A PRELIMINARY STUDY OF THE EFFECTS OF TEMPERATURE ON THE TIME OF ENDING OF THE EVENING SONG OF THE MOCKINGBIRD.

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THE twilight period or the time between day and night is a period of the greatest importance to students of bird activity. Here diurnal birds change their types of activity and gradually retire. Nocturnal birds awaken, become active and take the place of the diurnal group.

In view of the importance of this time region, it is strange that there has been so little investigation of the ecological factors involved. Why do song birds have an evening song? What are the daily recurring stimuli which give this reaction? Is this stimulus temperature, relative humidity, light, or some combination of these? What causes operate to end the song? To what is due its variable beginning and its variable ending on different days? These questions relate to just one activity, that of the evening song. (There are many other activities however related to the twilight region.) What answers can we give to these questions?

We know that there is some relation between the time of ending of the evening song of birds and sunset—at least for relatively normal spring days—due to the investigations of Wright and others. Wright[2] (1912, 1913), in gathering his data, was more interested in getting the relative time at which different birds stopped their evening song than in the meteorological conditions under which they sang.

Others however have observed the effects of meteorological factors on bird song in general. Bicknell[3] (1884) says, "The influence of almost impalpable meteorological changes on the

[1] Read at the Forty-seventh Stated Meeting of the American Ornithologists' Union, Philadelphia, October 23, 1929.

[2] Wright, Horace W. Morning Awakening and Even-Song. Auk, Vol. 29, pp. 307–325 (1912); Vol. 30, pp. 512–537 (1913).

[3] Bicknell, Eugene P. A Study of the Singing of Our Birds. Auk, Vol. 1, pp. 60–71. Also see his other papers in this series as follows: Auk, Vol. 1, pp. 126–140; 209–218; 322–332 (1884); Vol. 2, pp. 144–154; 249–262 (1885).

singing of birds cannot fail to have been remarked, and the effect of decided weather changes must often have been apparent even to the most unobservant."

Following this, Bicknell gives much general data on weather and especially climate and bird song. Little is given on the Mockingbird. Fowler[1] (1899) suggested that temperature was an important factor in influencing the singing of birds. Raspail[2] (1907) noted the very great decrease in song of birds during the cold, damp and cloudy season of 1907. The Alexanders[3] (1908) thought that the effect of weather on song was two-fold, (1) indirect, acting chiefly through the food supply, and (2) direct. In support of the first statement, they state that Robins and Hedge Sparrows stop singing when there is heavy frost. If, however, they are well-fed on crumbs, they will sing every day no matter how severe the weather. As an example of a direct effect, he mentions the Mistle Thrush, which ordinarily does not sing in winter, singing a great deal during the mild spells of December, 1907. There was just as much food on the bad days when it did not sing as on the good days when it sang.

Investigations on the influence of weather factors on the evening song of birds have been few.

Schwan[4] (1920) and Haecker,[5] (1924) regarded temperature and light—especially light—as the most important meteorological factors influencing the evening song. Alford[6] (1925) observed the effect of weather factors upon the time of ending of the evening song of the Song Thrush (*Turdus musicus clarkei*) from February 1 to June 10 for three years. He found that a clear or hazy sky was the most favorable factor for late song ending. The next factors in importance were wind force and wind direction. An increase

[1] Fowler, W. W. Songs of Birds Affected by Temperature. Zoologist, 1899, pp. 324–325. Cited from Zool. Rec., Vol. 36 (1899), Entry 221 under Aves.

[2] Raspail, Xavier. Influence Météorologique de l'Annee 1907 sur le Chant des Oiseaux. Paris, Bull. Soc. Zool., Vol. 32, pp. 131–135 (1907).

[3] Alexander, C. J. and H. G. Some Observations on the Song Period of Birds. British Birds, Vol. 1, pp. 367–372.

[4] Schwan, Albrecht. Vogelgesang und Wetter, physikalischbiologisch Untersucht. Pfluger's Archiv fur die gesamte Physiologie, Vol. 180, pp. 341–347 (1920).

[5] Haecker, V. Reizphysiologisches uber den Abendgesang der Vogel. Pfluger's Archiv. f. gesamte Physiologie, Vol. 204, pp. 718–725 (1924).

[6] Alford, C. E. Effect of Weather on the Song Impulse. British Birds, Vol. 18, pp. 306–312 (1925).

in wind force resulted in an early cessation of song. The most favorable wind was from the southeast and the next from the west or southwest. If other factors were favorable, then a rise or fall of temperature of some degrees was unfavorable.

Practically all students of this problem of evening song point out species differences in song reactions to weather factors. The Mockingbird might be expected to react differently from the Yellow-billed Cuckoo.

From this brief literature review, it is readily seen that most of the work on song and weather has been done under European meteorological conditions and with European species of birds. No work has been done under Tennessee weather conditions nor on the time of ending of the evening song of the Mockingbird (*Mimus polyglottos polyglottos*), so far as the authors are aware.

So the authors have set for themselves the task of analysing this one twilight activity—the ending of the evening song—of this one bird—the Mockingbird. For this first study in the series, they further limited themselves to the relation of this song activity to sunset and to temperature. Field observations were started by the junior author on October 23, 1928, and continued at intervals through April 20, 1929, a total of sixty-five evenings being spent in this manner. Each observation started at least thirty minutes before sunset and extended after sunset until sometime after the last bird call or note ceased.

A constant place for observation was used in order to make the data strictly comparable. The driveway back of the Gray building on the campus of George Peabody College for Teachers, Nashville, Tennessee, was selected because of accessibility and the number of Mockingbirds nearby.

Temperature readings were taken every fifteen minutes in the shade at a height of three feet from the ground with a standard Fahrenheit thermometer shaken to minimize radiation and insolation effects. The exact temperature for the time of ending of the song was determined by interpolation by a method described by Walker[1] (1929). The watch used to determine the exact time of

[1] Walker, Gladys. The Relation of Temperature, Relative Humidity and Wind Velocity to the Evening Song of Birds. Unpublished Master's thesis. George Peabody College for Teachers.

the ending of the evening song was checked daily by central standard time.

The data gathered in the field must now be studied in order to determine relationships. The data may first be displayed in graphs (Fig. 1). The time at which the Mockingbird ceases singing presents the usual fluctuating or saw-toothed curve. However, on the average this parallels sunset time to a remarkable degree and therefore is closely correlated with it. This fact makes it reason-

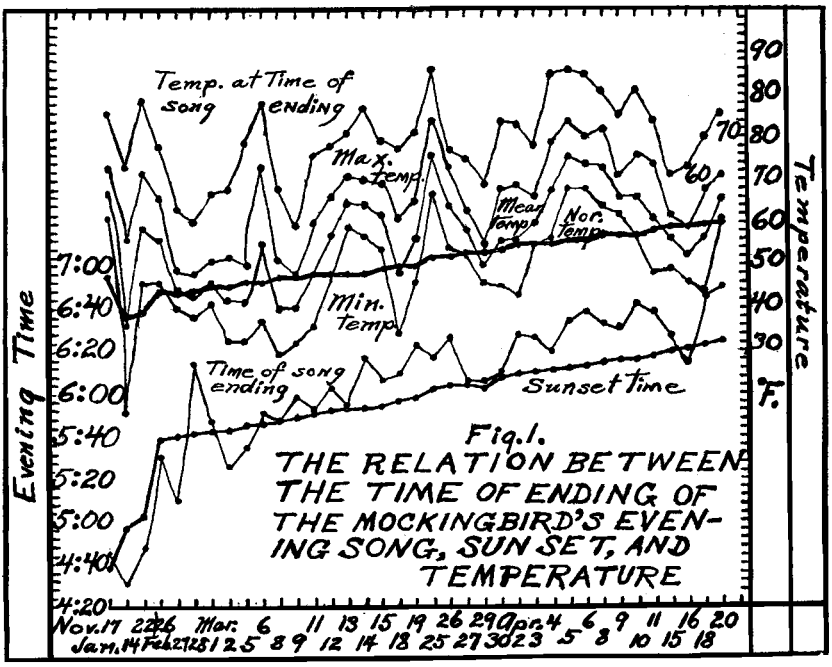


Fig. 1. THE RELATION BETWEEN THE TIME OF ENDING OF THE MOCKINGBIRD'S EVENING SONG, SUNSET, AND TEMPERATURE

ably certain that the cause or causes of the ending of the evening song of the Mockingbird are also highly correlated with sunset time. Many possible factors thus correlated suggest themselves, but only the one of temperature is being considered in this paper. Besides the temperature at the time of ending of the Mockingbird's song, maximum daily temperature, mean daily temperature, minimum daily temperature, and normal daily temperature, have been expressed in graphs in figure 1. (These last four groups of data were

kindly furnished by the Nashville Weather Bureau. Normal temperature is the average temperature for this date based on 58 years' records).

It is seen at once that all of the temperature curves, except the one of normal temperature, roughly parallel each other. In general, their trend is somewhat similar to that of normal temperature and therefore to sunset time, since normal temperature and sunset time are almost parallel to each other. This means, as regards their general trend, that these curves of temperature are all related to the time of ending of the evening song of the Mockingbird. In other words, the Mockingbird sings later in the evening when the average temperature is highest and stops singing earlier when the average temperature is lower. However the fluctuations in the temperature curves appear to be related to the fluctuation in the time of the song-ending curve in only a general way; there does not appear to be any very specific relation.

Since direct comparison of these temperature curves and the curve of the time of ending of the evening song of the Mockingbird is difficult, they were compared by a mathematical method—their product-moment correlation coefficients. Sunset time was also compared in this same manner with the time of ending of the Mockingbird's song. This last case might be used to illustrate the method of comparison. A ranking method was used (Table 1.)

This table is practically self-explanatory and so there will be no need to discuss it further except to point out the significance of the coefficient of correlation. Perfect correlation will give a coefficient (r) of 1.00, the absence of correlation will be indicated by 0, and perfect negative correlation by -1.00. The significance of the correlation depends in part on the size of the probable error and in part on the number of classes. This last factor is so small in this study as to make all results secured tentative.

The correlations obtained between time of ending of the Mockingbird's song and temperature by this method of study were as follows:

With temperature at the time of ending of the song,	$r = .27 \pm .10$
With daily maximum temperature,	$r = .41 \pm .09$
With daily mean temperature,	$r = .49 \pm .08$
With daily minimum temperature,	$r = .52 \pm .08$
With daily normal temperature,	$r = .81 \pm .08$

TABLE 1. ILLUSTRATING THE COMPUTATION OF THE PRODUCT-MOMENT CORRELATION COEFFICIENT.

Date	Time of Sunset (x)	Time of ending of Mocking-bird's song (y)	Deviation from assumed mean (d_x)		Deviation from assumed mean (d_y)		$(d_x)^2$	$(d_y)^2$	Product-moment ($d_x d_y$)	
Nov.			+	−	+	−			+	−
17	4:38	4:45		82		75	6,724	5,625	6,150	
Jan.										
14	4:55	4:31		65		89	4,225	7,921	5,785	
22	5:03	4:48		57		72	3,249	5,184	4,104	
Feb.										
26	5:39	5:30		21		30	441	900	630	
27	5:40	5:10		20		50	400	2,500	1,000	
28	5:41	6:15		19	15		361	225		285
Mar.										
1	5:42	5:47		18		13	324	169	234	
2	5:43	5:26		17		34	289	1,156	578	
5	5:45	5:35		15		25	225	625	375	
6	5:46	5:51		14		9	196	81	126	
8	5:48	5:47		12		13	144	169	136	
9	5:49	5:59		11		1	121	1	11	
11	5:51	5:52		9		8	81	64	72	
12	5:52	6:03		8	3		64	9		24
13	5:53	5:54		7		6	49	36	42	
14	5:53	6:17		7	17		49	289		119
15	5:54	6:06		6	6		36	36		36
18	5:57	6:09		3	9		9	81		27
19	5:58	6:23		2	23		4	529		46
25	6:03	6:17	3		17		9	289	51	
26	6:04	6:27	4		27		16	729	108	
27	6:04	6:05	4		5		16	25	20	
29	6:06	6:02	6		2		36	4	12	
30	6:07	6:10	7		10		49	100	70	

TABLE 1. ILLUSTRATING THE COMPUTATION OF THE PRODUCT-MOMENT CORRELATION COEFFICIENT—*Continued.*

Date	Time of Sunset (x)	Time of ending of Mocking-bird's song (y)	Deviation from assumed mean (d_x)	Deviation from assumed mean (d_y)	$(d_x)^2$	$(d_y)^2$	Product-moment ($d_x d_y$)
Apr.			+ −	+ −			+ −
2	6:09	6:28	9	28	81	784	252
3	6:10	6:26	10	26	100	676	260
4	6:11	6:20	11	20	121	400	220
5	6:12	6:35	12	35	144	1,225	420
6	6:13	6:39	13	39	169	1,521	507
8	6:15	6:33	15	33	225	1,089	495
9	6:16	6:31	16	31	256	961	496
10	6:16	6:42	16	42	256	1,764	672
11	6:17	6:38	17	38	289	1,444	646
15	6:20	6:27	20	27	400	729	540
16	6:21	6:14	21	14	441	196	294
18	6:23	6:46	23	46	529	2,116	1,058
20	6:25	6:51	25	51	625	2,601	1,275
Total	219:19	224:19	+ 232 − 393 = − 161	+ 564 − 425 = − 139	20,753	42,253	+ 26639 − 537 = + 26102
Mean	5:56	6:04	c_x = − 4.35 min.	c_y = 3.76 min.	560.891	1141.973	719.973
Assumed Mean	6:00	6:00	c_x^2 = 18.923	c_y^2 = 14.138	c_x^2 = 18.923	c_x^2 = 14.138	$c_x c_y$ = 16.356
$\sqrt{1127.835}$ or 33.583 = σ_y (Standard deviation)					541.968	1127.835	736.329

$\sqrt{541.968}$ or 23.2802 = σ_x (Standard deviation). $\sigma_x\sigma_y$ = 781.812

736.329 divided by $\sigma_x\sigma_y$ or 781.812 = .94 or r or coefficient of correlation

These coefficients are all suggestive but only the one with normal temperature is high enough to be regarded as significant. This high correlation was expected from the graph study (Fig. 1) since normal temperature parallels sunset time. In general then, average temperature (normal temperature in this case is the average of fifty-eight years) is most highly related to the time of ending of the Mockingbird's evening song, the song ending later when the average temperature is higher and earlier when the average temperature is lower.

The coefficients of correlation with temperature (temperature at time of the ending of the evening song, daily maximum temperature, daily mean temperature, and daily minimum temperature) are probably due to the fact that they are correlated with normal temperature. To determine to what extent this was the case, the influence of normal temperature on these correlations was eliminated by the statistical method of partial correlations. The method was as follows:

Let: 1 = Actual time of ending of the evening song of the Mockingbird
2 = The temperature at this time
3 = Normal temperature for the day

Then:

r_{12} = the correlation between 1 and 2 = .27
r_{13} = " " " 1 and 3 = .81
r_{23} = " " " 2 and 3 = .42

Substituting in the formula, $r_{12.3} = \dfrac{r_{12} - r_{13}r_{23}}{\sqrt{(1 - r^2_{13})\quad(1 - r^2_{23})}}$

$$r_{12.3} = \frac{.27 - .81 \times .42}{\sqrt{(1 - .81^2)\quad(1 - .42^2)}}$$

Solving $r_{12.3} = -.13$ Too low to be of value.

The correlations obtained between time of ending of the Mockingbird's song and temperatures, when the relations of normal temperature to the other temperatures were controlled were as follows:

With temperature at the time of ending of the song,	$r_{12.3} = -.13$
With daily maximum temperature,	$r_{12.3} = .03$
With daily mean temperature,	$r_{12.3} = .007$
With daily minimum temperature,	$r_{12.3} = .08$

These coefficients are too low for consideration. This fact, in connection with the high correlation coefficient between time of the song ending and normal temperature, strongly suggests that this song ending is related to climatic or average temperature but not to the fluctuating temperature from day to day.

However the preceding analyses do not show whether the Mockingbird stops singing later after sunset on warm days than on cold ones. They show that he sings later on warm days but sunset time is left out of the picture. By recording the deviations of the time as minus when the song ends before sunset and plus when the song ends after sunset, the data are brought into relation to sunset time.

Now a scatter diagram, such as is used by statisticians and has been used by Alford (1925) in his study of the Song Thrush, in which the time of ending of the song in relation to sunset is graphed against temperature, may be used to picture the relationship here. Such a diagram, using the temperature at the time of ending of the evening song (Fig. 2) shows the relation of temperature to the time of song ending.

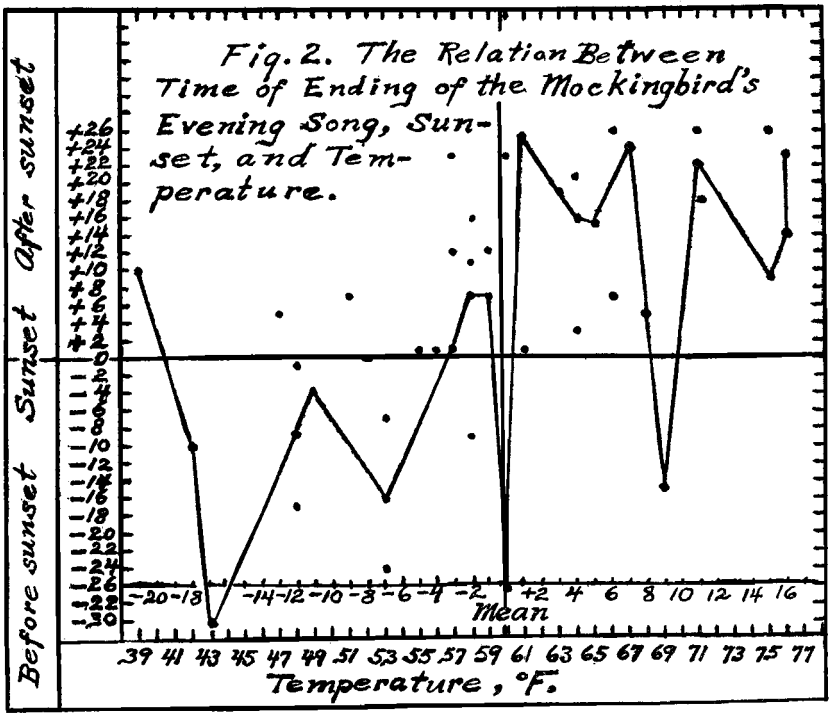
The nearer all points fall to a straight line the higher the correlation. From this fact, it is readily seen that a correlation exists in time of ending of the evening song of the Mockingbird from sunset but that it is not high. Since the other temperature factors give, with the time of ending of the evening song, a somewhat similar type of scatter, their scatter diagrams need not be given here. Instead the relations between the various temperatures and the time of ending of the evening song of the Mockingbird from sunset time might be conveniently summarized by means of coefficients of correlation as follows:

Correlation of time of ending of the evening song of the Mockingbird from sunset time with:

Temperature at time of ending of the song,	$r = .57 \pm .07$
Maximum temperature of day,	$r = .55 \pm .07$
Mean daily temperature,	$r = .52 \pm .07$
Minimum daily temperature,	$r = .46 \pm .08$
Normal daily temperature,	$r = .50 \pm .08$

These correlations strongly indicate a positive influence of temperature, the Mockingbird singing later after sunset on warm days and earlier on cold days.

However sudden and decided changes in temperature might conceivably be found to be significant, for Eagle Clarke[1] (1896, 1912) found these to be quite significant in initiating migration in both the autumn and spring season. These results were later confirmed by Cooke[2] (1913). Since Clarke compared the mean temperature



of the day with that of the preceding day, this method was first tried with our Mockingbird song data using Weather Bureau means. Daily mean temperature deviations were recorded as plus or minus and then compared with the song time deviations, from sunset (Fig. 2). These graphs indicate no relation between mean daily

[1] Clarke, W. Eagle. Effect of Weather on Birds. Rep. Brit. Assoc. Adv. Sci., 1896, pp. 451–477. Also see volume one, pages 171–187, of his three volumes, Studies in Bird Migration (1912).

[2] Cooke, Wells W. The Relation of Bird Migration to the Weather. Auk, Vol. 30, pp. 205–221.

temperature changes and the time of ending of the Mockingbird's song. Calculation of the coefficient of correlation gave r = .12. This is too low to be significant.

A similar temperature comparison was made between the deviations of the temperature at the time of ending of the Mockingbird's song *from* the daily mean temperature *and* the deviations of the time of ending of the song from sunset. The result was, r = −.11, and therefore of no significance.

On reflection, it appeared likely that small changes of temperature might have less value proportionately than great changes or they might have no effect whatever, even serving to neutralize the effect of the big changes. With this in mind, all mean daily temperature deviations of less than 5 degrees Fahrenheit from the preceding day, were eliminated and the coefficient of correlation determined for the remaining mean temperatures. It was, r = .11 and therefore of no significance. An examination of the few cases where the temperature deviations were as great as 10 degrees Fahrenheit indicated no relation here.

Another method of studying temperature relations used was to compare the temperature at the time of ending of the evening song with the temperature at sunset. These curves show that the temperatures of the two curves are practically the same throughout the period of study. In thirty-one cases, they were the same, or differed by less than half a degree (the thermometers used could be read accurately only to a half a degree), in the two curves; in six cases, they differed by as much as one degree. There were no greater differences. This renders valueless a comparison of temperature deviations from sunset temperature with time of ending of the Mockingbird's song from sunset time.

SUMMARY.

1. Field observations were made of the time of ending of the evening song of the Mockingbird and temperature at Nashville, Tennessee, from October 23, 1928 to April 30, 1929, a total of sixty-five evenings—mainly in February, March, and April—being spent in this way.

2. The time of ending of the evening song of the Mockingbird is highly correlated with the time of sunset, the correlation being .94 ± .01. Perfect correlation would be 1.00.

3. There is little relation between the temperature at the time of song ending and the time of ending of the Mockingbird's evening song. The coefficient of correlation here is .27 ± .10.

4. Maximum, minimum, mean, and normal temperatures were also found to be correlated with the time of ending of the evening song of the Mockingbird in this order: .41, .52, .49, and .81. This last correlation indicates the importance of average temperature on this activity. On the average the Mockingbird sings later on warm days and stops earlier on cold days.

5. There is no particular virtue in any one of these temperature groups over the others unless it be that of normal temperature. The correlations of song ending with maximum, minimum, and mean temperatures and with the temperature at the time of song ending are largely expressions of their correlations with normal temperature. This was indicated by eliminating the influence of normal temperature mathematically by the method of partial correlations.

6. Neither small nor large changes in mean temperature from the preceding day are related to changes in time of ending of the song of the Mockingbird. With changes of five degrees F. or more, the coefficient of correlation is .11; with all changes it is .12.

7. The deviations of the temperature at the time of the ending of the Mockingbird's evening song from the daily mean temperatures has no significant correlation with the time of ending of this song for r = − .11.

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