938-1948. 51 p. (Missouri. Conservation Commission, Bulletin no. 2)

Chambers, W. Lee. 1913. More band-tailed pigeon notes. Condor 15(1):41-42.

Cohen, A., H. S. Peters and L. E. Foote. 1960. Calling behavior of mourning doves in two midwest life zones. Journal of Wildlife Management 24(2):203-212.

Davis, J. 1958. Singing behavior and the gonad cycle of the rufous-sided towhee. Condor 60(5):308-336.

Dorney, R. S., D. R. Thompson, J. B. Hale and R. F. Wendt. 1958. An evaluation of ruffed grouse drumming counts. Journal of Wildlife Management 22(1):35-40.

Duke, G. E. 1966. Reliability of censuses of singing male woodcocks. Journal of Wildlife Management 30(4):697-707.

Duvall, A. J. and C. S. Robbins. 1952. Investigations of methods of determining abundance of breeding mourning doves in certain eastern states. In: Investigations of methods of appraising the abundance of mourning doves. Washington, D. C. p. 15-34. (U. S. Fish and Wildlife Service. Special Scientific Report: Wildlife no. 17)

Foote, L. E., H. S. Peters and A. L. Finkner. 1958. Design tests for mourning dove call-count sampling in seven southeastern states. Journal of Wildlife Management 22(4):402-408.

Gates, J. M. 1966. Crowing counts as indices to cock pheasant populations in Wisconsin. Journal of Wildlife Management 30(4):735-744.

Glover, F. A. 1953. A nesting study of the band-tailed pigeon in northwestern California. California Fish and Game 39(3):

397-407.

Goudy, W. H. 1960. Factors affecting woodcock spring population indexes in southern Michigan. Michigan Conservation Department, Game Div., Rept. no. 2281. 44 p. (Cited in: Duke, G. E 1966. Reliability of censuses of singing male woodcocks. Journal of Wildlife Management 30(4): 697-707)

Gullion, G. W. 1966. The use of drumming behavior in ruffed grouse population studies. Journal of Wildlife Management 30(4): 717-729.

Heath, R. G. 1961. A theoretical analysis of an audio-index. Lansing. 38 p. (Michigan. Department of Conservation. Game Division. Report no. 2273)

Houston, D. B. 1963. A contribution to the ecology of the band-tailed pigeon, Columba fasciata, Say. Master's thesis. Laramie, University of Wyoming. 74 numb. leaves.

Kabat, C. and D. R. Thompson. 1963. Wisconsin quail, 1834-1962 - population dynamics and habitat management. Madison. 136 p. (Wisconsin. Conservation Dept. Technical Bulletin no. 30)

Kendeigh, S. C. 1944. Measurement of bird populations. Ecological Monographs 14(1): 67-106.

Kerley, C. 1952. The call-road count as an index to breeding populations of the mourning dove in east Tennessee. In: Investigations of methods of appraising the abundance of mourning doves. Washington, D. C. p. 8-14. (U. S. Fish and Wildlife Service. Special Scientific Report: Wildlife no. 17)

Kimball, H. H. 1916. The duration and intensity of twilight. Monthly Weather Review 44(11): 614-624.

Kimball, J. W. 1949. The crowing count pheasant census. Journal of Wildlife Management 13(1): 101-120.

Kozicky, E. L. 1952. Variations in two spring indices of male ring-necked pheasant populations. Journal of Wildlife Management 16(4): 429-437.

Kozicky, E. L., T. A. Bancroft and P. G. Horneyer. 1954. An analysis of woodcock singing ground counts, 1948-1952. Journal of Wildlife Management 18(2):259-266.

Leopold, A. 1933. Game management. New York. Charles Scribner's Sons. 481 p.

Leopold, A. and A. E. Eynon. 1961. Avian daybreak and evening song in relation to time and light intensity. Condor 63(4):269-293.

McClure, H. E. 1939. Cooing activity and censusing of the mourning dove. Journal of Wildlife Management 3(4): 323-328.

McGowan, T. A. 1953. The call count as a census method for breeding mourning doves in Georgia. Journal of Wildlife Management 17(4): 437-445.

Mendall, H. L. and C. M. Aldous. 1943. The ecology and management of the American woodcock. Orono, Maine Cooperative Wildlife Research Unit. 201 p.

Neff, J. A. and J. C. Culbreath. 1947. Band-tailed pigeon natural history and its value for a management plan. Proceedings of the Annual Conference of the Western Association of State Game and Fish Commissioners 27: 154-164.

Norton, H. W., T. G. Scott, W. R. Hanson and W. D. Klimstra. 1961. Whistling-cock indices and bobwhite populations in autumn. Journal of Wildlife Management 25(4): 398-403.

Oregon. State Game Commission. Annual Report: Game Division. Portland, Oregon. 1967. 188 p.

Overton, W. S. 1969. Estimating the numbers of animals in game populations. In: Wildlife management techniques, ed. by R. H. Giles, Jr. 3d ed. The Wildlife Society. (In Press)

Peeters, H. J. 1962. Nuptial behavior of the band-tailed pigeon in the San Francisco Bay area. Condor 64(6): 445-470.

Peters, H. S. 1952. A summary of mourning dove call count investigations in Ohio. In: Investigations of methods of appraising the abundance of mourning doves. Washington, D. C. p. 35-46. (U. S. Fish and Wildlife Service. Special Scientific Report: Wildlife no. 17)

Petraborg, W. H., E. G. Wellein and V. E. Gunvalson. 1953. Roadside drumming counts, a spring census method for ruffed grouse. Journal of Wildlife Management 17(3):292-295.

Rosene, W., Jr. 1957. A summer whistling cock count of bobwhite quail as an index to wintering populations. Journal of Wildlife Management 21(2): 153-158.

Sheldon, W. G. 1953. Woodcock studies in Massachusetts. Transactions of the North American Wildlife Conference 18: 369-377.

Sisson, L. H. 1968. Calling behavior of band-tailed pigeons in reference to a census technique. Master's thesis. Corvallis, Oregon State University. 57 numb. leaves.

Snedecor, G. W. and W. G. Cochran. 1967. Statistical methods. 6th ed. Ames, Iowa State University. 593 p.

Southeastern Association of Game and Fish Commissioners. 1957. Mourning dove investigations, 1948-1956. Columbia, S. C. 166 p. (Technical Bulletin no. 1)

Stoddard, H. L. 1931. The bobwhite quail, its habitat preservation and increase. New York, Charles Scribner's Sons. 559 p.

Stone, C. P. 1966. A literature review on mourning dove song as related to the coo-count census. Denver. 28 p. (Colorado. Department of Game, Fish, and Parks. Special Report no. 11)

Swanson, C. V. 1968. Band-tailed pigeon research, July-September, 1968. [Olympia] 10 numb. and 27 unnumb. leaves. (Washington. Game Department. Progress Report no. 2 on Contract no. 14-16008-941: Contract to ascertain the distribution, effects of harvest regulations, mortality rates and habitats of band-tailed pigeons) (Duplicated)

Taber, R. D. 1949. Observations on the breeding behavior of the ring-necked pheasant. Condor 51(4): 153-175.

Wagner, F. H. 1952. Preliminary investigations on mourning dove index and survey methods in Wisconsin. In: Investigations of methods of appraising the abundance of mourning doves. Washington, D. C. p. 47-53. (U. S. Fish and Wildlife Service. Special Scientific Report: Wildlife no. 17)

Wales, J. H. 1926. The coo of the band-tailed pigeon. Condor 28(1):42.

APPENDICES

Appendix 1. Study areas used in this research.

Area	County, Oregon	Distance and Direction from Corvallis, Oregon	Elevation (ft.)
McDonald State Forest	Benton	5 miles, NW	500-1, 350
Burnt Woods	Lincoln	20 miles, W	750-1, 450
Marys Peak	Benton	15 miles, SW	1, 500-2, 800
Cougar Ridge	Linn	25 miles, SE	900-2, 400
Dawson	Benton	15 miles, S	1, 250-1, 750
Blodgett	Benton	12 miles, W	700-1, 500
Old Peak	Benton	8 miles, W	700-1, 500

Band-tailed Pigeon Call-count Survey

Observer ______________________
Address ______________________

Date ______________________

Route ______________________
County, State ______________________

Description of location of station no. 1 ______________________
____

local sunrise ______________________

Weather:	at start	at finish
temperature	___	___
cloud cover	___	___
wind vel.	___	___

General forest type ______________________
____

Station			Pigeons Heard		Remarks
no.	mileage @	time @	no. pigeons	no. calls	
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
Totals:			-----	----	

Appendix 2. A survey form suggested for use on call-counts of band-tailed pigeons. The actual form used should contain at least the information presented in this form.

Appendix 3. Instructions of suggested procedures for conducting call-count routes of band-tailed pigeons.

Instructions for Conducting Band-tailed Pigeon Call-counts

I. Use of the Route Form.

1. Record all information asked for at the top of the form.

2. Use the following Beaufort scale of wind velocity estimation.

Beaufort No.	Velocity (mph)	Indications of Velocity
0	< 1	Smoke rises vertically.
1	1-3	Direction shown by smoke drift but not by wind vanes.
2	4-7	Wind felt on face; leaves rustle; wind vane moves.
3	8-12	Leaves and small twigs in constant motion; wind extends light flag.

3. Record any changing or adverse weather factors (wind, rain, fog), any disturbing factors (stream noise, traffic noise), and any other pertinent information - under "Remarks" - for the proper station.

4. Record the odometer reading at each station. This assists in locating the same stations in future years.

5. Record the actual time that each station-observation is begun. Record this time for all stations.

6. Record the number of pigeons heard and calls heard (not notes) for each station observed. Record a zero (0) if no calling is heard. Record a dash (-) if the station is not sampled.

7. It is urged that the route form be completely filled-in. A fully-completed route form will greatly facilitate the analysis of call-count data.

II. Call-count Procedure.

1. Routes should be located and set-up prior to conducting a call-

count on it. When setting up the route, write a description of the location of station no. 1 on the route form. This will facilitate the use of the same starting point, and all successive stations, in the following years. A standard call-count route should consist of 20 stations, spaced at 1/2 mile intervals.

2. Each call-count route should be conducted once a year, during July 1-15.

3. Call-counts should not be conducted if there is a wind velocity greater than 7 miles per hour (greater than Beaufort 2) along the route. Call-counts should not be conducted during rain of any intensity.

4. Begin the call-count at station no. 1, at 6 minutes prior to sunrise, and proceed through station no. 20. The observation at station no. 20 should optimally be completed by 114 minutes after sunrise. It should be stressed that precision in the technique is lost if the route is not started at the prescribed time.

5. The listening interval at each station is precisely 3 minutes. Record the number of pigeons and the number of calls heard. Only record those pigeons that begin calling within the 3-minute listening interval, and those calls which are definitely heard.

6. At each station, turn off the engine and move a short distance from the vehicle prior to listening.

7. If a temporary disturbing factor (overhead plane, passing car, etc.) prevents suitable listening during the 3-minute interval, repeat the 3 minutes of listening when the vehicle has passed. If the distraction is very disturbing and will last (nearby logging operations, etc.), it would be better to by-pass the station (recording a dash for the proper station and the reason under "Remarks") than to get behind in the time schedule.