A PRELIMINARY REPORT ON THE INFLUENCE OF LIGHT INTENSITY UPON THE TIME OF ENDING OF THE EVENING SONG OF THE ROBIN AND MOCKINGBIRD[1]

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The very great importance of transition areas has long been recognized in animal ecology, but relatively little attention has been paid to transition intervals of time such as those between night and day.

The very great need of exact studies of the transition interval between day and night is well indicated by Elton (1927, page 89). He says that "A careful study of the changes in external conditions during the day and night with reference to corresponding changes in the activities of animals is very badly wanted, for our ignorance of the matter is profound. It is remarkable to reflect that no one really knows why rabbits come out to feed only at certain times, and at different times on different days . . . and yet rabbits are common animals and of great practical importance, and millions of people have watched their habits. We do not know whether light, temperature, humidity, or something else determines the appearance and retirement of animals at certain times."

All that Elton says about rabbits is equally true of birds. Some birds, as owls, come out only at night and retire early in the morning while most birds are active during the daytime and retire at nightfall. This last is true of most of our song birds. In studying this interval when day passes into night, bird activities are most useful and especially bird song since it may be recorded even when it is too dark to see the bird. Furthermore the song sung near sunset—called in this paper the evening song—has been shown by Shaver and Miss Gladys Walker (1930) to be highly correlated with sunset time in the case of the Mockingbird and to have a sharp end point. This makes this particular song well-fitted for study.

Many possible weather factors are changing rather rapidly during the twilight period and conceivably might be causally related to the time of ending of the evening song of diurnal species. The scanty literature on this subject indicates that light is one of the most important of these factors.

In 1916 and again in 1924, Haecker reported on studies of the relation between light and the time of beginning song in the morning and the time of song ending in the evening. In his first study (1916),

[1]Read by the senior author before the Ecological Society of America at the Des Moines meeting, December 30, 1929.

sunlight intensity was investigated both subjectively and objectively. In collecting his objective data on light, he used a crude apparatus consisting of a bar with a piece of spectacle glass at one end for an eye-piece and a sliding plate containing letters of a certain height at the other end. He moved this plate back and forth using the distance at which he could read the letters as the relative measure of the light intensity at the time that a bird began singing. His conclusions were that there is a definite and high correlation between the time of beginning song and the light intensity.

Later Haecker (1924) made observations on the evening song of birds. Light summation of the hours of sunshine per day was made and used as well as the data on light intensity. The light was measured photometrically. This work confirmed his earlier results on the very great importance of light in determining the time that birds quit singing in the evening. However, he found that the evening song began in much stronger light than the morning song but it also ended when more light existed than at the beginning of the morning song.

Schwan, according to Walker (1928) used more accurate methods of measuring light but secured quite similar results in the case of the awakening song.

Dorno (1924) repeated a part of Haecker's work and came to the conclusion that light was significant, but that the variation in the time between the beginning of the morning song and sunrise was due to differences in dispersal of light rays rather than the actual intensity of the light present. He is of the opinion that this dispersal is due to the latitude of the region and season of the year.

Walker (1928) in Tennessee made a study of the relation of light intensity to the awakening song of birds. The study was at first subjective, in that the weather was estimated as clear, cloudy, foggy, or smoky and later objective in that the Macbeth illuminometer was used for measuring light intensity in foot-candles.

Her findings seem to indicate that the length of time before sunrise at which a bird begins singing is probably dependent on the total amount of light present when measured in foot-candles but to a very great extent on other weather factors also.

Knowledge of the above results caused light intensity to be selected for this investigation. It seemed best not only to study one single factor, such as light, at a time, but to limit the first studies to a single species or, at most, to a very few species in order to simplify analysis. A permanent resident, the Mockingbird, and a summer resident, the Robin, were selected. Thus the problem involved the rela-

tion between the time of ending of the evening song of the Robin and of the Mockingbird, and light intensity.

Observations were made beginning February 1, 1929, and extending through May 7, 1929; a total of 53 evenings being spent in this way, distributed rather uniformly over each month as follows: 12 in February, 16 in March, 19 in April, and 6 in May.

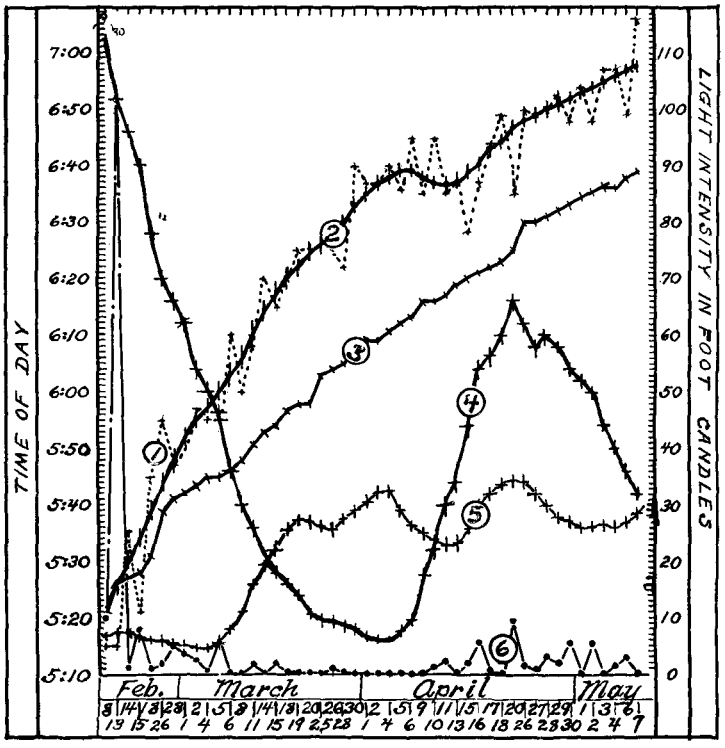

FIG. 3. A Comparison of the Time of Ending of the Evening Song of the Robin with Sunset and with Light Intensity. The numbered curves represent: 1, actual time of the ending of the evening song; 2, smoothed time of ending of the evening song; 3, time of sunset; 4, smoothed light intensity at the time of ending of the evening song; 5, smoothed light intensity at sunset; 6, actual light intensity at the time of ending of the evening song. It should be noted that curve 4 (smoothed light intensity at the time of ending of the evening song) is given on a greatly enlarged scale as respects the ordinate axis in order to emphasize its form. For this curve, each unit of the ordinate equals .05 foot candles.

The type of data gathered may first be displayed in graphs so as to show the seasonal changes in bird song activity and in light as compared to sunset. Figure 3 is for the Robin. It is noticed at once, in

spite of the saw-toothed curve of the song, that, in general, the time of ending of the Robin's song parallels sunset time. The light intensity at the time of the song ending varied from .1 to 10.0 foot-candles with the exception of one high day of 101.6 foot-candles. This exceptional day, February 13, 1929, was the second day of the year for the Robins to sing their evening song at this spot and was separated from the first day that they sang by two bright days when they did not sing. It is regarded as very significant that on 47 out of 48 singing days, the Robin stopped its evening song within a range of light intensity of 10 foot-candles. Median light intensity for all days was 6.2 foot-candles at the time of the song ending.

The variability of the evening song ending appears, as respects light intensity, to be related in part to other physiological activities of the Robin, being most variable during the period of the establishment of territory, and during the time of feeding the young, in which the male helps.

The light intensity at sunset was exceedingly variable, ranging from 2 to 115 foot-candles.

The graph (Fig. 4) of the time of ending of the Mockingbird's evening song, like that of the Robin, parallels, in a general way, the time of sunset. Light intensity at the time of ending of the Mockingbird's song is quite variable, ranging from .1 to 175.8 foot-candles, with a median of 19.35.

In data like this, it is desirable to get the average change as well as the actual change. This may be done by smoothing the curve by use of a formula selected by trial and error. The method of smoothing used here may be illustrated by Figure 5 where both the smoothed and unsmoothed curves for light intensity at sunset on the days the Robin sang are given. The unsmoothed values are given above the curves under the letters: *a*, *b*, *c*, *d*, . . . *t*, *u*, *v*. At the top of the figure is given the general formula used for smoothing and just below it the method of using the formula for determining smoothed values for February 8, 13, 14, 15, and 18, respectively. The letters as used in the formula stand for the light intensity values indicated above the graphs.

The smoothed curve of time of ending of the Robin's song (Fig. 3) diverges more and more from the sunset curve until April 6. This means that the Robin sings later and later after sunset on the average until April 6. Then the curves converge until April 13 when they proceed approximately parallel to the end of the period of observation. Apparently this period of convergence corresponds closely with the

period of the feeding of the newly hatched young. It indicates clearly that any study of this kind must consider the physiological activities associated with nesting.

The smoothed light intensity at the time of the ending of the Robin's song (Fig. 3) was such that the Robin stopped singing, when

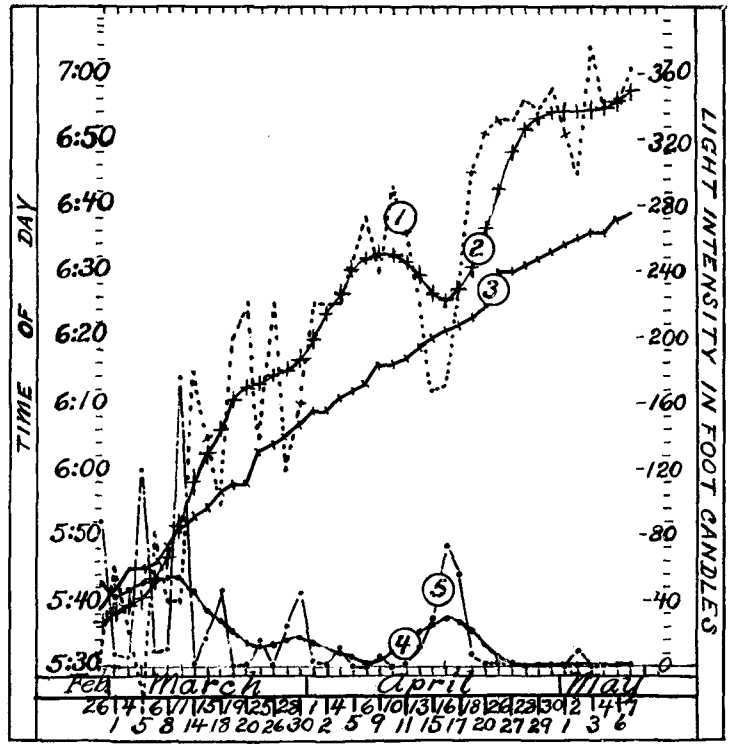

FIG. 4. A Comparison of the Time of Ending of the Evening Song of the Mockingbird with Sunset and with Light Intensity. The numbered curves represent: 1, actual time of ending of the evening song; 2, smoothed time of ending of the evening song; 3, time of sunset; 4, smoothed light intensity at the time of ending of the evening song; 5, actual light intensity at the time of ending of the evening song.

there was less and less light on successive days, until April 4, when it stopped singing with a greater and greater light intensity on successive evenings until April 20. From April 20 to May 7, the Robin stopped his evening song with the light intensity getting less and less. Thus, as far as these data go, there appears a periodic rhythm in this song activity as related to light. This rhythm seems to the authors to be related to the rhythm of physiological activities associated with the nesting cycle.

It should be noted that the actual light intensity at sunset is exceedingly variable, ranging from 2 to 115 foot-candles with a median of 43.5.

The smoothed curve of the time of ending of the Mockingbird's song (Fig. 4) shows similar rhythms to that of the Robin's song with the major depression occurring about April 15. In addition, there are two minor depressions about March 5 and 28. All of these depressions are like the single large depression in the case of the Robin in that the Mockingbird quits singing when the light intensity is higher than usual. It is thought that these rhythms in reaction to light are associated with the nesting cycle. However these rhythms might be associated with unmeasured environmental factors other than light since Shaver and Gladys Walker (1930) have found that the time of ending of the evening song of the Mockingbird is significantly related to temperature.

The data may be further analyzed by the product-moment correlation method of Pearson. This method of analysis gives a single number—the coefficient of correlation—to indicate the correlation between two curves. When the coefficient of correlation is 1.00, there is perfect positive correlation between the two curves; when this coefficient equals 0, there is no correlation; and when it is —1.0 it indicates perfect negative correlation. The method used in calculating this coefficient has been given in detail elsewhere (Shaver and Gladys Walker, 1930) and need not be repeated here.

Table I shows quite clearly the very high positive correlations existing between the time of sunset and the time of ending of the evening song of the Robin and the Mockingbird. This indicates, as has been previously pointed out, that the causative factors of these song endings are related to sunset. Light appears to be the most important of these.

The correlations between the time of ending of both the Robin's and Mockingbird's evening song and light intensity are negative. This apparently means that when these birds stop singing later in the evening than usual, they stop when the light intensity is less than when they stop singing earlier in the evening.

There are several elements which tend to increase the negative values of some of the coefficients. In the second correlation in the table, the increase in the length of the day as spring comes on, increases numerically the values for the time for ending of the evening song. Evening begins no longer at 5:21 but at 6:38. The error due to increase in length of day has been eliminated in correlations 3 by hav-

ing all time calculated from sunset (central standard time, Weather Bureau sunset data). It should be noted in the table that this gives lower coefficients of correlation, as was expected.

Correlations number 3, 5, and 6 are influenced by the increase in the length of twilight after sunset as spring advances because this increases the length of time after sunset to a light of a definite intensity.

TABLE I

The correlation betwen the time of ending of the evening song of the Robin and the Mockingbird and various factors.

No. of the Correlation	The Factors Correlated		*Correlation Coefficients*	
			Robin	*Mock'bird*
1	Time of ending of the evening song	Time of sunset	.92±.01	.94±.01
2	Time of ending of the evening song	Light intensity at the time of ending of the evening song	—.42±.08	—.62±.06
3	Deviation of the time of ending of the evening song from sunset time	Light intensity at the time of ending of the evening song	—.27±.09	—.55±.07
4	Deviation of the time of ending of the evening song from its smoothed value	Deviation of light intensity at the time of ending of the evening song from its smoothed value	—.30±.09	—.65±.06
5	Deviation of the time of ending of the evening song from sunset time	Deviation of light intensity at sunset from its smoothed value	.054±.097	—.36±.09
6	Deviation of smoothed time of ending of the evening song from sunset	Smoothed light intensity at the time of ending of the evening song	—.81±.03	—.77±.04

Finally, as brought out earlier in this paper, the physiological state of the bird, as respects its nesting cycle, apparently influences its song reaction to light.

When all of these things were taken into account, the correlations between the Robin's song ending and light intensity were regarded as expressing the real conditions very unsatisfactorily. In the field work when the days were bright and clear, our notes said that both the Robin and Mockingbird sang later than on cloudy days. The coefficients of correlation already given on light do not indicate this relation.

For a long time the reason for this failure was not apparent. Then it finally came to us that in calculating our coefficients of correlation, no measure of whether the day was cloudy or sunny had been used. We had merely gotten a numerical expression of the relation

between the time of song ending and the light intensity at that time. Just as should have been expected, it was found that when the birds sang later after sunset, they stopped singing at a lower light intensity than when they stopped singing earlier.

Now the light intensity at sunset would give a numerical measure of whether the day was sunny or cloudy and would in addition link light intensity with sunset just as has been done with the time of the song ending. Accordingly, coefficients of correlation between light intensity at sunset and the length of time after sunset to the song ending of both the Robin and Mockingbird were calculated. These coefficients were .54±.07 for the Robin and .58±.07 for the Mockingbird. These coefficients are high enough to be regarded as significant. They indicate that light intensity is a very important factor in causing the ending of the evening song. Still they are low enough to show that light is not the only factor affecting the time of ending of the evening song of these birds.

By correlating smoothed light intensity at sunset and smoothed time of song ending after sunset, similarity of trends can be discovered. The coefficients of correlation for these smoothed curves are .91±.02 for the Robin and .81±.04 for the Mockingbird. These coefficients are high and to the authors indicate that light is the main factor causing the ending of the evening song. Other factors may cause the song to end a few minutes earlier than usual or a few minutes later, but light intensity appears the most significant factor.

Conclusions

1. The time of ending of the evening song of the Robin and of the Mockingbird is highly correlated with sunset time, the coefficients of correlation being .92±.02 for the Robin and .94±.01 for the Mockingbird.

2. On 47 out of 48 days when the Robin sang the evening song, it finished its song within a light range from .1 to 10 foot-candles. This is regarded as a very significant light relation.

3. The light intensity at the time of ending of the evening song of the Mockingbird was quite variable ranging from .1 to 175.8 foot-candles with a mean of 19.3488 and a standard deviation of 36.2167. This gives no indication of the absolute light intensity being significant in the case of the Mockingbird.

4. There is some evidence, in the case of both of these birds, of a variation in the song ending with respect to light intensity according to the physiological relation of the bird as respects the nesting cycle.

5. There is a general tendency for both the Robin and the Mockingbird to stop their evening song at a low light intensity when they sing late after sunset. This is especially marked with the Mockingbird as indicated by the high negative correlations (No. 2, 3, and 4 in Table I).

6. Both the Robin and the Mockingbird sing later after sunset on bright days than on cloudy ones. That this is not the whole story is

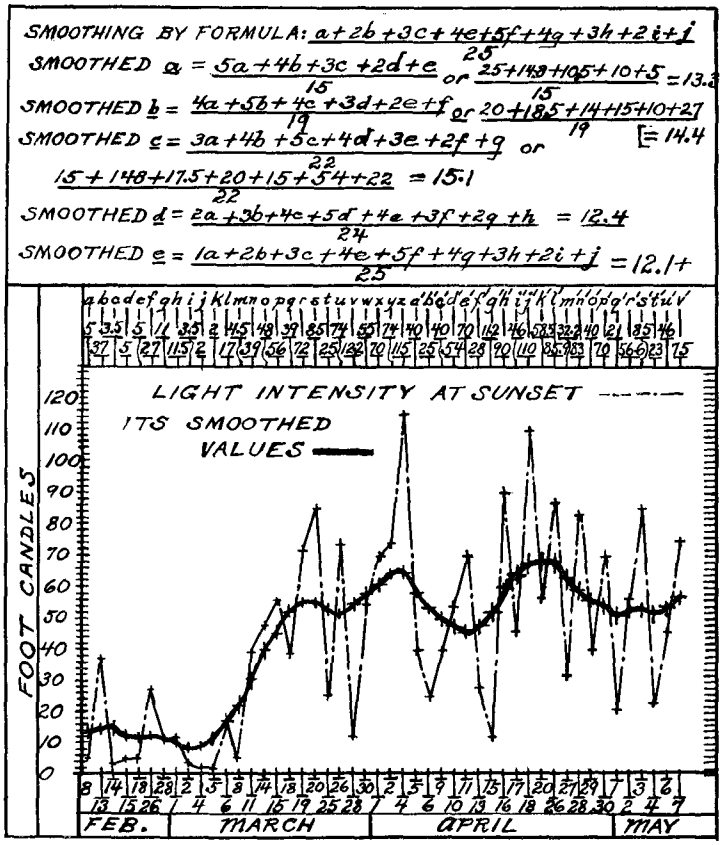

FIG. 5. The Method of Smoothing Curves.

indicated by the smallness of the coefficients of correlation when the time of song ending from sunset is compared with light intensity at sunset. These coefficients were .54±.08 for the Robin and .58±.07 for the Mockingbird.

7. Trends, as indicated by correlating smoothed curves, show that light intensity at sunset is very significant in relation to the time after

sunset that the Robin and the Mockingbird sing, the coefficients being .91±.02 and .81±.04, respectively. It seems highly probable that light intensity is the main cause of the song ending but that other factors cause it to vary somewhat, causing the song to end earlier than usual on some days and later on others.

Literature Cited

Dorno, C., 1924. Reizphysiologische studien über den Gesang der Vögel im Hochgebirge. Pflüger's Archiv für die gesamte Physiologie, 204: 642-651.

Haecker, V., 1916. Reizphysiologisches über Vögelzug und Frühgesang. Biologisches Centralblatt., 36: 403-431.

———— 1924. Reizphysiologisches über den Abendgesang der Vögel. Pflüger's Archiv für die gesamte Physiologie, 204: 718-725.

Schwan, Albrecht, 1920. Vogelgesang und Wetter. Pflüger's Archiv für gesamte Physiologie, 180: 341-347.

Shaver, Jesse M., and Gladys Walker, 1930. A Preliminary Study of the Effects of Temperature on the Time of Ending of the Evening Song of the Mockingbird. Auk, 47: 385-396.

Walker, Emily Barry, 1928. The Relation of Light to the Awakening Song of Birds. An unpublished master's thesis, George Peabody College for Teachers.

Walker, Gladys, 1929. The Relation of Temperature, Relative Humidity, and Wind Velocity to the Evening Song of Birds. An unpublished master's thesis, George Peabody College for Teachers.

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THE SOARING OF RAPTORIAL BIRDS*

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Perhaps the most spectacular of the many accomplishments of birds is that strange modification of their flight called soaring. An old red-tail, floating high in the air, moving in more or less irregular circles, banking in the sharp turns or against sudden gusts until he is a mere speck against the sky, "oozing around," as Riley says, and with scarcely a beat of the wing, does not fail to register on the mind of even a casual observer. A buzzard appearing as a mere dot in the distance and slowly moving towards a decaying carcass, bent on the

*This paper was transmitted to the present Editor in 1925 by his predecessor; the delay in publication has been due to the misplacement of the figures.—Editor.