VARIATION IN THE MORNING AWAKENING TIME OF SOME BIRDS IN SOUTH-CENTRAL MICHIGAN

By GEORGE F. FISLER

Many authors have commented on the regularity with which birds first sing in the morning, each species apparently having its own particular awakening time. Allard (1930:460), Nice (1943:108), and others have noted that different species followed each other in an orderly sequence of morning awakening song and have referred to this phenomenon as the "bird clock." The first serious study of awakening time was undertaken by Wright (1912, 1913) who recorded awakening times for several years in the mountains of New Hampshire. Allen (1913) published some additions and corrections to Wright's (1913) work and added some of his own records in 1915 and 1922. Allard's (1930) paper listed rising times of 14 species and was the first serious effort in this country to establish the factors that determine awakening times. Also, Allard's paper was the first published report concerned with the problem of awakening time in which several species of birds were systematically studied during several months of the year. Recently, Leopold and Eynon (1961) published an article dealing with 20 species which also offers a good review of some foreign literature. Other authors have listed their impressions of the awakening times of various species, and many writers have recorded awakening times, particularly for a single species. The most thorough of these latter are the works of Nice (1943) on the Song Sparrow (*Melospiza melodia*) and Armstrong (1955) on the Winter Wren (*Troglodytes troglodytes*). Others include Craig (1943) on the Eastern Wood Pewee (*Contopus virens*), MacQueen (1950) on the Least Flycatcher (*Empidonax minimus*), McCabe (1951) and King (1955) on the Traill Flycatcher (*Empidonax traillii*), and Davis (1958) on the Rufous-sided Towhee (*Pipilo erythrophthalmus*). There are many papers in the literature on the roosting times and flights of several species. The present paper deals only with the awakening time of ten species of birds.

Few workers have conducted their studies of awakening time through an entire year and noted the seasonal changes which occur. Allard's (1930) records were gathered from January 15 to September 1, while an unpublished thesis by Walker (MS) was based on records taken from October to July. The works of Nice (1943) and Armstrong (1955) contain records taken at all seasons over a period of several years. Leopold and Eynon (1961) presented data covering the song season only.

ACKNOWLEDGMENTS

This paper is based on a thesis submitted to Michigan State University in partial fulfillment of the requirements for the degree of Master of Science. The study was begun under Dr. George J. Wallace, to whom I am indebted for early advice. I wish to thank Dr. T. Wayne Porter for his guidance and criticisms during the major part of this study and for his critical reading of and revision of the thesis manuscript. Dr. Don W. Hayne advised me on the statistical treatment of the data and read portions of the thesis. Dr. Jesse M. Shaver of George Peabody College for Teachers kindly lent me a copy of the thesis by Emily B. Walker. I am indebted to the Department of Zoology, Michigan State University, for supplying facilities and financial aid during the course of the study. The Museum of Vertebrate Zoology and the Hastings Natural History Reservation provided certain facilities during the final revisions of the manuscript. The illustrations were prepared by Gene M. Christman.

METHODS

The study was conducted in a beech-maple-oak woodlot in East Lansing, Ingham County, Michigan (latitude 42° 44′ N, longitude 84° 29′ W), the boundaries of which included the Red Cedar River, two roads, two meadows, and a housing project. The observations were made from a location near the bank of the river in a clearing cut through the woods. Therefore, I had within my range of hearing birds occupying several habitats. The study period extended from January 11, 1955, to March 1, 1956.

Data were recorded in the following manner. I generally reached the place of observation about one-half hour before the birds began to vocalize. Ability to predict this time became quite accurate after a few mornings of study and proper adjustment of the time was made as the birds rose earlier or later. The number of individuals of each species that were singing and/or calling was recorded during each one minute interval. Observations continued from the time of arrival until all of the species under study had been recorded. Some difficulty in recording the awakening time was encountered because of the simultaneous and loud singing of all species during the spring chorus. The sound made by the more loudly singing birds may have been sufficient to obscure the first songs of the less vociferous species, but because of the close proximity of the species concentrated upon, I believe that any error in recording the awakening time is slight. Wright (1913), Saunders (1929:64), and Leopold and Eynon (1961:271) also noted the problem of noisy birds obscuring the songs of quieter species.

DEFINITION OF TERMS

Meteorological criteria.—The points of reference for awakening time which have been generally used are as follows: astronomical twilight (that time after sunset and before sunrise when the sun is 18° below the horizon), civil twilight (sun 6° below the horizon), and sunrise. True night is the period between evening and morning astronomical twilight when the sky is completely devoid of sunlight.

Awakening time.—The designation of a specific time of actual awakening of a bird in the field is essentially impossible. Therefore, some criterion must be chosen as the "awakening time" which will indicate the approximate time when a bird becomes truly awake and active. Assuming that light is the critical factor involved in awakening a bird, Allard (1930:455) believed that it was impossible to tell when the first light reached and thus awakened a bird whose head was under its wing. Therefore, he chose as a standard of awakening time any song heard after morning astronomical twilight. However, even Allard called this method only a "convenient demarcation." I believe that Allard's method did not recognize that "night singing" is not categorically confined to the period of true night. These biological phenomena (night song and awakening time) are not necessarily in complete accord with the more precise meteorological phenomena. The present study indicated that the songs uttered between astronomical twilight and the beginning of the dawn chorus were night songs. The songs of true night, and those uttered between astronomical twilight and the beginning of the dawn chorus are all sung in a like manner and consist of a few, scattered utterances from one or more birds, usually of the same species. No distinction should be made between night songs delivered before and after astronomical twilight. Allard's awakening time criterion was thus deemed unsuitable for this study.

Wright (1913:513) stated that the awakening time of a species was that time when more than one bird of the same species uttered several songs at intervals, but this criterion also does not recognize night song as occurring between astronomical twilight and the beginning of the dawn chorus.

Zimmer (1919:174) stated that song birds usually begin to sing at once after awakening, whereas "non-singing" species may or may not call at once. Saunders (1929:63) similarly stated that birds will begin singing continuously within a few minutes after awakening (the beginning of the dawn chorus). Earlier, Allen (1913) had also written that the true time of awakening occurred when more than one individual of the same species was singing regularly, thus distinguishing between the awakening time of the individual and the species.

The definition of awakening time established for this study is essentially a restatement of the discussion by Allen (1913:230–231). It is as follows: *The awakening time of a species is that time when more than one individual of that species has begun to sing continuously*. Any criterion used which involves only the first song heard of an individual takes into account neither the variability of individuals nor the occurrence of "night song" outside the limits of true night, and such a method does not accurately illustrate the awakening time of the species.

The problem of the songs of some birds influencing the awakening time of later risers falls into two categories: the individual's influence on its own species, and the influence of one or more individuals of a species on other species. Saunders (1929:72) has pointed out that the singing of one individual may stimulate another bird of the same or different species to sing. This view is borne out in the present study in that frequently when one bird sang at night, its song would be quickly followed by the vocalization of one or more individuals of the same or, rarely, of another species. However, after completion of these sporadic outbursts, these birds might not be heard again until the dawn chorus began, and then they would sing at their expected time. On occasion, some birds would sing at several different times in the night. However, it also frequently happened that only one night song, or one individual singing several songs, would be heard.

Craig (1943:102) expressed the belief that the awakening song of one Eastern Wood Pewee did not influence the awakening song of another, rather each individual had its own "hours." Armstrong (1955:259) stated that it is improbable that a male wren sings any sooner than it otherwise would when it hears another wren sing, and he did not believe "that any bird takes its arising cue from the song of any other species which precedes it." However, Armstrong goes on to state that "earlier songs may help to awaken the later birds." I believe that within narrow limits one species may influence the awakening of another species. However, as many have observed previously, the awakening time of a species is apparently dependent on some mechanism other than the disturbance created by the songs of other species.

Since the criterion of awakening time used in this study will hold only for the song season, substitution of the call notes for the full song is necessary on occasion in order to determine the awakening time. Also, the definition of awakening time used is not acceptable for some species, such as the Crested Flycatcher (*Myiarchus crinitus*), woodpeckers (the flickers of this study are a special case), and other species which are uncommon or vocalize only sporadically in the early morning.

Earlier workers (Allen, 1913; Wright, 1912, 1913) apparently used the term awakening time synonymously with awakening song. Later, however, Walker (MS), Allard (1930:455), and Nice (1943:99) realized that there were no data supporting synonymy here. Davis (1958:327) concurs with this view. It is obvious that actual awakening times are not known. The first songs and calls only indicate that a bird is active but do not necessarily define the actual beginning of activity. However, for the lack of more suitable terms, and with the above understanding, henceforth in this paper awakening song (or call) and awakening time will be used synonymously.

Night song.—The phenomenon of night song has been discussed in the preceding section but deserves further comment. Allard (1930:441) wrote that "night song is not a common and regular behavior." I disagree with Allard on the amount of night song because of the difference in criteria of awakening time used. As stated previously, I consider the early occasional outbursts between astronomical twilight and the beginning of the dawn chorus to be night songs rather than awakening songs. But, even using Allard's criterion of awakening time, I found that night song was of common and regular occurrence in many species studied, particularly in the Cardinal (*Richmondena cardinalis*), Catbird (*Dumetella carolinensis*), Song Sparrow, and Eastern Wood Pewee.

The definition of night song derived for use in this study is as follows: *Night song includes those individual songs which a bird will sing during the time between the end of the evening chorus and the commencement of regular and continuous singing the following morning.*

RESULTS

In discussing a subject as variable as the awakening time of birds over a yearly cycle, grouping the data in some meaningful manner becomes necessary. Since the awakening time varied with the time of year and the sequence of awakening of the species changed, the data were grouped in a manner to illustrate and compare these variations without obscuring the basic patterns. Four periods were derived by inspection of graphs of the awakening times of each species plotted against the sunrise and civil twilight curves as in figures 2, 3, and 4. The data for each species were computed for these periods (see table 2). Two species did not precisely fit the periods in their awakening times and these are discussed in the appropriate species account. The periods are as follows: period I, March 7 to April 30; period II, May 1 to July 31; period III, August 1 to November 30; period IV, December 1 to March 6. Each daily awakening time or each average

TABLE 1

RESIDENCY, DATES OF EARLIEST AWAKENING, AND NUMBER OF SINGING MALES IN THE STUDY AREA

Species	Period of residency	Approximate date of beginning of early awakening	Inclusive dates of earliest awakening	Number of singing males	
				Periods I, II, III	Period IV
Cardinal	Permanent	Feb. 28	Apr. 1–Apr. 19 Minor peak July 26–Aug. 12	5	3–4
Song Sparrow	Permanent	Feb. 28	Apr. 1–Apr. 19	10	2
Common Crow	Permanent	Feb. 18	Mar. 7–Apr. 30	5	30
White-breasted Nuthatch	Permanent	Feb. 15	Mar. 20–May 6 Minor peak June 26–Aug. 4	2	5
Yellow-shafted Flicker*	Permanent	Apr. 1	Apr. 16–May 4	3	0
American Robin†	Mar. 13–Nov. 12	Mar. 26	Apr. 2–July 13 Peak Apr. 21–May 6	12±	
Eastern Phoebe	Mar. 22–July 20	May 2	May 4–May 20	3	
Eastern Wood Pewee†	May 18–Sept. 19	June 1	June 6–July 22	5	
Catbird	May 4–Oct. 11	Awakening early on arrival (except first day)	May 6–May 26 Minor peak June 24–July 22	4+	
Yellow Warbler*†	Apr. 28–Sept. 6	Awakening early on arrival (except first day)	May 2–June 27	5	

* Earliest awakening period not completely in accord with defined periods; see species discussions.
† Earliest awakening time period includes summer solstice.

time for any period is expressed in the number of minutes before sunrise (indicated by a minus sign) that the song or call was heard.

Previous workers (Allard, 1930; Nice, 1943) have objected to the use of the sunrise curve as the basis for comparison, stating that the curve of awakening time more closely approximates the civil twilight curve. This is true in that most birds awaken closer to the time of civil twilight than to the time of sunrise, but inspection of figures 2, 3, and 4 shows that the curve of awakening time also deviates from the civil twilight curve in May and June and is not, in most species, a duplicate of that curve.

Since the civil twilight curve at this latitude varies from the sunrise curve by a moment of seven minutes per year, and consequently, any specific light intensity level also fluctuates in minutes before sunrise, comparison of the curve of awakening time with the civil twilight curve suggests that each species awakens in relation to a fixed light intensity and supports the hypothesis that light intensity is *the* factor determining awakening time. However, study of the curves for awakening time reported for many species, as well as the curves formulated in this study, shows that many species awaken to successively lower light values from about February through May and, conversely, to successively higher values thereafter. For a species awakening time curve to duplicate the civil twilight curve (duplication here means simply that the curve of awakening time was the same shape, but not necessarily the same time, as the civil twilight curve), a species would have to respond to the same light intensity through the year. This is not the case with most species (see Leopold and Eynon, 1961). The bird, if responsive primarily to light, is responding to different light intensities.

Of the many species studied, ten have been included in the discussions beyond. These are the Cardinal, Song Sparrow, Common Crow (*Corvus brachyrhynchos*), White-breasted Nuthatch (*Sitta carolinensis*), Yellow-shafted Flicker (*Colaptes auratus*), American Robin (*Turdus migratorius*), Eastern Phobe (*Sayornis phoebe*), Eastern Wood Pewee, Catbird, and Yellow Warbler (*Dendroica petechia*). The numbers recorded singing and the migration dates for the birds in the study area are given in table 1.

Previously, the averaging of awakening times was objected to by Allard (1930:445) because of its tendency to disguise trends toward earlier or later awakening. While this may be true for many species, the averaging of daily awakening times is convenient for easy comparison between species. I believe that the objection to the averaging of awaking times within a species arose because early workers such as Wright and Allen averaged their results indiscriminately without regard to changes in the times over the seasons, and then they presented the resultant average as the awakening time of the species concerned. In the light of more modern work, this is incorrect. However, with proper care in selecting periods, an average can be a valid representation of the species awakening time for that period.

The mean, standard deviation, and standard error were computed for each species during each of the four periods that it was present in the study area (table 2). A graphic method modified from Dice and Leraas (1936) is used in the comparison of species here (fig. 1), and cases bordering on a significant difference were verified by the "t" test. The 95 per cent confidence level is considered significant.

No attempt was made to distinguish the difference in the awakening times of males and females, but the data presumably reflect the awakening times of males only. Data obtained for both clear and bright cloudy nights are included. It is the objective of this paper to describe interspecific variation and the nature of the awakening time curve. Segregation of these data was not necessary because the effect of bright cloudiness on the awakening time was approximately the same for all species presented. Material con-

cerning the beginning of the early rising periods, the plateaus of early rising, and other pertinent data are given in table 1.

Cardinal.—The mean awakening time of the Cardinal decreased from −40.6 (period I) to a low of −23.2 (period IV). Figure 1 shows that periods I and II overlap as do periods III and IV. Neither of these was significantly different in mean awakening time. However, the means of the four periods still clearly illustrate that this species began its song activity at different times before sunrise during the year because period I differed significantly from periods III and IV and period II differed significantly from period IV.

Song Sparrow.—This species showed a decrease in the mean awakening time from

TABLE 2

SEASONAL DIFFERENCES IN AWAKENING TIME IN MINUTES BEFORE (−) AND MINUTES AFTER (+) SUNRISE

Species†	Period I	Period II	Period III	Period IV
Cardinal	−40.6±2.7 (21)* −17, −68 14.5	−35.5±0.9 (31) −26, −46 4.9	−26.8±1.4 (34) −12, −46 7.9	−23.2±1.8 (23) −8, −33 5.8
Song Sparrow	−45.9±3.0 (21) −26, −76 13.5	−33.6±0.8 (30) −23, −40 4.6	−25.8±0.8 (34) −16, −36 4.7	−17.8±1.8 (20) +2, −29 7.9
Common Crow	−25.9±1.4 (21) −11, −34 6.5	−18.5±1.2 (32) +2, −28 7.0	−19.0±1.0 (34) −7, −34 5.7	−16.3±1.8 (23) +8, −27 8.6
White-breasted Nuthatch	−11.9±1.0 (22) +3, −19 4.8	−9.7±1.4 (21) +6, −20 6.5	−6.2±1.4 (24) +10, −21 6.6	−1.7±0.9 (15) +5, −10 3.6
Yellow-shafted Flicker	−7.2±2.5 (10) +6, −16 8.0	−1.3±2.6 (9) +6, −24 7.8	−5.1±1.6 (14) +9, −17 5.9	
American Robin	−61.6±4.6 (20) −27, −95 20.6	−63.5±2.8 (28) −22, −86 15.0	−25.9±1.3 (20) −17, −40 5.8	
Eastern Phoebe	−20.0±2.2 (12) −3, −32 7.6	−31.4±1.2 (26) −22, −42 6.0		
Eastern Wood Pewee		−44.6±3.6 (23) +8, −57 17.4	−26.7±3.8 (15) −9, −48 14.8	
Catbird		−43.1±2.3 (29) −2, −63 12.4	−29.5±0.9 (24) −18, −38 4.2	
Yellow Warbler		−21.9±1.2 (28) −10, −31 6.4		

* Data given are the mean with standard error followed by the number of records (in parentheses), the extremes, and the standard deviation.

† Arrangement of species is approximately according to the number of records of awakening time available.

period I through period IV (fig. 2) similar to that of the Cardinal. The difference between the means of the periods are highly significant. The earliest awakening time was before the summer solstice (table 1), whereas Nice (1943:103) showed that the earliest awakening time for her birds was at the solstice.

Crow.—The earliest awakening time of the Crow in relation to sunrise occurred in period I. The means for the other three periods were considerably later and not significantly different from each other. Assurance that the awakening times of the Crow are

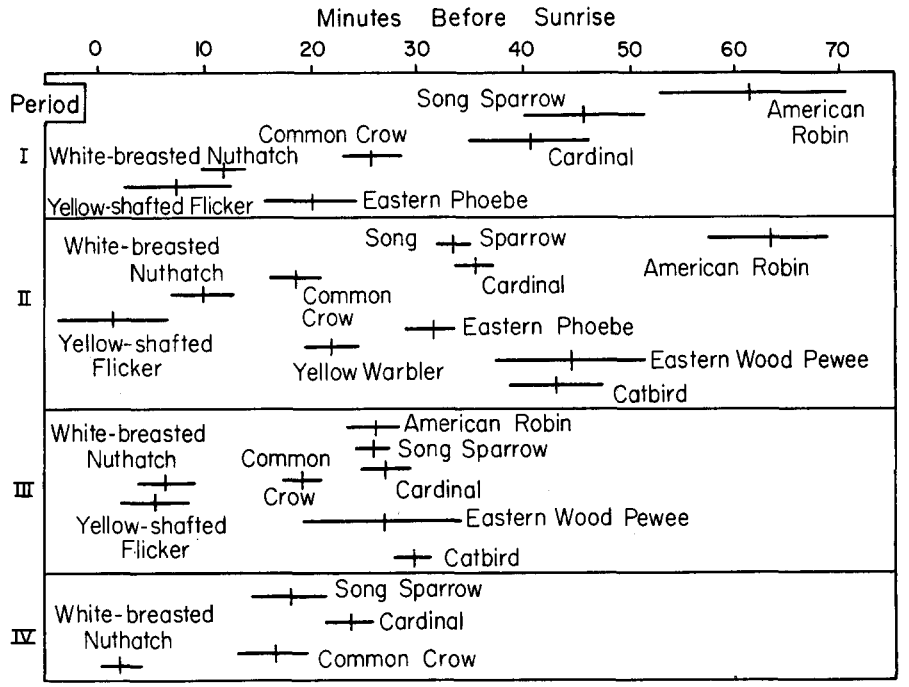

Fig. 1. Comparison of the average awaking times by periods and species. Vertical lines represent the average; horizontal lines represent two standard errors on either side of the average.

reasonably correct is provided by the fact that they both nested and roosted near the observation post used throughout this study.

White-breasted Nuthatch.—This species had a mean awakening time that became progressively later over the seasons beginning with period I. However, the difference of the means between periods were not as great as the differences between the means of other species studied, probably because of the generally late rising habits of this species. Period IV was the only period that differed significantly from all other periods.

Yellow-shafted Flicker.—The flicker was present in the woodlot during all four periods of the year, but only one bird was resident during period IV. This individual was seen only in the afternoon and either did not roost in the area or was a very late riser. Therefore, there are no records for this species in period IV.

The flicker is one of the two species in which the use of arbitrary periods in computing the mean awakening time was misleading in that it partly disguised the trend in awakening time. While the mean awakening times of this species were considerably different, none was significantly so. This lack of significance indicates that the flicker arose

at about the same time, statistically, during all three periods, but this is not entirely true. Study of a figure of the awakening time curve and the sunrise curve (similar to figs. 2, 3, and 4) showed that the division between periods I and II occurred at the height of the earliest awakening time. The flicker actually arose earlier from about April 1 until its earliest awakening time was reached on May 4. After the latter date, there was a decline in the earliness of awakening. The birds arose very irregularly through June to December and never again approached the early awakening time of spring.

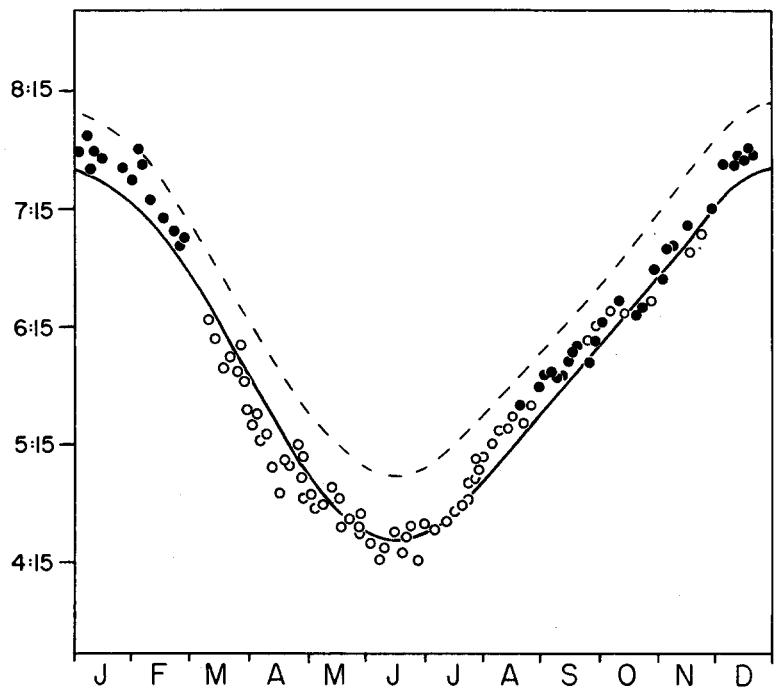

Fig. 2. Sunrise and civil twilight curves with the daily awakening time of the Song Sparrow (*Melospiza melodia*). Dashed line represents the sunrise curve; solid line represents the civil twilight curve; open circles represent songs; shaded circles represent calls. Eastern Standard Time was used throughout.

Flickers roosted near my observation post and I could see the birds when they emerged from their roosting holes. They invariably called and flew to another tree upon emerging. How long they were awake before leaving the roosting holes is unknown.

American Robin.—This species exhibited the greatest difference of the means between periods of any of the species studied. The Robin arose at approximately the same time during the spring-summer period (periods I and II), but the birds no longer vocalized as early with the subsidence of the song season. The mean awakening time in the fall was very close to that of the other species listed. However, Vaurie (1946:168) stated that in Pennsylvania the Robin was the earliest rising species during middle and late summer. His observation was not corroborated in my study because several species (recorded also by Vaurie) arose earlier than did the Robin during this period.

Eastern Phoebe.—This species was the anomaly among the birds studied because it arose earliest in its second period of residency (period II). All other species studied rose earliest during their first period in the woodlot. The means of periods II and III are

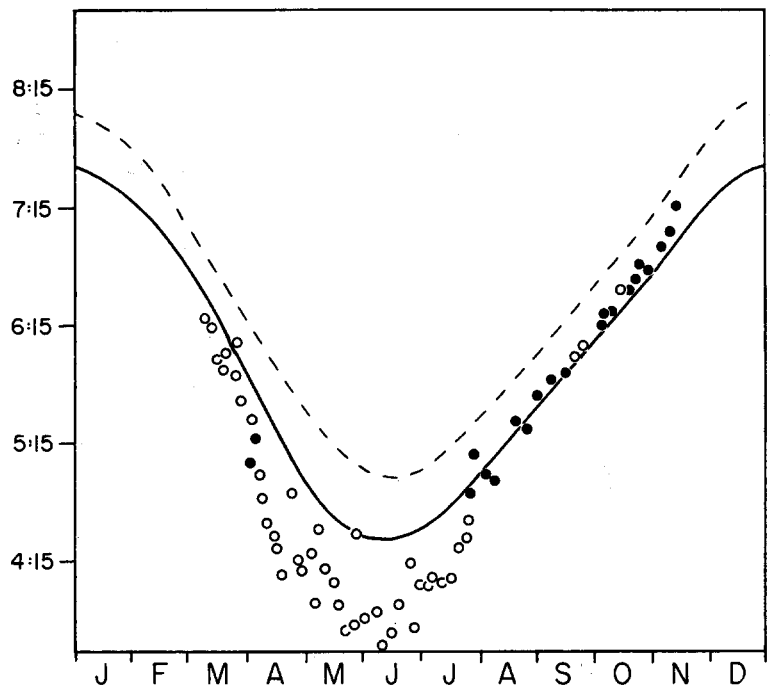

Fig. 3. Sunrise and civil twilight curves with the daily awakening time of the American Robin (*Turdus migratorius*). For explanation of symbols see figure 2.

significantly different. There were no notable fluctuations in the awakening times within a period except that near the end of period II the birds tended to give their awakening song a little later.

Eastern Wood Pewee.—The pewee followed the usual pattern of rising earliest in the first period in which it was present. The mean of period II is significantly different from the mean of period III. This species, as did most others, awakened later as the season progressed into fall (fig. 4). There were no major fluctuations of the awakening time within any given period, but there were several later rising times during the latter part of period III.

Wright (1913) found the wood pewee to be the earliest riser of all the species that he studied. However, Allen (1915:112) aptly pointed out that the pewee sings frequently at night and so Wright's records undoubtedly reflect his use of night songs as awakening songs. Craig (1943:99) stated that the pewee was one of the earliest birds to sing in the morning, but he did not indicate that it was the earliest of all species.

Catbird.—The Catbird was the most regular riser of the species studied. For example, in one part of period II, the daily awakening times were −41, −40, −39, −40, and −38. In period III, there was one sequence of awakening times as follows: −28, −29, −23, and −28. During the same periods that the above records were taken, other species were much more variable.

The termination of the records of awakening time of the Catbird differed from that of the other species. Other species gave their awakening songs or calls later, immediately before leaving on the fall migration. The awakening time of the Catbird, in contrast, remained constant until the birds departed from the area.

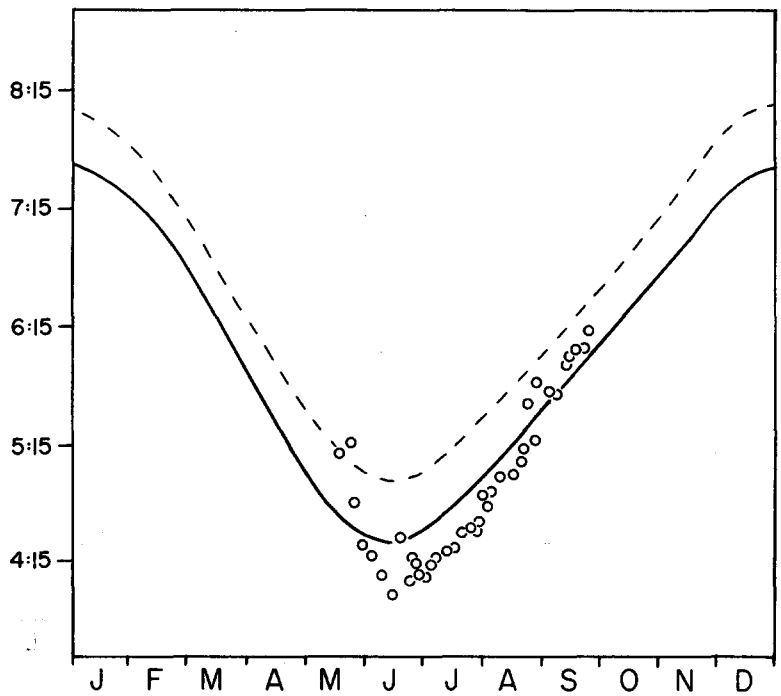

Fig. 4. Sunrise and civil twilight curves with the daily awakening time of the Eastern Wood Pewee (*Contopus virens*). For explanation of symbols see figure 2.

Yellow Warbler.—This species was not present in the study area during period I and in period III it did not sing or call often enough to permit the recording of the awakening time.

The Yellow Warbler maintained a fairly constant awakening time. However, this species is the second bird to exhibit variation of the awakening time within a given period. After June 29 the Yellow Warbler began rising several minutes later than it had been rising before that date. From June 29 until the last reliable record was taken on August 2, this species arose steadily later. The average for period II does not represent the awakening time curve accurately, but it is close enough to allow comparison with other species.

DISCUSSION

A standard awakening time criterion.—Because of seasonal differences, the use of indiscriminate averages, suspected latitudinal differences, and, most importantly, because of the differences in the criteria of awakening time used, little comparison of my data with awakening times available in the literature was undertaken. To illustrate the difficulties encountered in comparison of data, the case of the American Robin and the Song Sparrow will be discussed. The problem of comparison exists in subtle form in other species but is often overlooked; the use of an extreme example more clearly illustrates the situation.

Robins rarely sing at night, whereas the Song Sparrow indulges in much night song. Nice (1943:102) observed the same behavior. Thus, by using Wright's (1913:513) cri-

terion of awakening time, one would find that the Song Sparrow arose earlier than did the Robin. Nice (1943:102), in an accurate treatment of this problem, was of the opinion that both Wright's (*op. cit.*) and Allard's (1930) records included night songs of the Song Sparrow, and she stated that the Robin was the earlier riser. Wright's (1913) average awakening time for the Song Sparrow was −73, whereas my average for a similar period was −33. Allen (1915:112) gave −29⅜ as an average for the Song Sparrow. Wright's (*op. cit.*) average for the Robin was −64, and Allen's (1913) was −63. Later, Allen (1915:112) gave an average of −53⅔ for the Robin. My average awakening time for the Robin over a similar period was −62. The average for the Robin was remarkably constant among the data given. The differences in the observations obviously lie in the different averages for the Song Sparrow. Allard believed that this difference was based on the "*fact*" (italics mine) that birds of higher latitudes would sing earlier in the morning than birds of lower latitudes. Some credence is lent this by Miller (1958) although his data are not analyzed with reference to the sunrise and civil twilight curves. Craig (1943:116) stated that pewees at southern latitudes begin to sing at lower light intensities than those farther to the north. In minutes before sunrise, his table (*op. cit.*:115) shows a difference of 16 minutes from 35° to 45° N latitude. Nice (1943:99) also stated that latitude made a profound difference. Wright's (1913) awakening time averages for New Hampshire would, then, be expected to differ from Allen's (1913, 1915) averages for Boston, but the latitudinal difference does not explain a difference of 40 minutes in the awakening time of the Song Sparrow and no difference in that of the Robin. A species difference is unlikely here. A further difference in the data of Wright and Allen is the fact that Allen's averages represented a longer period of the year. However, the most important reason for the differences between the awakening times of these two species is found in the difference of the awakening time criterion used, and the use by Wright of night songs of the Song Sparrow as awakening songs. These factors caused large discrepancies in the data. Proper understanding of the influence of latitude, night song, time of year, and averages, together with a clearly defined awakening time standard, can eliminate this problem. Although correcting for latitude and other factors may be possible, correcting for differences in the definition of awakening time is impossible. A standard definition usable by all workers is desirable in order that future comparisons may be more meaningful.

The curve of awakening time.—The fact that birds rise earlier by the clock in the spring than at any other time of the year is well known. However, the curves of awakening time of the species of birds studied here became earlier, not only by clock time as the seasons progressed, but also, as was stated earlier, in relation to the sunrise and civil twilight curves. After each species reached its earliest rising time, the awakening time curve again more closely approached the sunrise and civil twilight curves as fall approached and continued accordingly through the winter period. Several authors have found this same tendency, notably Walker (MS), Allard (1930), Craig (1943), Nice (1943), Armstrong (1955), Davis (1958), Leopold and Eynon (1961), and others. Therefore, it can now be stated that this is undoubtedly the normal course of events for many song birds in the middle latitudes. However, there is one exception in that Emlen (1937) observed a female Mockingbird (*Mimus polyglottos*) that awakened later in relation to sunrise as the nesting season approached. Most of the other records published presumably reflect the awakening times of males.

Allard (1930) believed that the earliest rising time in relation to sunrise occurred at the summer solstice. This is what led him to the conclusion that the awakening time curve was more or less a duplicate of the civil twilight curve. Figures 2, 3, and 4 indicate that this is not true, at least for most birds in this study. The greatest deviation from

the civil twilight (and the sunrise) curve occurred at times other than the summer solstice (earliest time of civil twilight), with three exceptions. The Robin and Yellow Warbler arose earliest prior to and continuing beyond the summer solstice (table 1). The Eastern Wood Pewee arose earliest from June 6 to July 22 (table 1). The Robin actually had a minor peak of early awakening times that did not coincide with the summer solstice, and, in all three species, the earliest awakening times occurred over long periods which only included the summer solstice within their ranges. The curve of awakening time did not follow the civil twilight curve much more closely than it followed the sunrise curve. Although the awakening time curve is often about the same time in minutes from the sunrise curve as is the civil twilight curve, variation is too great to consider the awakening time and civil twilight curves identical in all but a few cases.

The period of the earliest mean awakening time for the permanent residents in this study was period I. The migratory species had their earliest mean awakening times during the first period in which they were present (except the Eastern Phoebe). It is obvious, not only from this statement, but also from perusal of the limits of the periods as used in this paper, that most birds had their earliest awakening times before the summer solstice (for example, see fig. 2, Song Sparrow). Other species had earliest awakening times that included the summer solstice (fig. 3, Robin), or that were primarily after the summer solstice (fig. 4, Eastern Wood Pewee). However, Nice (1943:103) has shown that the Song Sparrow arose earliest at the summer solstice. Other authors have found the same for different species. A close duplicate of the civil twilight curve has been found by Leopold and Eynon (1961:276) for the House Wren (*Troglodytes aedon*).

The types of awakening time curves as put forth by Leopold and Eynon (1961:276) are not precisely comparable to the curves found in the present study. None of the species studied here shows the first type of curve presented by Leopold and Eynon, that is, a symmetrical curve with the earliest arising occurring at the summer solstice. The second type, in which the awakening time curve deviates "from the civil twilight curve at a medium angle until about the time of the solstice, after which the return to [the] civil twilight curve is at a sharper angle," is found here only in the Robin and Yellow Warbler. The remaining two types of awakening time curves are not represented in my data. Leopold and Eynon further stated that "perhaps the majority of song birds are of the second type." Seven of the ten species in this paper (exceptions are the Robin, Eastern Wood Pewee, and Yellow Warbler) follow this general shape but with the important exception that the earliest arising and the return toward the civil twilight curve both occur *before* the summer solstice.

The above differences, I believe, may be due to varying local environmental conditions, differences in the physiological states of the birds involved, or to differences in population density. These differences present a good argument for experimental laboratory work in the future with caged birds kept under controlled conditions. Only in this manner can the various factors involved in awakening time be sorted out.

The bird clock and order of awakening.—The bird clock has been described by several writers as the more or less orderly and definite succession of awakening song of a series of species. Armstrong (1955:70–71) believed in the bird clock but modified it somewhat by stating that "out of season anomalies occur" and that he "very occasionally" heard the wren before the robin in autumn. This implies that normally the Winter Wren arose after the European Robin (*Erithacus rubecula*) and that the bird clock is operational all year. Allard (1930), on the other hand, found that the order of awakening of species did change over the year. Figure 1 indicates the changes in this study and some specific examples are given in table 3. It should be pointed out that for table 3 during period I the Song Sparrow almost always arose before the Cardinal. Seasonal

changes in awakening order were common. These changes in the order of awakening time were noticeable in the field when both species of a changing duo briefly arose at about the same time and then changed order completely. Allard detected changes in

TABLE 3

THE BIRD CLOCK THROUGH THE SEASONS AS ILLUSTRATED BY FOUR PERMANENT RESIDENT SPECIES

Change of awakening of Song Sparrow	Period	No change in sequence of awakening
Song Sparrow (45.9)*†	I	Cardinal (40.6)
Cardinal (40.6)		Common Crow (25.9)
Common Crow (25.9)		White-breasted Nuthatch (11.9)
Cardinal (35.5)	II	Cardinal (35.5)
Song Sparrow (33.6)		Common Crow (18.5)
Common Crow (18.5)		White-breasted Nuthatch (9.7)
Cardinal (26.8)	III	Cardinal (26.8)
Song Sparrow (25.8)		Common Crow (19.0)
Common Crow (19.0)		White-breasted Nuthatch (6.2)
Cardinal (23.2)	IV	Cardinal (23.2)
Song Sparrow (17.8)		Common Crow (16.3)
Common Crow (16.3)		White-breasted Nuthatch (1.7)

* See text concerning change of order of Cardinal and Song Sparrow.

† Figures in parentheses are means during that period in minutes before sunrise. Means are significantly different except where bracketed.

order in data collected from January through August. Walker (MS) could detect no change from October through July. In the present study, changes could be pointed out in every month of the year except December and January. Wright (1913) and Allen (1913, 1915) did not indicate that any changes in the order of awakening took place. Nice (1943:108) stated that "the bird clock is a well known phenomenon" but "some species are better 'time-keepers' than others." Craig (1943:98) wrote that the order held true at the solstice but not always in May and August. Davis (1958:324) stated that of the five species in his "middle group," the exact order of awakening usually differed on any two consecutive mornings. The clock applied to only parts of the study period and was not a long term phenomenon (Davis, *op. cit.*:326). The present author has found the same and will not illustrate it any further than to direct the reader's attention to Davis' figure 3 (*op. cit.*:325) which quite satisfactorily clarifies this situation.

When one is considering ten or twelve species, many of which vocalize within a minute or two of each other, it is almost inconceivable to presume that they could be so exact, or, that the observer could be so accurate in recording data, as to fall in exactly the same relationship morning after morning. However, if one studied only three species, for example, the Cardinal (an early riser), the Common Crow (a middle riser), and the White-breasted Nuthatch (a late riser), one could quickly establish a bird clock for the entire year for these three species (see table 3). This clock would also hold on a daily basis.

Confusion could easily arise concerning the extent and duration of a bird clock, because study of a few species with widely differing awakening times (as suggested above) quickly reveals a bird clock as a daily and a seasonal phenomenon. Study of

many species or those which have very similar awakening times, particularly early risers which have a much larger range of awakening times over the year than do later risers, indicates that there is no clock in operation. The discussion of whether or not a bird clock exists seems academic. The important point is that each species has a definite seasonal variation of awakening times which is not basically dependent on the awakening times of other species (with the possible exception of closely competing species).

SUMMARY

A year-long study of the awakening times of several species of birds was undertaken in a woodlot in East Lansing, Michigan. The awakening time data gathered for each species were averaged by using periods of relatively constant awakening times in order to compare the variation both within and between species. A discussion of awakening time and night song is given with an attempt to clarify the relationships between the two terms. The awakening time of a species is that time when two or more individuals of that species are singing continuously. Night song includes those songs uttered between the end of the evening chorus and the beginning of regular and continuous singing the next morning.

A discussion of the problems involved in the determination of awakening time is presented using data available for the Robin and the Song Sparrow. It is concluded that a definite awakening time criterion should be established to permit valid comparison of data compiled by various workers from many localities.

The awakening time curves of most species of birds studied approximated the sunrise and civil twilight curves during the year, but birds awaken earlier in the spring, not only in relation to the clock, but also in relation to the sunrise and civil twilight curves. This phenomenon has been found for other species, both in this country and in Europe, and therefore is apparently the normal course of events for most songbirds of the middle latitudes. Most species did not awaken earliest in relation to sunrise at the summer solstice. The three exceptions in the ten species studied, the Robin, Yellow Warbler, and Eastern Wood Pewee, merely included the summer solstice in a plateau of early rising. The Robin actually had a minor peak of early rising which did not correspond to the summer solstice.

Permanent resident species awakened earliest in relation to sunrise during period I (March 7 to April 30) while summer residents awakened earliest during the first period in which they were on their nesting grounds (with the exception of the Eastern Phoebe). Several types of curves of awakening time are discernible but these do not always correspond with data gathered by other workers. Laboratory experimentation is necessary to elucidate the factors involved in awakening time.

The order of awakening for many species varied through the year. The bird clock is not seasonally constant for some species, particularly early risers. There are also day to day variations in species awakening times which change the daily sequence of rising. The influence of one species on the awakening of another is minor as each species awakens according to its own, as yet undescribed, requirements.

LITERATURE CITED

Allard, H. A.
1930. The first morning song of some birds of Washington, D.C.; its relation to light. Amer. Nat., 64:436–469.
Allen, F. H.
1913. More notes on the morning awakening. Auk, 30:229–235.
1915. The status of the song sparrow and the chipping sparrow as early birds. Auk, 32:110–113.
1922. Some little known songs of common birds. Natural History, 22:235–242.
Armstrong, E. A.
1955. The wren (Collins, London).
Craig, W.
1943. The song of the wood pewee *Myiochanes virens* Linnaeus: a study of bird music. N. Y. State Mus. Bull., 334:1–186.
Davis, J.
1958. Singing behavior and the gonad cycle of the rufous-sided towhee. Condor, 60:308–336.
Dice, L. R., and Leraas, H. J.
1936. A graphic method for comparing several sets of measurements. Cont. Lab. Vert. Gen., Univ. Mich., 3:1–3.
Emlen, J. T.
1937. Morning awakening time of a mockingbird. Bird-banding, 8:81.
King, J. R.
1955. Life history of Traill's flycatcher. Auk, 72:148–173.
Leopold, A., and Eynon, A. E.
1961. Avian daybreak and evening song in relation to time and light intensity. Condor, 63:269–293.
MacQueen, P. M.
1950. Territory and song in the least flycatcher. Wilson Bull., 62:194–205.
McCabe, R. A.
1951. The song and song-flight of the alder flycatcher. Wilson Bull., 63:89–98.
Miller, R. C.
1958. Morning and evening song of robins in different latitudes. Condor, 60:105–107.
Nice, M. M.
1943. Studies in the life history of the song sparrow II. The behavior of the song sparrow and other passerines. Trans. Linn. Soc. N. Y., 6:1–328.
Saunders, A. A.
1929. Bird song. N. Y. State Mus. Handbook, 7:7–202.
Vaurie, C.
1946. Early morning song during middle and late summer. Auk, 63:163–171.
Wright, H. W.
1912. Morning awakening and even-song. Auk, 29:307–327.
1913. Morning awakening and even-song. Auk, 30:512–537.
Zimmer, C.
1919. Der Beginn des Vogelgesanges in der Frühdämmerung. Verh. Ornith. Gesellsch. Bayern, 14:152–180.

Department of Zoology, Michigan State University, East Lansing, Michigan, and *Hastings Reservation, University of California, Carmel Valley, California, October 3, 1961.*