PHYSICAL ANALYSIS OF A SIMPLE BIRD SONG AS EXEMPLIFIED BY THE CHIPPING SPARROW

By PETER MARLER and DONALD ISAAC

The study of variation is an important means of obtaining indirect information about the effects of natural selection on the characteristics of animals. This paper is the first of a series of studies of variation in bird song, directed partly toward establishing adequate physical descriptions of bird vocalizations, and partly toward an attempt to infer from the nature and extent of variation something about the kind of selective influences to which song may be subjected (cf. Marler, *in press*). The methods are essentially those of the comparative anatomist applied in a new context. In discussing the effects of natural selection on the properties of bird song, we are embarking upon a subject which may be more akin to the study of cultural evolution in man than to organic evolution.

While morphological characters are under predominantly genetic control, we know that the species-specific songs of some birds are acquired during the life of the individual. Even where song traditions play no part in development, it is likely that genetic factors have only imprecise control over the detailed characteristics of the song (Marler, *in press*). However, in spite of the different mechanisms which ensure the perpetuation of the trait in the next generation, selection is likely to operate upon the final results in much the same way. Just as a genetic mutation which places its bearer at a disadvantage will be selected against, so any new learned tradition may be eliminated if it imposes some kind of biological disadvantage upon its users. In this way behavior may become as precisely adapted to its function as the structure of the body, even though it might be independent from detailed genetic control.

If we accept the position that the characteristics of bird songs are likely to be adaptive, we are then faced with the problem of explaining the remarkable degree of variation which they exhibit. Not only are there differences between geographically separated populations of the same species, but there are also marked variations between individuals in the same population, and even in successive songs of the same individual. Although most attention has been directed toward geographical variation, it is difficult to describe such variation adequately until we have a clear picture of the song repertoire of the individual.

As a first step, in a survey which we hope will ultimately throw some light on the significance of song variation, the Chipping Sparrow (*Spizella passerina*) has been selected as a simple case in which there is little audible variation in successive songs of an individual bird. The aim of this paper is to establish the limits of song variation in some individual Chipping Sparrows and to make some comparison between individuals, thus preparing the ground for treatment of other species in which singing behavior is more complex.

METHODS OF PHYSICAL ANALYSIS

The songs were all recorded in the field with a Magnemite 610–E tape recorder at a tape speed of 15 inches per second, using an Altec 633–A microphone mounted on an aluminum parabolic reflector. A Madison Fielding Micamp was used in the microphone circuit. The tapes were played back on a Viking Model 75 recorder adapted to operate at 15 inches per second. Analyses were made with a Kay Electric Company Sona-graph and Amplitude Display Unit, using the "high shape" filter setting in all cases.

Three types of analysis are presented in this paper. Most of the data come from the standard frequency/time analyses, using the wide band-pass setting. Since pitch is chiefly a function of frequency, these records can be read in much the same way as a musical score, from left to right. A small number of songs were analyzed for amplitude/time using the narrow band-pass setting and the ampli-

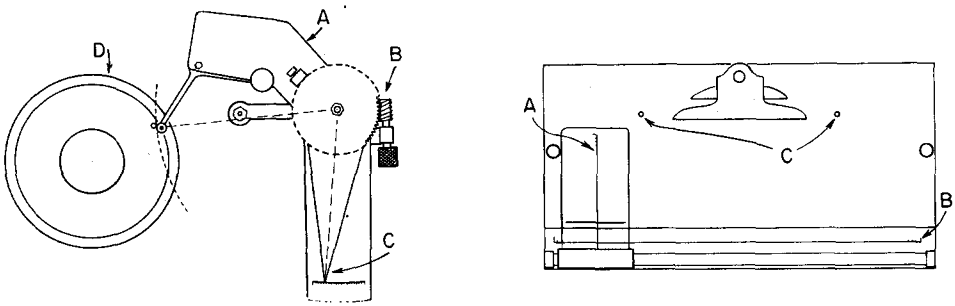

Fig. 1. Left, diagram of modification of sonagraph sectioning mechanism (top view). A, microswitch assembly for sectioner; B, worm and gear for controlling position of microswitch arm; C, pointer and calibrated scale; D, sonagraph drum with pin in place for tripping microswitch. The addition of the worm and gear, with its pointer and calibrated scale, allows precise control of the timing of tripping the sectioning microswitch in relation to the recorded signal.

Right, clip board for reading sonagrams. A sonagram sheet can be placed on this board and positioned so that its base line is matched to the horizontal mark on the sliding scale. A, transparent plastic slider with index lines and vertical scale calibrated for frequency to 50 cycles/second; B, horizontal scale calibrated for time to 5 milliseconds; C, positioning pins for sonagram sheets.

tude display unit. Single syllables selected from songs of several individuals were subjected to amplitude/frequency sectioning, with the narrow band-pass setting. The resulting sections are, in effect, histograms of the distribution of amplitude versus frequency at a selected point in the syllable. With the original sonagraph, sections can be made only at arbitrarily selected intervals of approximately 40 milliseconds (msec.). Since the syllables to be analyzed are also of about 40 msec. duration, no systematic information about their structure could be obtained. Therefore a worm gear and screw were added to the switch assembly of the sectioner (see fig. 1) which, coupled with a pointer and calibrated scale, made it possible to move the position of the switch arm in relation to the recording drum in scale increments as small as 2.5 msec.

Since the usefulness of data for analysis depends upon the accuracy of measurement, the following steps were taken. First, sonagrams were prepared of recordings made from a calibrated signal generator at 1 KC/sec. steps from 1 up to 8 KC/sec., with the narrow band-pass setting. Two scales were made. One, for frequency, was taken directly from the signal traces and subdivided to the nearest 50 cycles/sec. The other, for time, was made by taking the duration of the record to be 2.4 seconds and subdividing to the nearest 5 msec. These scales were then incorporated in a clip board (fig. 1) on which the sonagrams could be fastened, with the baseline adjusted to the index mark on the frequency scale. Thus readings could be made to the nearest 50 cycles/sec. and to the nearest 1–2 msec. The reliability of the readings was checked by repeated observations by a second observer.

The recordings were made at two locations in México during the summer of 1958. At Cuauhtemoc, near Chihuahua, two birds were recorded as follows: bird 1, June 21, 52 songs, June 22, 28 songs; bird 2, June 22, 27 songs. At El Salto, in Durango, six birds were recorded as follows: bird 1, June 29, 1 song; bird 2, June 30, 5 songs; bird 3, July 1, 2 songs; bird 4, July 1, 1 song; bird 5, July 2, 2 songs; bird 6, July 2, 2 songs.

GENERAL DESCRIPTION

The Chipping Sparrow song is normally "a simple trill or series of rapid notes, all on one pitch and delivered in a voice of dull, unmusical quality" (Saunders, A Guide to Bird Songs, 1935). The time/frequency analysis reveals repetitions of more or less identical syllables at approximately constant intervals (fig. 2). So far only one syllable type has been found in each individual. The syllable structure may, however, differ from one individual to another, even if the birds are neighbors (fig. 2). There is some variation in loudness of syllables. The song begins softly and quickly builds up to a maximum which is maintained to the end. Figure 2 shows this typical pattern of loudness, or more strictly, of amplitude modulation. Amplitude variations in other parts of the song may result from such things as movements of the bird's head. The overall pattern is thus a very simple one, and the extent of individual variation is not too difficult to define.

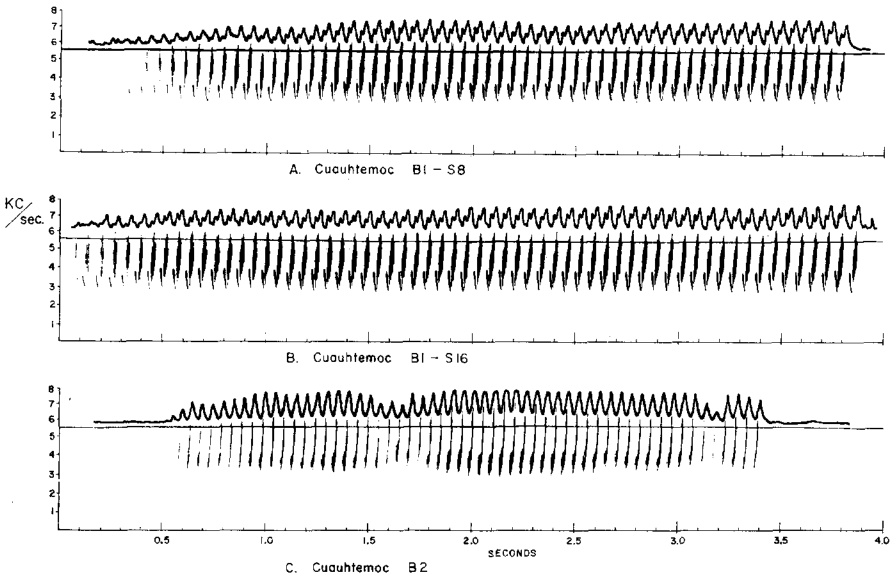

Fig. 2. Amplitude displays and frequency/time sonagrams of three songs selected from birds from Cuauhtemoc (A and B, bird no. 1; C, bird no. 2). The lower tracing in each record is the analysis of frequency/time and can be read from left to right in much the same way as a musical score. The upper record, in the form of a continuous line, registers the variation in loudness or, more strictly, in amplitude, of successive syllables of the song. The distance of the tracing above the base line is a function of the total amplitude at any one moment. Since it is only a relative measurement, we have arbitrarily referred it to the frequency scale on the left of the record.

ANALYSIS OF VARIATION

The songs of bird 1 from Cuauhtemoc.—Estimates of song variation in the individual are based on two continuous recordings of this bird made on consecutive days. No consistent differences were found between performance on the two days and the results are grouped together unless otherwise stated.

(a) Temporal pattern of singing. During sustained singing (fig. 3) the pause between songs (8.1±1.9 secs.) was more than twice the duration of the song (3.65±0.45 secs.). As expected, there is considerable variation in the interval between songs. The variation in song duration is more surprising, the longest songs being twice the duration of the shortest. Some other species such as the Brown Towhee (*Pipilo fuscus*) and the Oregon Junco (*Junco oreganus*) show less variation in this respect (Marler, MS).

(b) Number of syllables per song. The number of syllables per song is 55.1±6.7 (fig. 4). The distribution resembles that of song duration, and if we plot these against each other they fall into a linear relationship (fig. 4). The slope of the line corresponds with a rate of 15.1 syllables per second, irrespective of song duration.

(c) Frequency characteristics. Graphs of the maximum and minimum frequency from the sonagrams of each song reveal different degrees of variation (fig. 5). While the

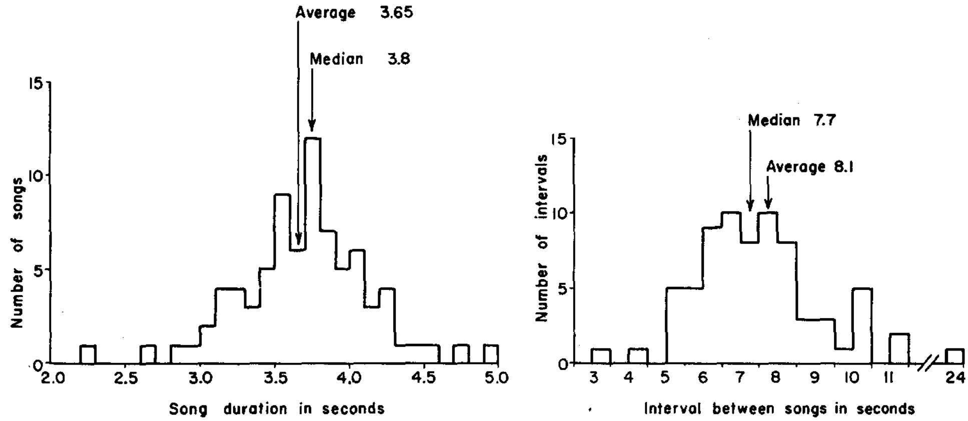

Fig. 3. Frequency distributions of song duration and intervals between songs for bird no. 1 from Cuauhtemoc. Song duration was measured from the sonagrams. The intervals between songs were measured with a stopwatch directly from the tape recording.

minimum is rather consistent, around 2.5 KC, the maximum, and therefore the frequency spread, have considerable variation. It is important to determine whether this frequency variation can be explained through varying rates of fading of the high frequencies with distance in comparison with the low frequencies, or whether it implies variations in actual production. A complete answer must await analysis of recordings

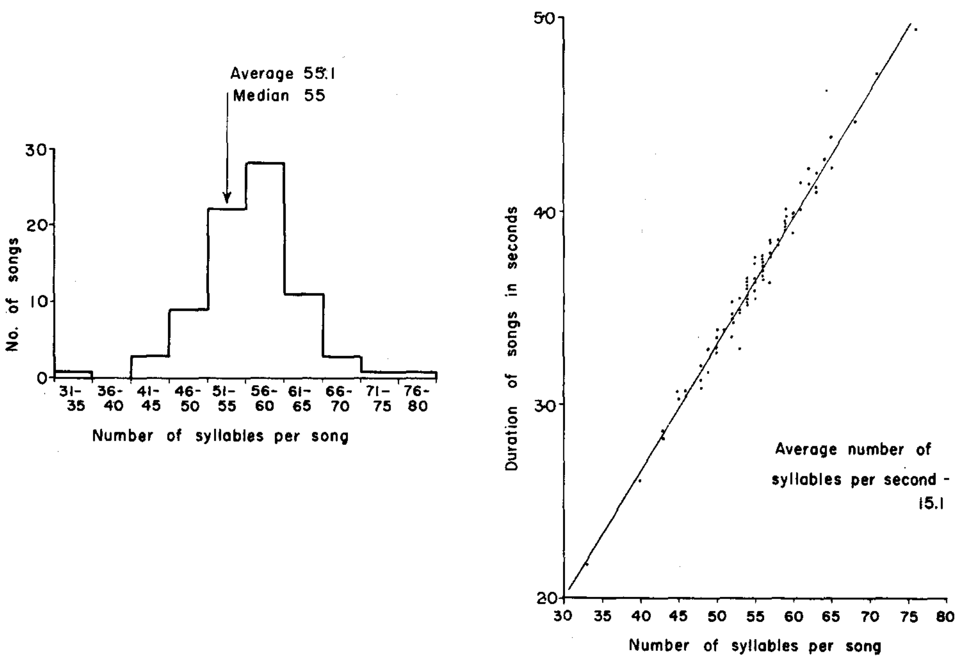

Fig. 4. Left, frequency distribution of number of syllables per song for bird no. 1 from Cuauhtemoc.

Right, plot of number of syllables per song against duration of song for bird no. 1 from Cuauhtemoc.

made under strictly controlled conditions. Meanwhile indirect evidence is available from a comparison of the frequency characteristics of different syllables in the same song and the pattern of amplitude modulation.

Eight songs from the first day were selected for amplitude analysis. The two presented in figure 6 are typical. The frequency range is narrow at the start of the song and broadens to a maximum which is more or less maintained to the end (A, B). The variation in maximum amplitude of the syllables follows a similar pattern (C). Thus the syllables with low maximum amplitude have a slightly higher minimum frequency (B) and a markedly lower maximum frequency (A). This is true of soft syllables, whether they are those with which a song always begins, or those sometimes occurring in other parts of the song (for example, song 1, syllables 10–20, song 2, syllables 30–50). It seems likely that much of the variation in frequency of songs recorded at a distance from the bird is a result of such amplitude variations, especially if allowance is made for the different attenuation rates of high and low frequencies with distance under different conditions (Pasquinelly, Ann. Epiphyties, 1954:49–62).

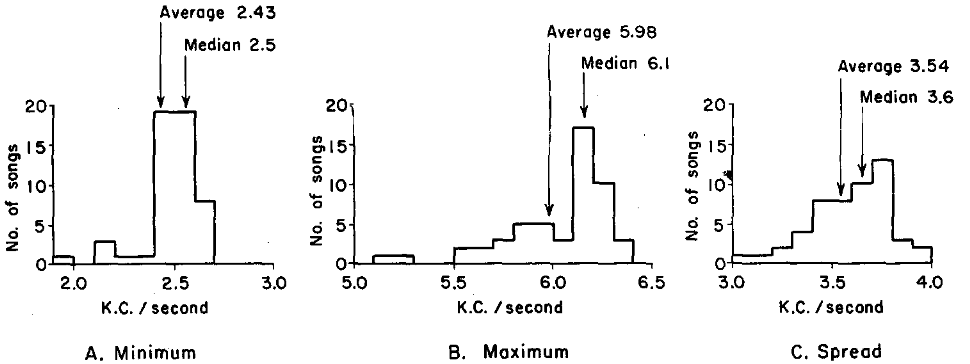

Fig. 5. Bird no. 1 from Cuauhtemoc (first day only): A, minimum frequency of song; B, maximum frequency of song; C, frequency spread of song. These measurements were made from wide-band sonagrams.

(d) Duration of syllables and syllable intervals. In addition to progressive changes in frequency and amplitude through the song there is also a measurable increase in the duration of syllables (fig. 6, D1 and D2) and a decrease in the intervals between syllables (fig. 6, E1 and E2) from the beginning to the end of the song. Once again allowance must be made for the effects of amplitude variation. A low relative amplitude is associated with a reduction in syllable duration and an increase in the interval. Perhaps one of these measures is simply a function of the other in which shorter notes result in longer intervals. If this were true, a graph of the sum of the two figures should form an approximately straight line, which is not the case (fig. 6, D1 and E1, D2 and E2). In fact in a sample of 31 songs of this bird, the interval between the start of successive syllables was found to be somewhat longer at the beginning and end of the song. This trend does not seem to be closely related to amplitude changes; but it is difficult to make measurements which are independent from amplitude effects to check this.

Two solutions to this problem were found. For some birds (see beyond) the loudest frequency in the syllable was selected, and the intervals between its onset in each syllable were measured through the song. For bird 1 from Cuauhtemoc the intervals between the inflections of frequency part way through the syllable could be measured (fig. 2) either directly, in syllables with high amplitude, or by extrapolation, in syllables with low amplitude (fig. 6, F1 and F2). The changes in these measures through the song are broadly similar to those in the interval between the start of successive syllables, but there are longer intervals at the end of the song and shorter ones at the beginning. Again there is no discernible relationship with amplitude variations.

Thus there are at least two factors contributing to the detailed temporal pattern of the song as seen in a sonagram. A low relative amplitude at the start and in other parts of the song is associated with shorter syllables and longer intervals between syllables. This is superimposed on a basic tendency for more widely spaced syllables at the beginning and end of the song.

(e) Time, frequency and amplitude characteristics of the syllable. The normal frequency/time sonagram gives only an approximate picture of the structure of the syllable, even using narrow band-pass filters. More detailed analysis is possible by making amplitude/frequency sections, with the narrow band-pass setting, at short intervals through the syllable (see fig. 1). The duration of the syllables of bird no. 1 as determined

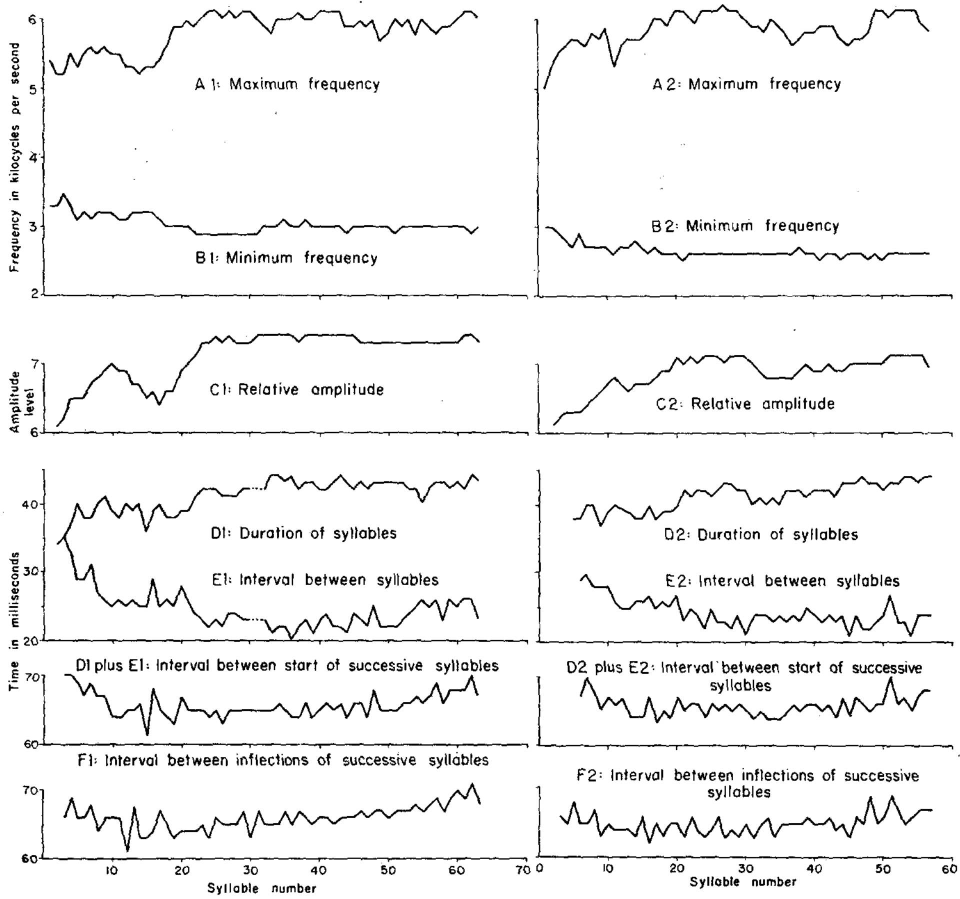

Fig. 6. Sequential analyses of two songs selected from bird no. 1 from Cuauhtemoc. The horizontal scale represents the sequence of occurrence of the syllables in the song (in certain cases the first one or two were too faint to make the particular measure and are not included). The amplitude graphs (C1 and C2) represent the maximum values for each syllable measured arbitrarily on the frequency scale (see fig. 2).

Table 1

Comparison of Song Measurements for Eight Chipping Sparrows from México[1]

		Cuauhtemoc		El Salto						
		Bird 1	Bird 2	Bird 1	Bird 2	Bird 3	Bird 4	Bird 5	Bird 6	Summary
A	Number of songs analyzed	80	27	1	5	2	1	2	2	......
B	Average song duration in seconds	3.65±.45	3.08±.13	2.88	3.71	2.90	2.92	2.25	2.84	3.03 (2.25–3.71)
C	Number of syllables per song	55.1±6.7	55.1±2.5	54.0	63	48.5	56.0	46.5	54.0	54.0 (46.5–63.0)
D	Average syllables per second	15.1±0.2	17.9±0.3	18.8	17.0	16.7	19.2	20.7	19.0	18.1 (15.1–20.7)
E	Syllable duration in milliseconds	43.3±1.2	33.3±2.4	37	35.5	49.0	39	......	36.5	39.1 (33.3–49.0)
F	Average minimum frequency in KC/sec.	2.43±.14	2.42±.10	3.2	2.9	2.4	2.9	......	3.2	2.8 (2.4–3.2)
G	Average maximum frequency in KC/sec.	5.98±.27	6.52±.19	7.0	6.7	6.3	6.5	......	6.2	6.5 (6.0–7.0)
H	Average frequency spread in KC/sec.	3.54±.20	4.10±.25	3.8	3.8	3.9	3.6	......	3.0	3.7 (3.0–4.1)

[1] Note that the term average is used as a synonym for the arithmetic mean. While the table is self-explanatory, individual figures are subject to the following conditions: Bird 1, from Cuauhtemoc, B–G represent calculated averages and standard deviations (B–E for whole sample, F–H for first day only); bird 2, from Cuauhtemoc, B–H represent calculated averages and standard deviations for whole sample; birds 1 and 4, from El Salto, represent actual measurements from a single record each; birds 3, 5, and 6 represent average values for two records each (bird 5, E–H, record too poor for these measurements); bird 2, from El Salto, B–H represent average values of five recordings; summary, B–H represent averages and extremes of the average values given for all of the birds involved.

directly from the wide band, frequency/time analysis is about 43 milliseconds in the latter part of the song (fig. 6, D1, D2). Figure 7A presents a series of 18 sections at 2.5 millisecond intervals through such a typical, high amplitude syllable.

We see a different structure in the two parts of the syllable. The first downward-inflected note is a single tone, with the widest frequency spread in the middle. The peak frequency falls continuously with time and then levels out at about 3.5 KC. Then ampli-

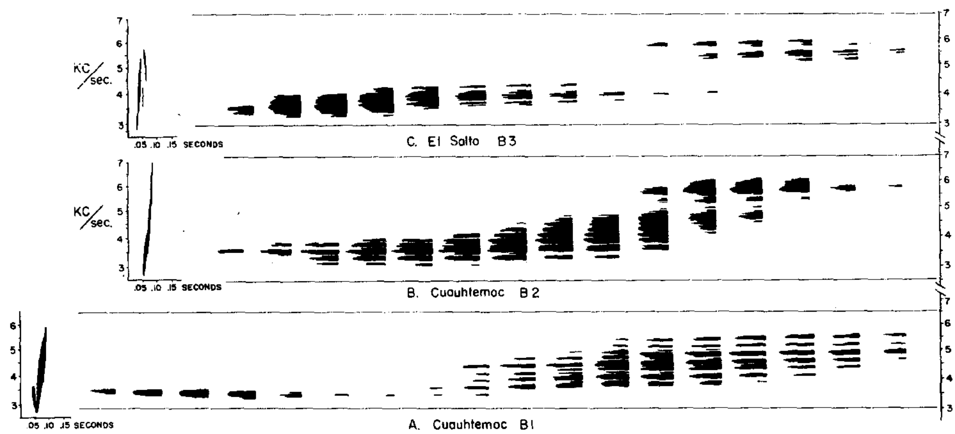

Fig. 7. Serial sections of syllables selected from songs of three different birds. A, bird no. 1 from Cuauhtemoc; B, bird no. 2 from Cuauhtemoc; C, bird no. 3 from El Salto. Wide-band frequency/time sonagrams of the syllables are shown at left. Amplitude/frequency serial sections are illustrated at right, proceeding from left to right through the syllable at 2.5 millisecond intervals.

tude declines, but before this note dies out it is joined by first one and then several overtones at about 250 cycle intervals. From this point onward each note and its overtones tend to rise in frequency. But the overall change in frequency characteristics is achieved by a transfer of emphasis from lower to higher overtones, the lower ones fading and dropping out and additional higher ones coming in.

By this method we can thus obtain a rather complete picture of the frequency structure of the syllable and the comparison with songs of other individuals which follows is largely concerned with these details of syllable structure.

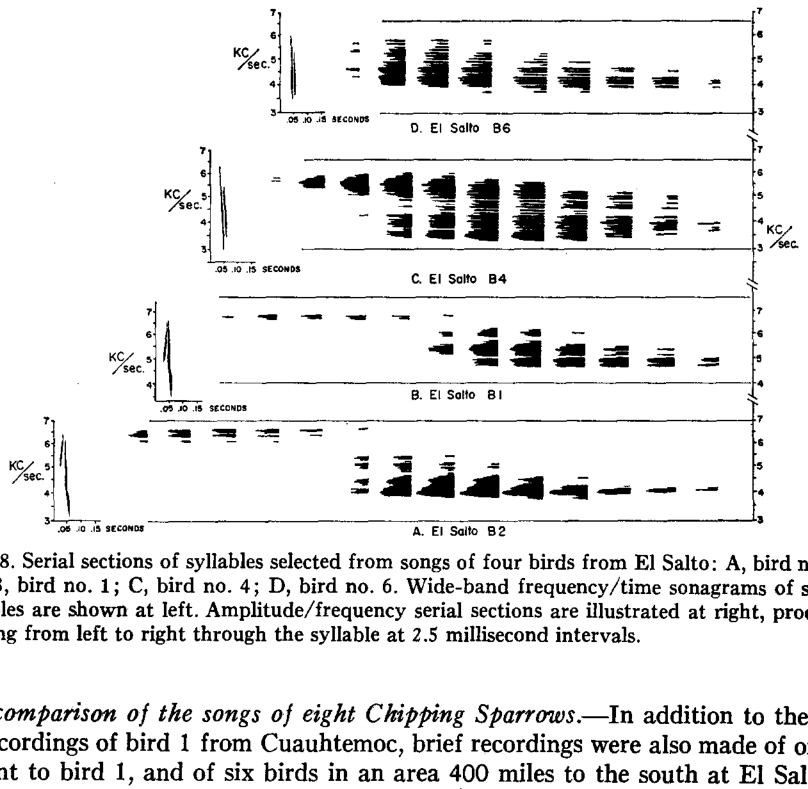

Fig. 8. Serial sections of syllables selected from songs of four birds from El Salto: A, bird no. 2; B, bird no. 1; C, bird no. 4; D, bird no. 6. Wide-band frequency/time sonagrams of syllables are shown at left. Amplitude/frequency serial sections are illustrated at right, proceeding from left to right through the syllable at 2.5 millisecond intervals.

A comparison of the songs of eight Chipping Sparrows.—In addition to the extensive recordings of bird 1 from Cuauhtemoc, brief recordings were also made of one bird adjacent to bird 1, and of six birds in an area 400 miles to the south at El Salto (see page 125). Usually only one or two songs were recorded, which limits this analysis to certain aspects of variation, particularly that involving syllable structure. Before considering this, the other characteristics will be reviewed briefly. For purposes of comparing variability, standard deviations are given for measures of the two larger samples from the birds from Cuauhtemoc (table 1).

General characteristics. Average song duration (3.03 seconds for the whole sample) varies somewhat between individuals but in most cases falls within twice the standard deviation of the average for Cuauhtemoc B1. In contrast with this, the number of syllables per second is more or less constant within the individual, and the differences found between individuals are probably consistent. In spite of these variations the sample as a whole fell within quite narrow limits with an average of 18.1 syllables per second and extreme values of the averages for each individual of 15.1 and 20.7. Last of the temporal characteristics to be measured is syllable duration, which is subject to change with loudness, as described previously, and thus varies considerably within the individual.

The differences between individuals recorded here are probably not reliable, although it is likely that if the comparison had been restricted to high amplitude records, consistent inter-individual differences would have been found.

A sample of songs from all birds was measured for spacing of syllables through the song. Intervals between either an inflection in the syllable, or between the onset of the dominant frequency, were measured in the first ten and the last ten syllables and compared with a sample of ten from the middle of the song. In every case the average interval in the middle of the song was shorter than that at the beginning and end, indicating the same trend as in bird 1 from Cuauhtemoc.

Frequency characteristics are also subject to variation with amplitude, especially in the upper part of the scale. Thus the maximum frequency varies more in the individual than the minimum frequency. Whereas individual differences in maximum frequency are not consistent, those in minimum frequency may be significant. The average spread of frequency is fairly consistent through the whole sample.

Syllable structure. As can be seen from the frequency/time analyses (figs. 2, 7, and 8), syllable structure is similar in some individuals and different in others.

The variations in syllable structure are seen more clearly in the serial sections. The three birds illustrated in figure 7 show marked differences in detailed structure. In comparison with bird 1 from Cuauhtemoc (A), which has already been described, bird 2 from Cuauhtemoc (B) lacks the initial note with a downward inflection and has a discontinuity in the rising note which, incidentally, is not evident on the frequency/time analysis. These two birds had adjacent territories and were within earshot of each other. The third record (C) of a bird from El Salto shows another syllable type with first a rising and then a falling inflection. In contrast, figure 8 shows two pairs of songs with very similar syllable structure, all drawn from the same population.

In spite of these variations in syllable structure, we notice that all birds share the characteristic pattern of overtones, with changes in overall frequency resulting largely from a shift in emphasis from one overtone to another. The tonal quality of the notes which make up the syllable must be strongly affected by this overtone structure. Comparative studies of such serial sections will provide the best means of discovering whether there are any species-specific tonal qualities in bird song which might be used in species recognition. The overtone pattern also has implications for the mechanism of sound production, the shift of emphasis being perhaps more likely to result from changes in the dimensions of resonating cavities than from changes in the mechanism producing the fundamental frequencies.

DISCUSSION

The temporal pattern of singing.—The Chipping Sparrow was chosen for this study because its song is simple and "monotonous," varying relatively little within the individual. In particular, we do not find individuals with a multiplicity of song themes, such as many more "versatile" song birds employ. Hartshorne (Auk, 73, 1956:176–192) has pointed out a general relationship between the variability of a species' song and the time it spends in song. The more versatile species tend to be "continuous" singers, and the more "monotonous" or "non-versatile" ones to be discontinuous singers. Discontinuous singers are broadly defined as those which are actually singing for less than 30 per cent of the performance time. Bird 1 from Cuauhtemoc, an example of a highly non-versatile singer, sang for 31 per cent of the performance time, which is a good approximation to Hartshorne's estimate. At least in these records, made in the midmorning, the Chipping Sparrow is no exception to the generalization, although Saunders (*op. cit.*) points out it may sing more continuously just after dawn.

In some species the hypothesis is more difficult to apply. In certain cases this is a result of our ignorance of the extent of "versatility," a property of which our ears may be a poor judge. Thus in the European Willow Warbler (*Phylloscopus trochilus*) which Hartshorne cites as an extremely non-versatile singer, the individual may actually have a number of themes. A series of 47 consecutive songs was recorded near Cambridge, England, on May 15, 1957. The sonagrams have not yet been analysed in detail, but there are at least a dozen different themes and the basic themes are also modified in many different ways in consecutive songs. Conversely one can be overimpressed by the variation of some of the versatile singers by just listening to them. There is sometimes a great deal of repetition of themes by the Song Thrush (*Turdus ericetorum*), which is regarded as a highly versatile singer. We need more quantitative information on individual variation before Hartshorne's interesting generalizations can be tested.

A second problem arises in determining the degree of continuity of the singing of birds like thrashers and mockingbirds. The briefness of the pauses occurring at very frequent intervals may give an impression of continuity in birds which are actually silent for a relatively high proportion of the performance time. It is necessary first to ascertain what actually constitutes a single song in a versatile singer before the temporal characteristics of the singing can be worked out.

Song as a means of specific and individual recognition.—The question of which properties of a song may be used in specific and individual recognition can only be finally answered by experiment. However, indirect evidence may be obtainable by the study of natural variation. In general we may expect that characteristics functioning as means of recognition, if they exist, will appear consistently in the songs of the individual. Those which could be used for individual recognition should differ from bird to bird, while those for species recognition should be consistent in all members of the species, or at least in all members of a population.

For specific recognition it is a prerequisite that the song should be readily distinguished from those of other species likely to be heard at the same time and place. Comparative study is therefore necessary to determine which characteristics of the song may be important, and we do not yet have the necessary information to make this possible in the Chipping Sparrow. However, we can speculate about the properties which could be used in individual recognition.

General frequency characteristics are unlikely to be useful for individual recognition in the Chipping Sparrow, since they vary with the loudness of the song and attenuate differently with distance. Song duration and the number and duration of the syllables also vary widely within the individual. Most consistent within the individual are (a) the rate of syllables per second and (b) the detailed frequency/amplitude structure of the syllable. However, pairs of birds have been found within the population at El Salto whose songs are very similar in one or both of these characteristics. In these cases it is difficult to see how reliable individual recognition would be possible. The detailed resemblance between songs of some members of the same population seems to imply a degree of causal relationship, but only further experimentation can tell whether this is a result of genetic factors, of learning, or simply of chance.

Serial frequency/amplitude sectioning as a method of song analysis.—It has been suggested that the distinctive tonal quality of the songs of some birds may be important in specific recognition (Thorpe, Ibis, 100, 1958:535–570). The physical properties which convey this tonal quality, including in particular the patterns of overtones, are difficult to discern from the wide band, frequency/time sonagrams most commonly used. We believe that the method of frequency/amplitude serial sectioning described in this paper can give valuable information about these details of note structure.

For example, although individual differences in syllable structure are evident in the Chipping Sparrow, birds from both populations share the same overtone structure. The intervals between overtones vary. Those in bird 1 from Cuauhtemoc are about 250 cycles apart, and in bird 2, where they are less regular, about 200 cycles apart. In birds 1 and 2 from El Salto they are irregular, but in birds 4 and 6, there is a remarkably regular pattern of as many as 18 simultaneous overtones at 100 cycle intervals. It is conceivable that this pattern of several, evenly spaced overtones is distinctive of the song of the Chipping Sparrow and might be used in specific recognition.

The problem of making reliable measurements from sonagrams.—Some of the data presented in this paper are derived from fine measurements, which are susceptible to sources of error from which coarser measurements are free. In the first place we must not forget that a natural sound is subject to many distortions before a sonagram is obtained. Frequency response in particular is influenced by the characteristics of microphone, recorder and playback amplifiers, the setting of the "shaping" switch on the sonagraph, and the band-pass settings which are used. The final measurements are relative and it is therefore necessary to state the conditions under which they are made.

For example, the frequency measures given in this paper are taken from sonagrams made with the wide-band setting, which distorts by expanding the apparent frequency spread of a given note. The reason for using this, rather than the narrow-band setting, is that wide band sonagrams reveal the temporal characteristics of the sound most clearly. While the measures of frequency are thus distorted, the distortion is a systematic one, so that the results can be used for comparative purposes. However, if comparisons are to be made between sonagrams from different machines it is necessary to calibrate each sonagraph.

In addition to these instrumental effects, attention has been drawn to the more subtle influence which variations in amplitude can have, both on the temporal and on the frequency characteristics of a sound. Especially when fine measurements are being made, such variations must be taken into account if the results are to be meaningful.

SUMMARY

As the first subject in a series of studies of variation in bird song, the Chipping Sparrow was selected because of the relatively slight degree of variation within the individual. The extent of this variation is traced in a large sample of songs of one bird (bird 1) and comparisons are then made with smaller samples from seven individuals. All recordings were made at two locations in México, in Chihuahua and in Durango.

In bird 1, the average values for 80 songs are: song duration, 3.65±0.45 seconds; interval between songs, 8.1±1.9 seconds; number of syllables per song, 55.1±6.7; rate of syllables per second, 15.1±0.2; minimum sound frequency, 2.43±0.14 KC/sec.; maximum frequency, 5.98±0.27 KC/sec.; frequency spread, 3.54±0.20 KC/sec. The interval between the start of successive syllables is longest at the beginning and end of the song. Superimposed on this is an apparent reduction in syllable length where the amplitude is relatively low. This amplitude variation also has an effect on frequency characteristics and must be taken into account in making precise measurements.

A new device is described for modifying the sonagraph to make frequency/amplitude sections serially through a syllable at intervals down to 2.5 milliseconds. Analysis of syllable structure by this means reveals, in bird 1, an elaborate pattern of evenly spaced overtones, with the overall changes of frequency effected mainly by a shift of emphasis from one overtone to another.

A comparison with the songs of the seven other birds reveals differences in syllable structure, which are sometimes striking, even between neighboring birds. However,

some adjacent birds had a very similar syllable structure. All songs analyzed showed signs of the same pattern of multiple, evenly spaced overtones. Significant individual differences, which might be used in individual recognition, were found in the number of syllables per second, and possibly in syllable duration and minimum frequency in some cases. Differences in other frequency characteristics, song duration and number of syllables per song are probably not statistically significant as determined from these samples.

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