VARIATION IN CAROLINA WREN SONGS

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THERE is a great deal of variation in the songs of the Carolina Wren (*Thryothorus ludovicianus*), but the extent of this variation is not well known. Many writers speak of the "large number of different songs" any individual bird may sing but make no statement of the exact number. A. A. Saunders, who possesses an exceptional ability to analyze bird songs by ear, reports (Bent, 1948: 213) hearing 8 different songs from one individual in less than half an hour and 36 different songs from one individual in the course of one season. I have seen no definite statement as to whether or not two different individuals may sing identical songs.

The accounts of Carolina Wren songs in the literature are based on auditory analyses and, considering the complex rhythms of these songs and the rapid rate with which they are uttered, it is not surprising that so few writers have attempted to give an exact account of the variation in them. However, the difficulties in studying the variation in bird songs can be largely overcome by the use of tape recordings and an audiospectrograph. The purpose of this paper is to report on the variation in Carolina Wren songs as determined by audiospectrographic analyses of tape recordings.

This study has been aided by grants from the Development Fund and the Graduate School of Ohio State University. I am indebted to Dr. Carl R. Reese, of the Department of Zoology and Entomology, Ohio State University, for assistance in making many of the recordings, and to Mrs. Mary Jane Alluisi, of Ohio State University, for assistance in the preparation and analysis of the audiospectrographs. I wish to thank Dr. Carl R. Reese, Dr. Edward S. Thomas, and Mr. Jeff Swinebroad, of Ohio State University, for their careful reading and criticisms of the manuscript.

This study is based on 58 tape recordings of Carolina Wren songs made by my associates at Ohio State University and myself; 28 were made in Florida, 23 in Ohio, 4 in North Carolina, and 1 each in South Carolina, Alabama, and Kentucky. These recordings contain 71 song series and 753 songs; 18 of the Florida recordings, containing 24 song series, were made of a single individual in Myakka River State Park (this bird is hereinafter referred to as wren M-4). A list of the recordings studied is given in Table 1.

Five of the Ohio recordings (the first five listed in Table 1) were made with a Brush Soundmirror recorder, using a tape speed of 7.5 inches per second; all the others were made with a Magnemite recorder,

TABLE 1

CAROLINA WREN RECORDINGS STUDIED

Recording number	*Where recorded*	*Time of day*	*Date*	*Number of song series*	*Recorded by*
147	Eubank, Kentucky	6:30 A.M.	March 26, 1950	1	Borror
164	Worthington, Ohio	6:30 A.M.	May 3, 1950	4	Borror and Reese
172	Worthington, Ohio	6:05 A.M.	May 4, 1950	1	Borror and Reese
231	Columbus, Ohio	7:00 A.M.	April 19, 1951	1	Borror and Reese
232	Columbus, Ohio	7:15 A.M.	April 19, 1951	1	Borror and Reese
329	Delaware Co., Ohio	11:00 A.M.	March 14, 1953	1	Borror
355	Bradenton, Florida	10:30 A.M.	March 23, 1953	1	Borror
365	Columbus, Ohio	6:05 A.M.	April 3, 1953	1	Borror and Reese
371	Dublin, Ohio	9:30 A.M.	April 4, 1953	1	Richard Banks
428	Columbus, Ohio	6:30 A.M.	May 1, 1953	1	Borror
431	Columbus, Ohio	8:15 A.M.	April 29, 1953	1	Borror and Reese
438	Franklin Co., Ohio	6:00 A.M.	May 4, 1953	1	Borror and Reese
552	Columbus, Ohio	8:30 A.M.	May 28, 1953	1	Borror and Reese
663	Columbus, Ohio	9:25 A.M.	May 28, 1953	1	Borror and Reese
731	Columbus, Ohio	1:15 P.M.	March 6, 1954	1	Borror and Reese
737	Columbus, Ohio	8:50 A.M.	March 10, 1954	1	Borror and Reese
744	Gahanna, Ohio	9:30 A.M.	March 13, 1954	1	Borror
779	Columbus, Ohio	6:55 A.M.	March 27, 1954	3	Borror
802B	Troy, Alabama	7:55 A.M.	April 2, 1954	2	Borror
808B	Tallahassee, Florida	6:50 A.M.	April 3, 1954	1	Borror
825B	Myakka River State Park, Florida	7:30 A.M.	April 8, 1954	2	Borror (wren M-2)
828B	Myakka River State Park, Florida	6:00 P.M.	April 8, 1954	4*	Borror (wren M-4)
836B	Myakka River State Park, Florida	2:10 P.M.	April 9, 1954	1	Borror (wren M-4)
837B	Myakka River State Park, Florida	4:00 P.M.	April 9, 1954	1	Borror (wren M-4)
840B	Myakka River State Park, Florida	9:20 A.M.	April 10, 1954	1	Borror (wren M-4)
844B	Myakka River State Park, Florida	5:52 P.M.	April 10, 1954	1	Borror (wren M-4)
847B	Myakka River State Park, Florida	7:10 A.M.	April 11, 1954	1	Borror (wren M-3)
849B	Myakka River State Park, Florida	7:26 A.M.	April 11, 1954	1	Borror (wren M-2)
850B	Myakka River State Park, Florida	9:35 A.M.	April 11, 1954	2†	Borror (wren M-4)
853B	Myakka River State Park, Florida	2:35 P.M.	April 11, 1954	1	Borror (wren M-4)
854B	Myakka River State Park, Florida	3:22 P.M.	April 11, 1954	1	Borror (wren M-4)
855B	Myakka River State Park, Florida	3:47 P.M.	April 11, 1954	1	Borror (wren M-4)
858B	Myakka River State Park, Florida	6:15 A.M.	April 12, 1954	1	Borror (wren M-4)
859B	Myakka River State Park, Florida	6:25 A.M.	April 12, 1954	2	Borror (wren M-4)
862B	Myakka River State Park, Florida	7:12 A.M.	April 12, 1954	1	Borror (wren M-3)
863B	Myakka River State Park, Florida	9:25 A.M.	April 12, 1954	1	Borror (wren M-3)
866B	Myakka River State Park, Florida	9:55 A.M.	April 12, 1954	1	Borror (wren M-2)
868B	Myakka River State Park, Florida	10:14 A.M.	April 12, 1954	1	Borror (wren M-1)

TABLE 1 (Cont.)

Recording number	*Where recorded*	*Time of day*	*Date*	*Number of song series*	*Recorded by*
870B	Myakka River State Park, Florida	12:20 P.M.	April 12, 1954	1	Borror (wren M-4)
871B	Myakka River State Park, Florida	12:32 P.M.	April 12, 1954	1	Borror (wren M-4)
872B	Myakka River State Park, Florida	4:08 P.M.	April 12, 1954	2	Borror (wren M-4)
874B	Myakka River State Park, Florida	8:12 A.M.	April 13, 1954	1	Borror (wren M-4)
875B	Myakka River State Park, Florida	8:45 A.M.	April 13, 1954	1	Borror (wren M-4)
880B	Myakka River State Park, Florida	4:25 P.M.	April 13, 1954	1	Borror (wren M-4)
881B	Myakka River State Park, Florida	4:40 P.M.	April 13, 1954	1	Borror (wren M-4)
893B	Tampa, Florida	11:00 A.M.	April 17, 1954	1	Borror
910B	Ruffin, South Carolina	9:22 A.M.	April 23, 1954	1	Borror
915B	Greensboro, North Carolina	11:18 A.M.	April 24, 1954	1	Borror
918B	Greensboro, North Carolina	11:37 A.M.	April 24, 1954	1	Borror
922B	Greensboro, North Carolina	4:15 P.M.	April 24, 1954	1	Borror
932B	Greensboro, North Carolina	7:52 A.M.	April 25, 1954	1	Borror
951	Worthington, Ohio	8:03 A.M.	May 2, 1954	1	Borror
974	Franklin Co., Ohio	7:00 A.M.	May 8, 1954	1	Borror
1007	Westerville, Ohio	9:25 A.M.	May 13, 1954	1	Borror
1080	Brown Co., Ohio	6:58 P.M.	May 28, 1954	1	Borror
1084	Brown Co., Ohio	6:30 A.M.	May 29, 1954	1	Borror
1107	South Bloomingville, Ohio	4:56 P.M.	May 30, 1954	1	Borror and Reese
1131	Hocking Co., Ohio	8:13 A.M.	June, 6 1954	1	Borror

* For the first several songs in this recording the songs of two types alternate.
† The songs of the two types alternate in the recording.

using a tape speed of 15 inches per second. The recordings are in the Laboratory for the Study of Animal Sounds, Department of Zoology and Entomology, Ohio State University.

Samples of the 71 song series have been graphed with an audiospectrograph; this technique has been described in a previous paper (Borror and Reese, 1953). The audiospectrograph used in the preparation of these graphs was a Vibralyzer, manufactured by the Kay Electric Co., Pine Brook, N. J. Unless otherwise indicated, all graphs in this paper were made using the narrow band filter, and only a portion of each song is shown. All the graphs in a given plate, unless otherwise indicated, were made using the same time and frequency scales. The successive notes in the phrases of the Carolina Wren songs are indicated in the graphs by the letters A, B, C, etc.

SINGING BEHAVIOR

A Carolina Wren song consists of a series of similar phrases, each phrase consisting of two or more notes. The notes are uttered rapidly, and the entire song usually lasts two seconds or less. A given song

is usually sung at fairly regular intervals for a period of time (in this paper the term *song series* is used for such a group of similar songs), then the bird either stops singing for a while or starts singing a different song. In all but two of our 58 Carolina Wren recordings, successive songs are of the same type over a period of time; in two recordings (828B and 850B) the bird sang two song types alternately.

The rate of singing varies, both in a given song series and in the singing of different birds. A summary of the data on this point is given in Table 2; the time measurements were made to the nearest one-fourth second.

TABLE 2

SINGING RATE OF CAROLINA WRENS

Source of recordings	*Number of measurable intervals between songs*	*Time in seconds from beginning of one song to beginning of next*	
		Range	*Mean* $\pm \sigma_m$
Florida M-4	147	4.50–12.50	6.06 ± 0.12
Florida Others	72	3.25–14.00	6.98 ± 0.25
Florida Total	219	3.25–14.00	6.37 ± 0.12
Ohio	335	2.50– 8.50	4.41 ± 0.02
Miscellaneous	57	4.00–12.25	5.88 ± 0.21
All recordings	611	2.50–14.00	5.25 ± 0.07

There is no indication in my data of any factors which might influence or be correlated with the singing; there is no correlation, for example, between the singing rate and the time of day the bird was singing. There was greater variation in singing rate in some song series than in others, even with the same bird. In many of the longer recordings, containing a dozen or more songs, some intervals between songs were twice as long as other intervals. The greatest variation in a single recording was in No. 164, which is the longest recording (nearly 14 minutes); this recording contains four song series, of 11, 53, 89, and 51 songs. The time from the beginning of one song to the beginning of the next averaged 4.36 sec. in the first series, 4.20 sec. in the second, 3.39 sec. in the third, and 3.61 sec. in the fourth. The bird was apparently not becoming tired.

The singing rate in the birds recorded varied from 4.3 to 24.0 songs per minute, and from 4.8 to 13.3 per minute in the songs of one individual. The singing rate averaged 11.4 songs per minute in all the recordings and was significantly higher in Ohio birds than in Florida birds.

SONG LENGTH

The measurements of song length were made to the nearest 0.01 sec. on graphs made using the wide band filter. These measurements are summarized in Table 3.

TABLE 3

SUMMARY OF DATA ON THE LENGTH OF CAROLINA WREN SONGS

Source of recordings	Number of series	Number of songs	Song length (in seconds) Range	Mean ± σ_m Based on all songs	Based on series averages
Florida M-4	24	174	0.93–2.43	1.80 ± 0.02	1.76 ± 0.04
Florida Others	11	88	0.85–2.37	1.68 ± 0.03	1.72 ± 0.08
Florida Total	35	262	0.85–2.43	1.76 ± 0.02	1.75 ± 0.04
Ohio	28	413	0.51–2.42	1.46 ± 0.01	1.51 ± 0.05
Miscellaneous	8	78	1.11–2.24	1.73 ± 0.03	1.78 ± 0.08
All recordings	71	753	0.51–2.43	1.60 ± 0.01	1.66 ± 0.03

In any given series of songs, the songs containing the same number of phrases did not vary more than 0.01 or 0.02 sec. in length, but there was considerable variation in the lengths of songs of different types, and (in a given series) of songs containing different numbers of phrases. In several song series there were some songs twice as long as others, and in one Ohio series (164-III, with 89 songs) some songs were more than three times as long as others.

The recorded songs varied in length from 0.51 to 2.43 sec. and averaged 1.60 sec. Because different series contained different numbers of songs, an average based on the series averages may more nearly represent the average for the species; this average was 1.66 sec. The songs of Ohio birds averaged significantly shorter than those of Florida birds.

THE PHRASES OF CAROLINA WREN SONGS

The phrases of Carolina Wren songs vary in completeness, number, length, the number of notes they contain, and in the character of the notes. Some of these variations (e.g., in phrase number and completeness) occur in the songs of a given series; other variations occur in the different songs of a given bird and in the songs of different birds.

Phrase Completeness.—All the phrases in a song may be complete (Plate 3, Figure 1), or the first and/or last phrase of the song may be incomplete (Figures 2–4), that is, the bird may begin and/or end a song in the middle of a phrase. The first note or two of the song may in some cases be quite weak compared with these same notes in subsequent phrases (Figure 4). The songs of one Ohio bird began with a note that was different from any others in the song (Plate 4, Figure 5, A).

When all the phrases of a song are not complete, it is sometimes difficult to determine whether it is the first or the last phrase that is incomplete. The phrases of some songs are fairly distinct, with a

longer interval between phrases than between any two notes in a phrase; in other songs (e.g., Plate 3, Figure 3) the notes are more evenly spaced and the phrases are less distinct. The limits of the phrases were determined by listening to the recordings played at a reduced tape speed.

TABLE 4

COMPLETENESS OF PHRASES IN CAROLINA WREN SONGS

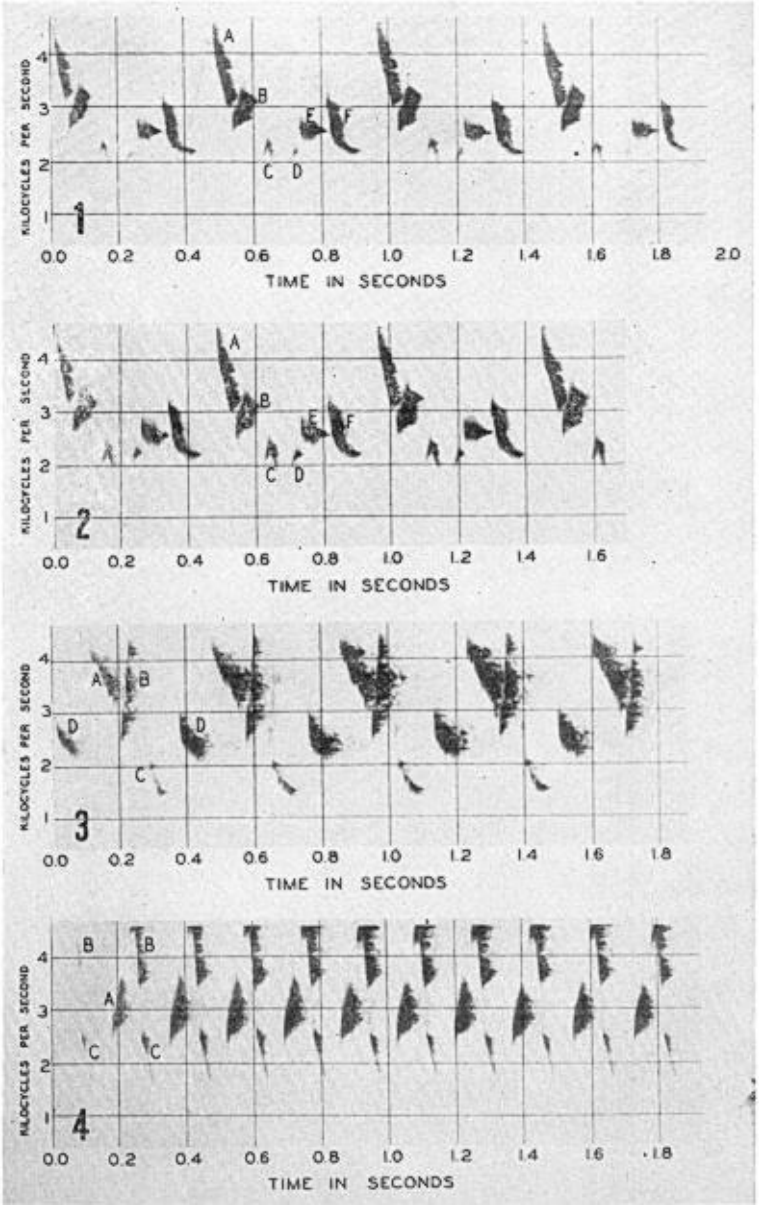
	Florida					
Completeness of phrases	*M-4*	*Others*	*Total*	*Ohio*	*Misc.*	*Total*
All phrases complete	17.72*	9.68	27.40	12.58	3.20	43.18
	73.83†	88.00	78.29	44.93	40.00	60.82
Last phrase incomplete	4.18	0.25	4.43	13.42	4.80	22.65
	17.42	2.27	12.66	47.93	60.00	31.90
First phrase incomplete	1.10	0.00	1.10	1.00	0.00	2.10
	4.58	0.00	3.14	3.57	0.00	2.96
First and last phrases incomplete	1.00	1.07	2.07	1.00	0.00	3.07
	4.17	9.73	5.91	3.57	0.00	4.32
Total song series	24	11	35	28	8	71

* The upper figure of each pair is the number of song series which have the phase completeness indicated; fractions take into account variations within a single song series.

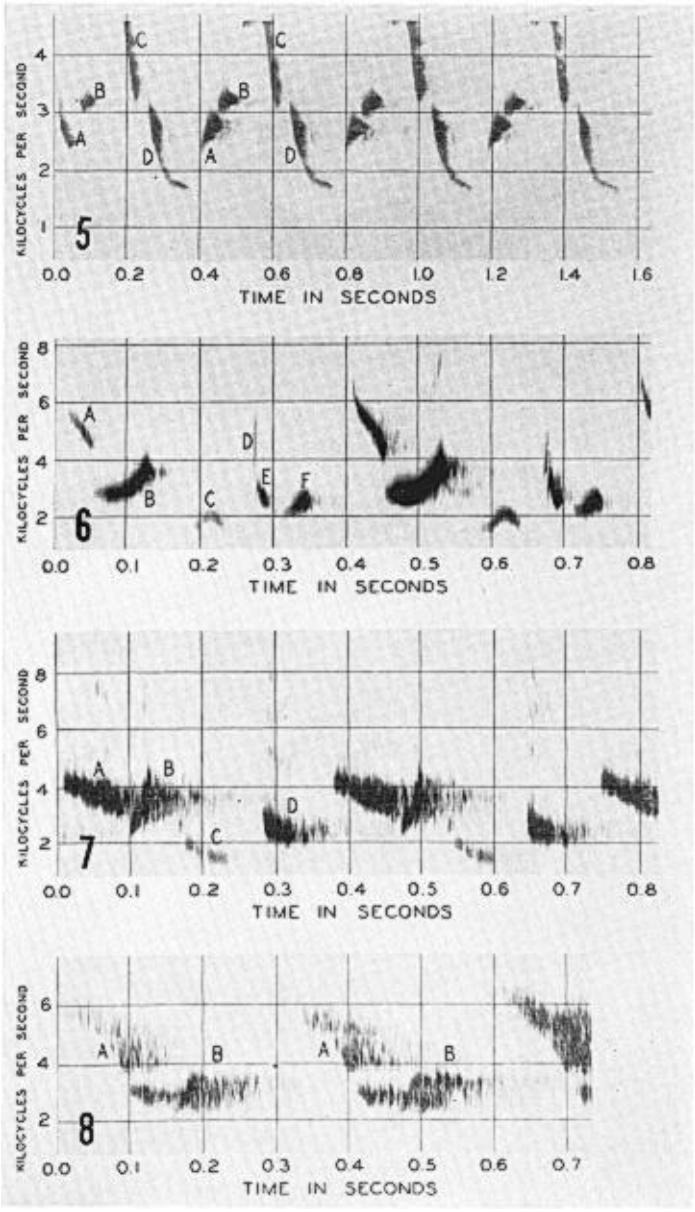
† The lower figure of each pair is the percentage of the song series from the locality in question.

The data on phrase completeness in the songs in our recordings are summarized in Table 4. All the phrases were complete in most (60.82 per cent) of the song series; nearly a third (31.90 per cent) had all but the last phrase of the song complete; only a few had the first phrase (2.96 per cent) or both the first and last phrases (4.32 per cent) incomplete. The last phrase of the song was incomplete considerably more often in the songs of northern birds than in those of Florida birds. All the songs in a series were alike in phrase completeness in about four series out of five (81.69 per cent), and this percentage varied but little in the series from different areas. In about ten per cent of the songs the first note of the first phrase was considerably weaker than in subsequent phrases (e.g., Plate 4, Figure 6, A). The variation in phrase completeness was about the same in the songs of a given individual (e.g., wren M-4) as in all the recorded songs of the species.

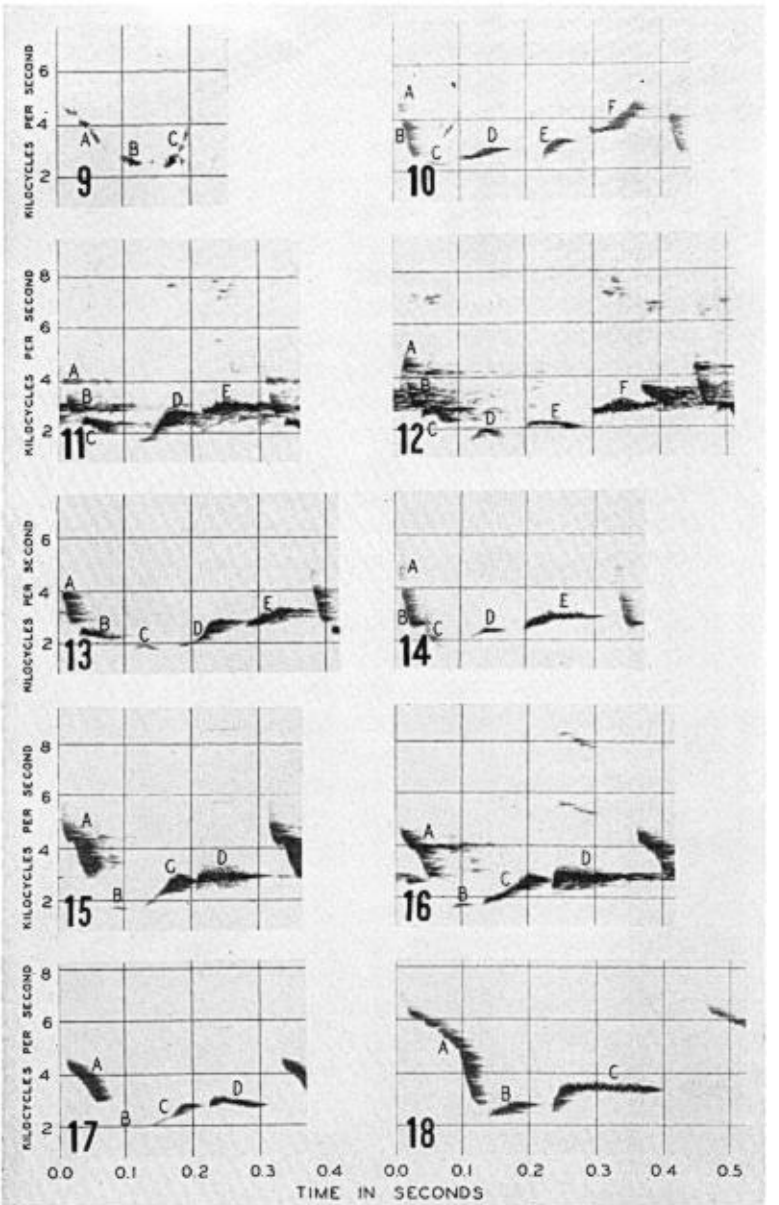
The Number of Phrases in a Song.—The data on the number of phrases in the Carolina Wren songs in our recordings are summarized in Table 5. For the purpose of this table, each incomplete phrase was counted as a phrase, except in cases where both the first and last phrases of the song were incomplete; since these two incomplete phrases were always less than a single complete phrase they were counted in the table as one phrase.



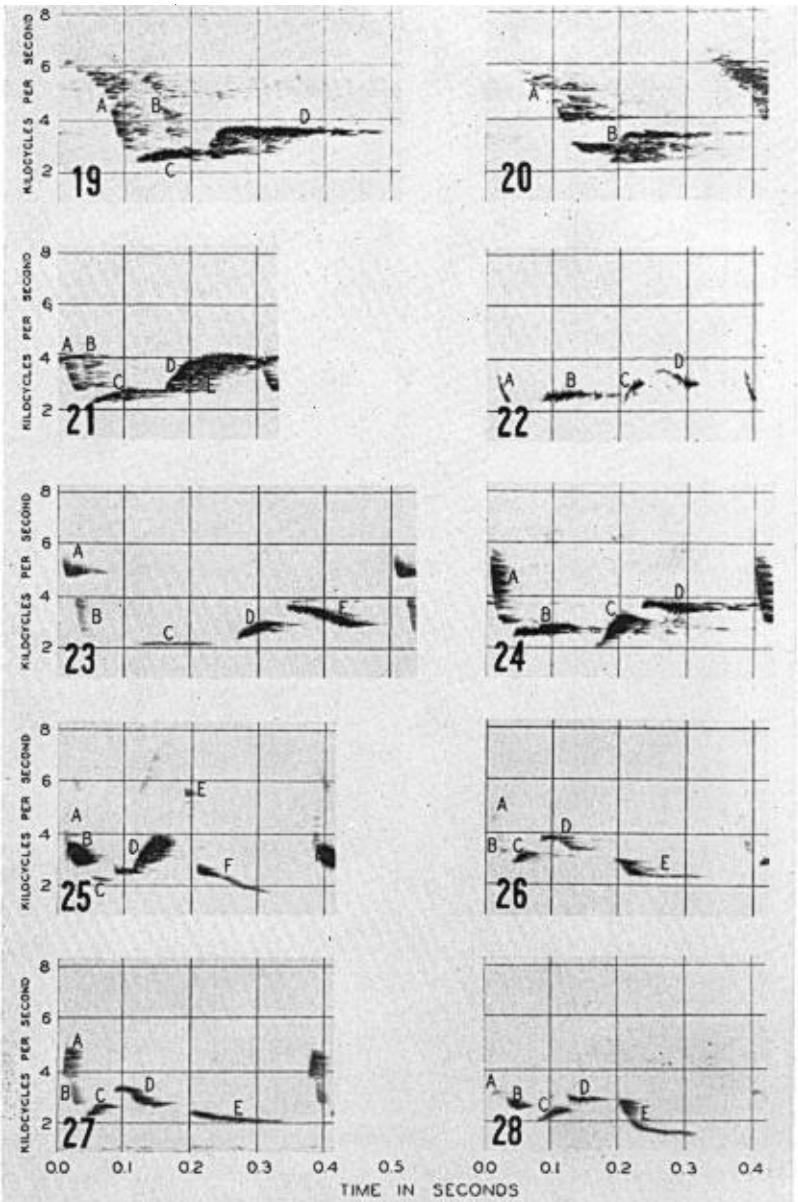
AUDIOSPECTROGRAPHS OF CAROLINA WREN SONGS; each graph shows the entire song. Figures 1 and 2, two songs from series 779-I; the first contains four complete phrases, and the second contains three complete phrases and a partial fourth phrase. Figure 3, a song from series 855B, with both the first and the last phrases incomplete. Figure 4, a song from series 866B, with the first phrase incomplete; the frequencies in note B extend slightly beyond the limit of the graph (cf. Plate 10, Figure 68).



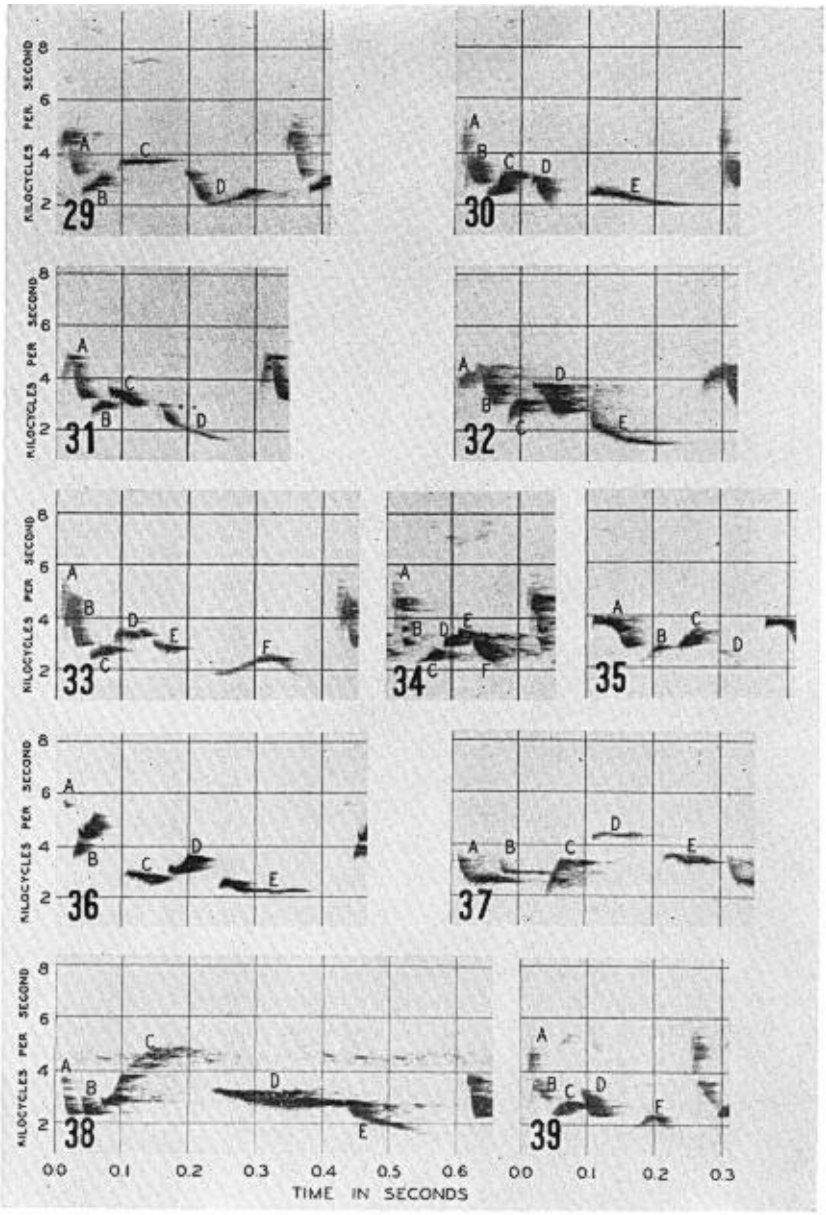
AUDIOSPECTROGRAPHS OF CAROLINA WREN SONGS; FIGURE 5 made using the narrow-band filter, and Figures 6-8 with the wide-band filter. Figure 5, a song from series 951; note A in the first phrase is different from the A note in the other phrases; the frequencies in note C extend slightly beyond the limit of the graph (cf. Figure 71). Figure 6, the first two phrases of a song in series 871B, a song showing very little modulation (cf. Figure 52). Figure 7, two phrases of a song in series 855B, a song showing some modulation (cf. Figures 3 and 75). Figure 8, two phrases of a song in series 828B-IV, a song showing considerable modulation (cf. Figure 20).



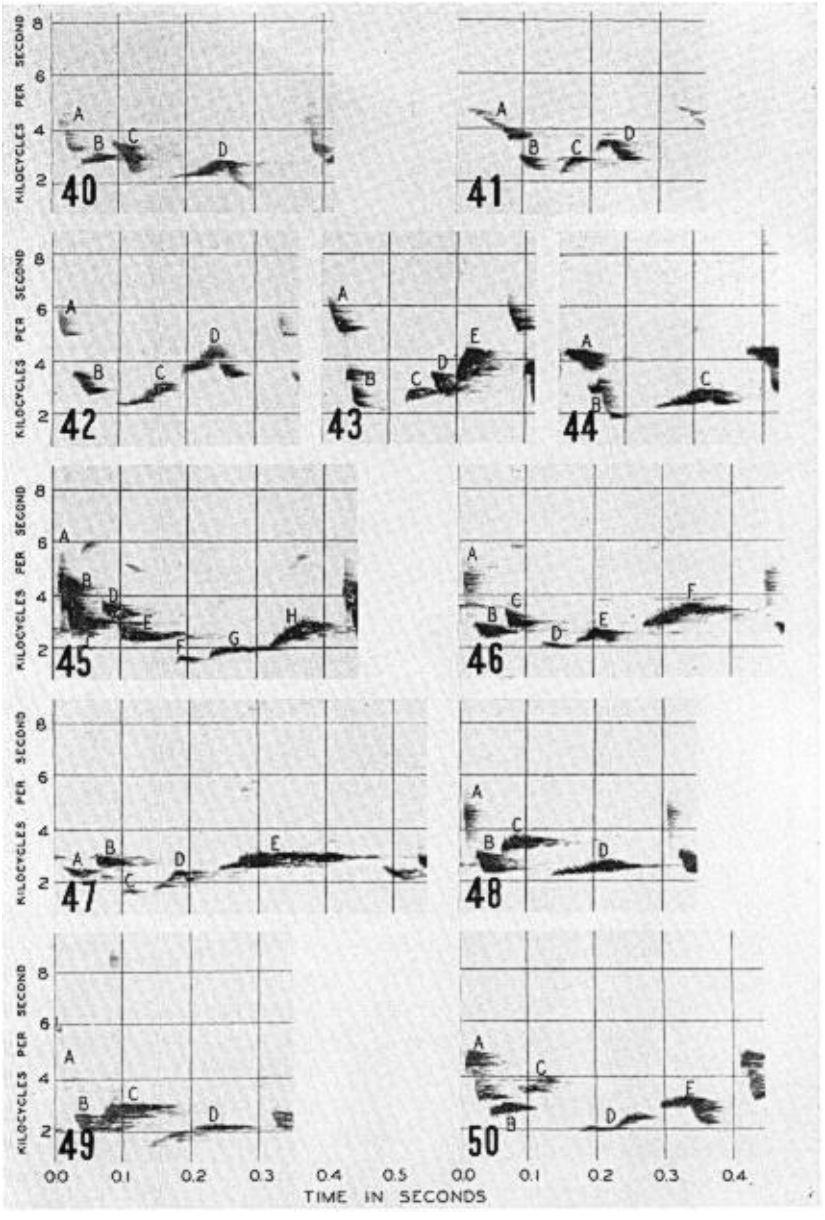
AUDIOSPECTROGRAPHS OF INDIVIDUAL PHRASES OF CAROLINA WREN SONGS. Figure 9, series 232. Figure 10, series 910B. Figure 11, series 428. Figure 12, series 1107. Figure 13, series 552. Figure 14, series 932B. Figure 15, series 862B. Figure 16, series 863B. Figure 17, series 825B-I. Figure 18, series 874B.



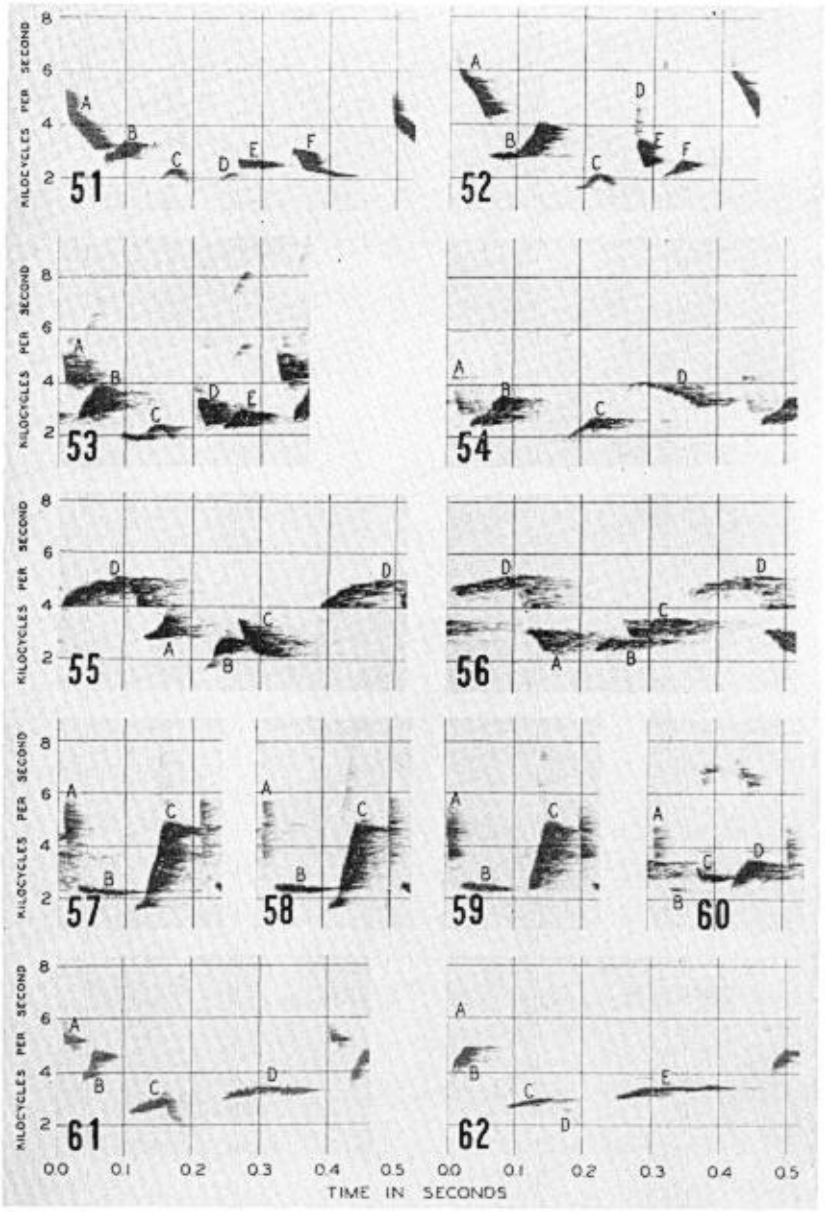
AUDIOSPECTROGRAPHS OF INDIVIDUAL PHRASES OF CAROLINA WREN SONGS. Figure 19, series 859B-II. Figure 20, series 828B-IV. Figure 21, series 853B. Figure 22, series 147. Figure 23, series 779-III. Figure 24, series 918B. Figure 25, series 825B-II. Figure 26, series 172. Figure 27, series 438. Figure 28, series 1080.



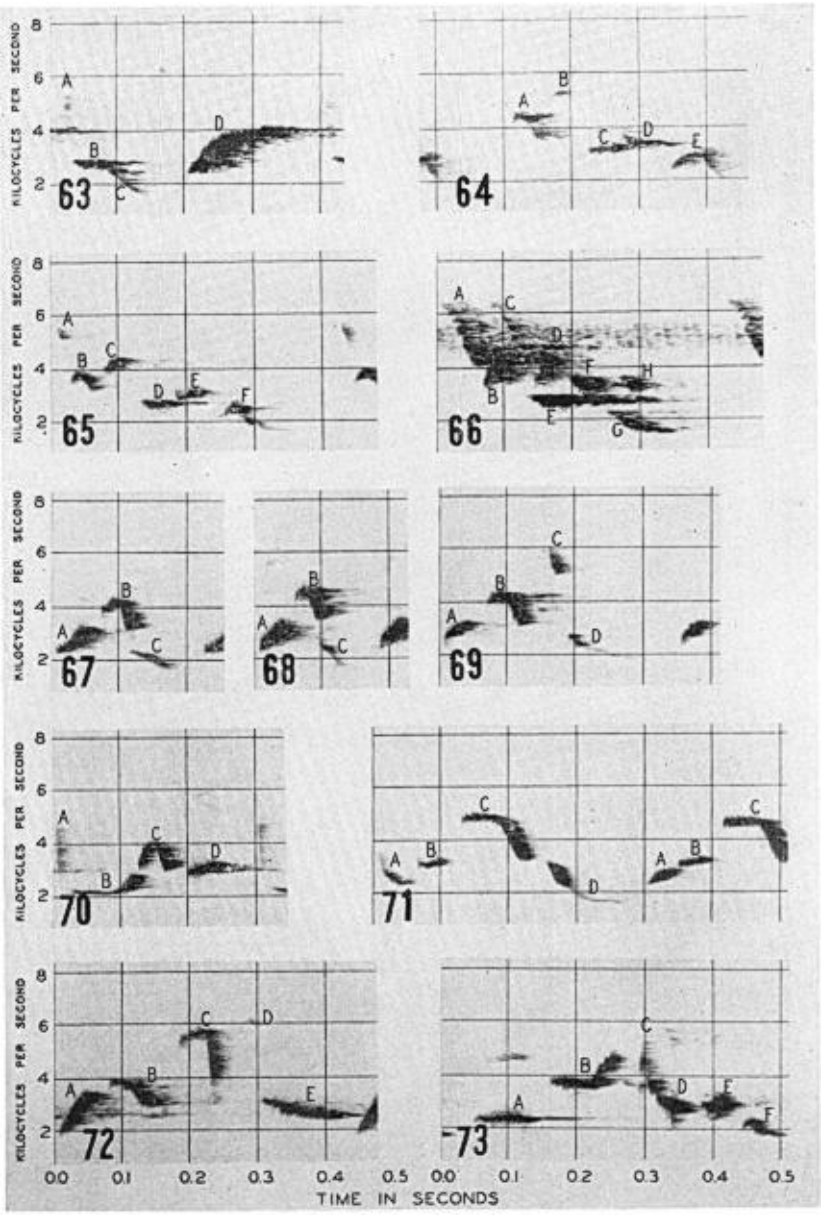
AUDIOSPECTROGRAPHS OF INDIVIDUAL PHRASES OF CAROLINA WREN SONGS. Figure 29, series 329. Figure 30, series 802B-I. Figure 31, series 808B. Figure 32, series 854B. Figure 33, series 779-II. Figure 34, series 881B. Figure 35, series 849B. Figure 36, series 1131. Figure 37, series 164-II. Figure 38, series 1084; the noise in the background (between about 4000 and 5000 cps) is that of an insect. Figure 39, series 663.



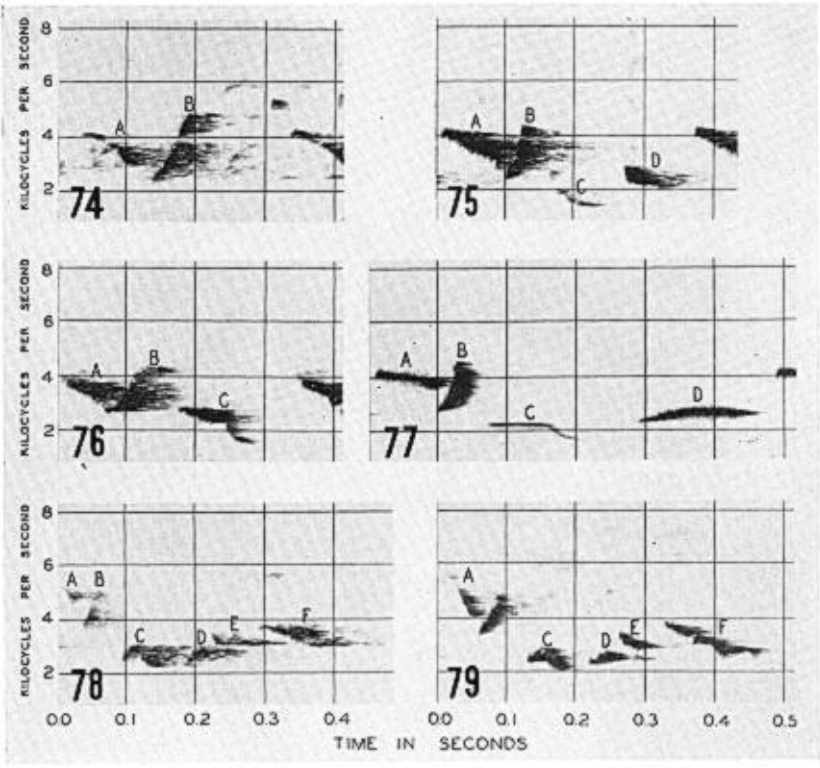
AUDIOSPECTROGRAPHS OF INDIVIDUAL PHRASES OF CAROLINA WREN SONGS. Figure 40, series 731. Figure 41, series 893B. Figure 42, series 802B-II. Figure 43, series 828B-III. Figure 44, series 1007. Figure 45, series 872B-I. Figure 46, series 868B. Figure 47, series 828B-I. Figure 48, series 875B. Figure 49, series 828B-II. Figure 50, series 922B.



AUDIOSPECTROGRAPHS OF INDIVIDUAL PHRASES OF CAROLINA WREN SONGS. Figure 51, series 779-I. Figure 52, series 871B. Figure 53, series 872B-II. Figure 54, series 164-III. Figure 55, series 858B. Figure 56, series 837B. Figure 57, series 870B. Figure 58, series 850B-I. Figure 59, series 840B. Figure 60, series 880B. Figure 61, series 974. Figure 62, series 737.



AUDIOSPECTROGRAPHS OF INDIVIDUAL PHRASES OF CAROLINA WREN SONGS. Figure 63, series 836B. Figure 64, series 164-IV. Figure 65, series 431. Figure 66, series 859B-I; the noise in the background (between about 4700 and 5700 cps) is that of an insect. Figure 67, series 844B. Figure 68, series 866B. Figure 69, series 915B. Figure 70, series 850B-II. Figure 71, series 951 (cf. Figure 5). Figure 72, series 365. Figure 73, series 231.



AUDIOSPECTROGRAPHS OF INDIVIDUAL PHRASES OF CAROLINA WREN SONGS Figure 74, series 744. Figure 75, series 855B. Figure 76, series 355. Figure 77 series 847B. Figure 78, series 164-I. Figure 79, series 371.

TABLE 5

SUMMARY OF DATA ON THE NUMBER OF PHRASES IN CAROLINA WREN SONGS

		Number of phrases in song	Number of Songs M-4	Others Florida	Total Florida	Ohio	Other states	Total—all states
		2	0	4	4	4	0	8
		3	2	11	13	85	0	98
		4	18	19	37	234	11	282
		5	47	17	64	80	39	183
		6	50	13	63	9	22	94
		7	4	19	23	1	6	30
		8	9	1	10	0	0	10
		9	27	0	27	0	0	27
		10	17	0	17	0	0	17
		11	0	3	3	0	0	3
		12	0	1	1	0	0	1
Total			174	88	262	413	78	753
Number of song series			24	11	35	28	8	71
Number of phrases in song	*Range*		3 to 10	2 to 12	2 to 12	2 to 7	4 to 7	2 to 12
	Average	*Based on all songs*	6.47 ±0.15	5.30 ±0.21	6.08 ±0.13	4.02 ±0.04	5.29 ±0.09	4.87 ±0.06
		Based on series Average	6.08 ±0.39	5.71 ±0.69	5.96 ±0.34	4.21 ±0.15	5.31 ±0.27	5.20 ±0.20
Coefficient of correlation between number of phrases in song and phrase length		*Based on all songs*	−0.913*	−0.833*	−0.886*	−0.398*	−0.647*	−0.799*
		Based on average number of phrases in each song series	−0.942*	−0.856*	−0.910*	−0.539*	−0.618†	−0.826*

* Highly significant. † Scarcely significant.

The phrases in different songs varied in number from 2 to 12, and from 3 to 10 in the different songs of one bird (wren M-4). The songs in a given series usually did not vary more than a phrase or two in length. The songs of Florida birds contained, on the average, significantly more phrases than the songs of Ohio birds. The songs in our recordings averaged 4.87 phrases per song (based on series averages, the average was 5.20 phrases per song).

The Length of a Phrase.—The data on phrase length are summarized in Table 6. The phrase length varied from 0.169 to 0.620 sec. in all the songs studied, and from 0.195 to 0.460 sec. in the different songs of one bird (wren M-4). There was a significant correlation between the phrase length and the number of phrases in the song (except in the miscellaneous songs, in which correlation was based on the average number of phrases per song in each song series); in general, the more phrases in the song, the shorter these phrases were (Table 5). The phrases in the songs of Florida birds averaged

TABLE 6

SUMMARY OF DATA ON PHRASE LENGTH AND THE NUMBER OF NOTES PER PHRASE IN CAROLINA WREN SONGS

		Source of recordings					
		M-4	*Others Florida*	*Total Florida*	*Ohio*	*Other states*	*Total—all states*
Number of song series		*24*	*11*	*35*	*28*	*8*	*71*
Phrase length	*Range*	0.195 to 0.460	0.169 to 0.582	0.169 to 0.582	0.247 to 0.620	0.316 to 0.400	0.169 to 0.620
	Average	0.322 ±0.018	0.345 ±0.032	0.329 ±0.016	0.401 ±0.015	0.375 ±0.010	0.363 ±0.010
Notes per phrase	*Range*	2 to 8	3 to 6	2 to 8	2 to 6	4 to 6	2 to 8
	Average	4.42 ±0.30	4.18 ±0.30	4.34 ±0.22	4.86 ±0.20	4.63 ±0.26	4.58 ±0.14
Coefficient of correlation between phrase length and the number of notes per phrase		0.381‡	0.379‡	0.356†	0.509†	0.497‡	0.448*

* Highly significant. † Significant. ‡ Not significant.

significantly shorter than those in the songs of Ohio birds. There was a significant correlation between the length of a phrase and the number of notes it contained, considering all the songs studied; in some series this correlation was not significant (Table 6).

The Number of Notes per Phrase.—It is relatively easy to determine the number of notes per phrase in some songs, but in others this is not the case. The notes in many songs are more or less run together and considerably modulated, so that it is difficult to determine where one note ends and the next begins. In some songs, two or three distinct frequency bands may be uttered at the same time; when these are separated and are not harmonics, they are considered as distinct notes. A bird may sometimes utter a note containing a given band of frequencies, and before ending that note begin another containing a different band of frequencies; in other songs the bird may maintain a note of a given frequency for a short period, and at the same time utter another that is slurred downward in frequency. A single note slurred over a considerable frequency range in one phrase may in another phrase of the same song be divided into two notes slurring over this same frequency range; in such cases this is counted as one note, if it appears as such in any phrase of the song.

I have in general counted as a single note what shows as a single "blob" on a graph made using the narrow band filter; cases where only the wide band graph shows that an up-slur and a down-slur are connected are considered as single notes (e.g., Plate 8, Figure 42, D).

Table 6 contains a summary of the number of notes per phrase in the Carolina Wren songs in our recordings. The phrases contained from 2 to 8 notes each, averaging 4.58 notes. The differences in the number of notes per phrase in the songs from different areas were scarcely significant.

TYPES OF NOTES IN CAROLINA WREN SONGS

The individual notes in Carolina Wren songs vary in length, loudness, and degree of modulation, and they may be either steady in pitch or slurred. Occasionally a bird will utter complex notes: two or three distinct groups of frequencies uttered simultaneously. The notes are generally short (rarely over 0.10 sec. in length), loud, and separated by intervals that are seldom longer than the notes themselves.

The notes of this species can be grouped into three categories: (1) notes that are little or not at all slurred, (2) slurred notes, and (3) notes containing both steady and slurred elements.

The notes that are little or not at all slurred are of two types, (a) musical notes, containing a fairly narrow band of frequencies, and (b) noise-like notes, containing a relatively broad band of frequencies. Notes of the first type are usually at least 0.05 sec. in length, and may be 0.10 sec. or more in length (e.g., Plate 6, Figures 23, C, and Plate 7, Figure 37, D); they sometimes are slurred upward (e.g., Plate 9, Figure 61, D) or downward (e.g., Plate 11, Figure 78, E) very slightly at the beginning. Notes of the second type (e.g., Plate 9, Figure 60, A) are always very short and weak. About 12 per cent of all the notes in our recordings were of the first type, and about 5 per cent were of the second type; notes of the second type were more frequent in the songs of Florida birds than in the songs of Ohio birds.

Slurred notes may be slurred upward or downward, or may contain both up- and down-slurred elements. The slurring may occur very quickly (e.g., Plate 6, Figure 24, A, and Plate 9, Figure 59, C) or over a longer period (e.g., Plate 7, Figure 30, E, and Plate 10, Figure 63, D), and may be at a uniform rate (represented graphically by a slanting straight band) or at a variable rate (represented graphically by a slanting curved band, e.g., Plate 5, Figure 18, A, and Plate 7, Figures 31, D, and 38, C). The slurring may be over a varying frequency range, up to an octave or more (Plate 5, Figure 18, A). Down-slurred notes occur a little more frequently than up-slurred notes; these two types made up about 64 per cent of all the notes in our recordings, and the percentage varied little in the songs of birds from different localities.

Notes that are first slurred upward and then downward made up about 12 per cent of all the notes, and occurred more frequently in the songs of Ohio birds than in the songs of Florida birds. These notes vary somewhat, particularly in the extent of the up-slurring at the beginning of the note; in most cases the up-slurred part of the note is short and the slurring is over a short frequency range (e.g., Plate 8, Figure 43, B), with the down-slurred part longer and over a greater frequency range. Notes of this type look a little like a crochet hook when graphed and are often preceded by a weak, very short, rapidly up-slurred note (e.g., Plate 7, Figures 30 and 33, notes A and B). In other cases the up-slurred part of the note is longer, and the note graphically resembles an inverted "V" (e.g., Plate 8, Figure 42, D, and Plate 10, Figure 70, C).

Notes that are first down-slurred and then up-slurred occur but are scarce, making up less than two per cent of all the notes (e.g., Plate 7, Figure 29, D).

Notes containing both steady and slurred elements are uncommon, making up only about five per cent of all the notes, and are of four main types: (a) steady, then up-slurred (e.g., Plate 9, Figure 52, B), (b) steady, then down-slurred (e.g., Plate 10, Figure 71, C), (c) up-slurred, then steady (e.g., Plate 5, Figure 18, C), and (d) down-slurred, then steady (e.g., Plate 6, Figure 26, E). The steady portion of these notes is usually at least 0.05 sec. in length.

Most of the notes in our Carolina Wren songs (83 per cent) were slurred or contained portions that were slurred. Relatively few notes (17 per cent) were steady in pitch. The songs of the northern birds contained a higher proportion of slurred notes than the songs of Florida birds. About one-fifth of the notes in our recordings contained either both up- and down-slurred elements or both steady and slurred elements. The proportion of such notes was higher in the songs of Ohio birds than in the songs of Florida birds.

Some Carolina Wren songs show a high degree of modulation, while others show relatively little. (A note is said to be modulated when it consists of a very rapid series of short pulses, rather than a steady output of sound.) Of the 71 song series in our recordings, 38 showed very little modulation (e.g., Plate 4, Figure 6), 20 show some modulation (e.g., Figure 7), and 13 showed considerable modulation (e.g., Figure 8); this proportion was about the same in the songs of birds from different localities.

Complex notes in which two or more notes or distinct frequency bands are uttered simultaneously occurred in about one-fifth (21.1 per cent) of the songs; they occurred somewhat more often in the songs

of wren M-4 at Myakka River State Park, Florida (24.1 per cent) than in the songs of Ohio birds (17.9 per cent).

Most cases of complex notes in these songs were the result of one note continuing for a short time after the following note began; in a few cases a single note (at least with the frequency bands connected) contained both steady and slurred elements (e.g., Plate 10, Figure 65, F); in one case (series 859B-I) three notes were uttered simultaneously. Where one note began before the previous note ended, one of the notes (usually the first) was generally steady in pitch while the other was slurred (e.g., Plate 10, Figure 63, B and C); rarely (Plate 5, Figure 12, B and C) a note that slurred upward and then downward was uttered before a preceding note ended. In a few cases (e.g., Plate 8, Figure 43, D and E, and Plate 9, Figures 55–56, D and A) one slurred note followed another before the first one ended. At one point in each phrase of 859B-I (Plate 10, Figure 66) there was a moment when two down-slurred notes (H and G) and a steady note (E) were uttered simultaneously.

FREQUENCIES IN CAROLINA WREN SONGS

The frequencies in the Carolina Wren songs recorded were measured on graphs made using the narrow band filter. These measurements are believed to be accurate to within about two per cent of the frequency range covered by the graph; the possible error in the lower frequencies of the songs is about one musical interval (one half-note on the piano), and less in the higher frequencies of the song. The error may be greater in the case of weak notes.

Table 7 summarizes the data on the range in pitch in the Carolina Wren songs studied. The octave of the approximate piano note equivalent is indicated in this table by a subscript number; middle C on the piano (256 cps) would be represented by C_0, the C above middle C (512 cps) by C_1, etc.; thus the notes in the second octave above middle C would be those from C_2 (1024 cps) through B_2 (1920 cps). The highest note on the piano is C_4 (4096 cps). One musical interval is one half-note on the piano; 12 intervals make an octave.

The range in pitch in the various songs of a single individual (wren M-4, Table 7) was as great as that in the songs of different individuals. The notes in the different songs of a single individual varied in pitch over more than two octaves (1300–7000 cps, 29 intervals), even in a given song (25 intervals in series 871B, the song with the greatest pitch range). The lowest pitch in different songs varied over nearly an octave (11 intervals), and the highest pitch varied over slightly more than an octave (13 intervals).

TABLE 7

PITCH RANGE IN CAROLINA WREN SONGS

			Source of recordings					
			M-4	*Others Florida*	*Total Florida*	*Ohio*	*Other states*	*Total—all states*
Lowest pitch in song	*Range*	*cps*	1300 to 2400	1500 to 2300	1300 to 2400	1500 to 2300	1700 to 2400	1300 to 2400
		Approximate piano note	E_2 to D $\#_3$	G_2 to D_3	E_2 to D $\#_3$	G_2 to D_3	A_2 to D $\#_3$	E_2 to D $\#_3$
	Average	*cps*	1821 ±77	1800 ±73	1814 ±57	1907 ±45	2025 ±90	1875 ±35
		Approximate piano note	A $\#_2$	A $\#_2$	A $\#_2$	B_2	C_3	B_2
Highest pitch in song	*Range*	*cps*	3200 to 7000	4000 to 5700	3200 to 7000	3200 to 6100	4200 to 6100	3200 to 7000
		Approximate piano note	G $\#_3$ to A_4	C_4 to F $\#_4$	G $\#_3$ to A_4	G $\#_3$ to G_4	C $\#_4$ to G_4	G $\#_3$ to A_4
	Average	*cps*	5404 ±194	4927 ±162	5254 ±146	5096 ±134	5288 ±219	5196 ±92
		Approximate piano note	F_4	D $\#_4$	E_4	E_4	E_4	E_4
Pitch range in individual songs (in musical intervals)		*Range*	13 to 25	11 to 22	11 to 25	12 to 23	10 to 20	10 to 25
		Average	18.88 ±0.79	16.82 ±0.92	18.23 ±0.63	16.96 ±0.52	16.50 ±1.04	17.54 ±0.39

There was not much difference in the frequencies present in the songs of birds from different localities. Both the lowest (1300 cps) and the highest (7000 cps) frequencies found in any song were found in the songs of a Florida bird (wren M-4). The differences in pitch range in the songs of birds from different localities were not significant.

SONG PATTERNS (PHONETICS) IN CAROLINA WREN SONGS

Bird songs are often described in terms of their rhythms or patterns by the use of words or syllables that sound like the song. A great many such descriptive words have been applied to the songs of the Carolina Wren, e.g., *tea-kettle, tea-kettle, tea-kettle; jew-Peter, jew-Peter, jew-Peter;* and *che-wortel, che-wortel, che-wortel.* Such paraphrasing of a song is useful in describing its phonetics or pattern but is often of little value in critical diagnosis. Two or more people listening to the same song might paraphrase it differently, or a person might paraphrase two different songs similarly.

The audiospectrograph is of great value in demonstrating the pattern of any given song, and in showing slight differences in similar songs. Sample phrases from each of the 71 song series studied are shown

in Plates 5–11 (Figures 9–79). The graphs show that there is a tremendous variety in the patterns of different Carolina Wren songs.

Classification of Carolina Wren Song Patterns.—The principal basis of the classification here proposed is the pitch trend of the notes in an individual phrase of the song. The chief difficulty encountered in applying such a criterion was the delimiting of the phrases; when there was any doubt from an examination of the graph, the phrases were delimited by listening to the recording played at a reduced tape speed. A different delimitation of the phrases would for most songs result in a different classification.

On this basis our Carolina Wren songs may be classified into four groups, the largest of which may be further subdivided. This classification is outlined below.

I. Songs with the pitch falling at the beginning of a phrase and rising in the notes later in the phrase (Plates 5–10, Figures 9–63).
   A. The pitch in a phrase first falling, then rising, without marked irregularities (Plates 5–6, Figures 9–25).
   B. The pitch rising and then falling, following the first (down-slurred) note of the phrase; the last note of the phrase usually long and down-slurred (Plates 6–7, Figures 26–38).
   C. Two groups of notes that rise and fall in pitch, following the first (down-slurred) note of the phrase (Plates 7–8, Figures 39–40).
   D. The down-slurring at the beginning of the phrase consisting of two notes, with irregularities in the general pitch trend in the rest of the phrase (Plate 8, Figures 41–49).
   E. The phrase beginning with two strong notes, the first down-slurred and the second up-slurred, the first note higher in pitch than the second; the pitch in the rest of the phrase fluctuating (Plates 8–9, Figures 50–56).
   F. The phrases short and containing only two notes that are strong, a low steady note and a rapidly up-slurred note (Plate 9, Figures 57–60).
   G. The phrases consisting of two or three notes of decreasing pitch and ending in a relatively long note that may be up-slurred at the beginning (Plates 9–10, Figures 61–63).

II. Songs in which the general trend in pitch through the phrase is downward (Plate 10, Figures 64–66).

III. Songs in which the pitch rises at the beginning of the phrase and falls later in the phrase (Plate 10, Figures 67–73).

IV. Songs in which the phrases begin with a down-slurred note followed by an up-slurred note, these two notes covering a similar range in pitch (Plate 11, Figures 74–79).

TABLE 8

CLASSIFICATION OF CAROLINA WREN SONGS

Series	*Classification*	*Figure*	*Series*	*Classification*	*Figure*	*Series*	*Classification*	*Figure*
Wren M-4, Florida			*Other Florida Birds*			*Ohio birds-cont.*		
828B-I	I-D	47	355	IV	76	552	I-A	13
828B-II	I-D	49	808B	I-B	31	663	I-C	39
828B-III	I-D	43	825B-I	I-A	17	731	I-C	40
828B-IV	I-A	20	825B-II	I-A	25	737	I-G	62
836B	I-G	63	847B	IV	77	744	IV	74
837B	I-E	56	849B	I-B	35	779-I	I-E	51
840B	I-F	59	862B	I-A	15	779-II	I-B	33
844B	III	67	863B	I-A	16	779-III	I-A	23
850B-I	I-F	58	866B	III	68	951	III	71
850B-II	III	70	868B	I-D	46	974	I-G	61
853B	I-A	21	893B	I-D	41	1007	I-D	44
854B	I-B	32	*Ohio birds*			1080	I-B	28
855B	IV	75				1084	I-B	38
858B	I-E	55	164-I	IV	78	1107	I-A	12
859B-I	II	66	164-II	I-B	37	1131	I-B	36
859B-II	I-A	19	164-III	I-E	54			
870B	I-F	57	164-IV	II	64	*Miscellaneous birds*		
871B	I-E	52	172	I-B	26			
872B-I	I-D	45	231	III	73	147	I-A	22
872B-II	I-E	53	232	I-A	9	802B-I	I-B	30
874B	I-A	18	329	I-B	29	802B-II	I-D	42
875B	I-D	48	365	III	72	910B	I-A	10
880B	I-F	60	371	IV	79	915B	III	69
881B	I-B	34	428	I-A	11	918B	I-A	24
			431	II	65	922B	I-E	50
			438	I-B	27	932B	I-A	14

An attempt has been made to number the figures so that the closer together the figures of any two series are (within a given group of the classification) the more alike the songs are. The classification and figure number of each song series are given in Table 8.

A summary of the number of song patterns in each group from the different localities is given in Table 9. All of the major groups were represented in both the Florida and Ohio songs, and most of these groups were about equally well represented in the songs from these two areas. The patterns of subgroups B and D, group I, were more common in Ohio songs than in Florida songs, and the patterns of subgroup F, group I, occurred only in Florida songs. Thus there appears to be only a little geographic variation in the song patterns of this species.

Cases of Identical Patterns Sung by Different Birds.—The songs listed in a given group in the above classification are similar, but not necessarily identical. Two or more song patterns may appear identical or nearly so to the ear, but the ear frequently does not detect the minor differences that are brought out by the audiospectro-

TABLE 9

OCCURRENCE OF DIFFERENT PATTERNS OF CAROLINA WREN SONGS IN RECORDINGS MADE IN DIFFERENT LOCALITIES

Song pattern group		*Number of song series*					
		M-4	*Others Florida*	*Total Florida*	*Ohio*	*Other states*	*Total—all states*
Group I	A	4	4	8	5	4	17
	B	2	2	4	8	1	13
	C	0	0	0	2	0	2
	D	5	2	7	1	1	9
	E	4	0	4	2	1	7
	F	4	0	4	0	0	4
	G	1	0	1	2	0	3
	Total	20	8	28	20	7	55
Group II		1	0	1	2	0	3
Group III		2	1	3	3	1	7
Group IV		1	2	3	3	0	6
Total		24	11	35	28	8	71

graph. The best method of determining just how similar any two songs are is to compare their audiospectrographs.

There are several cases of striking similarity in the songs of different series:

1. The series represented by Plate 5, Figures 15 (862B), 16 (863B), and 17 (825B-I), recorded in Myakka River State Park, Florida. The patterns of these three series are practically identical; that of Figure 17 is perhaps a little different from that of the other two (the last note of the phrase is a little less strong). Recordings 862B and 863B were made about 75 yards and two and one quarter hours apart, and were thought to be made by the same bird; 825B was recorded about one-fourth mile from the points where the other two recordings were made. The differences in the three graphs are probably no greater than might be encountered in graphs of different songs in the same series. It would thus appear that two different birds in Myakka River State Park were singing the same song.

2. The series represented by Plate 6, Figures 22 (147, Ky.) and 23 (779-III, Ohio). Recording 147 is a very poor one and the graph of it is not clear, but from what can be made out for 147 it appears that these two are the same pattern.

3. The series represented by Plate 9, Figures 57–59 (870B, 850B-I, and 840B) are recordings of the same bird, wren M-4 in Myakka River State Park, Florida. These are identical, indicating that the bird sang this particular pattern on at least three different occasions. The pattern in Figure 60 (880B), sung by the same bird, is very similar, but it is not quite identical.

4. The series represented by Plate 10, Figures 67 (844B, wren M-4, Florida), 68 (866B, wren M-1, Florida), and 69 (915B, N. C.). Recordings 844B and 866B were made about one-half mile apart. The patterns in Figures 67 and 68 are identical except for the phrase length; the latter has shorter phrases than the former. The pattern in Figure 69 is extremely similar but has an extra note in the phrase (note C), and the phrases are still longer than in the other two patterns.

5. The series represented by Plate 11, Figures 78 (164-I, Worthington, Ohio) and 79 (371, Dublin, Ohio). These two patterns are practically identical; there are slight differences in some of the notes, but much of the apparent difference in the graphs is due to the difference in the quality of the two recordings.

The above cases represent what I believe to be instances in which the patterns are the same in different songs. In addition to these there are several other cases where two or more songs are almost identical and may represent variations of a basic general pattern; these are noted below.

6. The series represented by Plate 10, Figures 64 (164-IV, Worthington, Ohio) and 65 (431, Columbus, Ohio). The differences between these two patterns are very slight; the phrases in Figure 64 lack the first rather high note of those in Figure 65, and there are slight differences in the third and last notes of the phrases in the two patterns, but they are basically much the same. They sound alike to the ear.

7. The series represented by Plate 5, Figures 11 (428) and 13 (552), recorded about eight miles apart in Columbus, Ohio. These two sound alike, but note C in Figure 13 is lacking in Figure 11, and the first two notes of the phrase in Figure 11 (A and B) are represented by a single note (A) in Figure 13.

8. The series represented by Plate 7, Figures 31 (808B, Tallahassee, Florida) and 32 (854B, Myakka River State Park, Florida). These two patterns are very similar, differing only in the detailed character of some of the notes; the phrases are a little shorter in Figure 31 than in Figure 32. To the ear the former sounds a little faster; otherwise they sound alike.

9. The series represented by Plate 6, Figures 26 (172) and 27 (438) recorded about twenty miles apart in Franklin Co., Ohio. These two patterns are alike except for slight differences in the first and last notes of the phrase. The first note of the phrase is much stronger in Figure 27 than in Figure 26, and the last note is slurred a little differently in the two. These two songs sound alike to the ear.

10. The series represented by Plate 8, Figures 45 (828B-I) and

46 (868B), recorded about one-half mile apart in Myakka River State Park, Florida. These two patterns are very similar, differing only in the character of a few notes. The first and the last two notes of the phrase are a little different in the two series. These two songs sound only very slightly different to the ear; a casual listener would probably consider them identical.

The fact that there are only four cases in these recordings (Numbers 1, 2, 4, and 5, above) in which an identical song pattern was sung by different birds indicates that there is tremendous variation in the song patterns of this species. In 24 series recorded from one bird there were 22 different patterns; hence it appears that each individual has a considerable repertoire, probably considerably more than 22 patterns. The 22 patterns sung by this bird (wren M-4, Myakka River State Park, Florida) were sung over a period of a week; Saunders (Bent, 1948, p. 213) reports recording 36 different songs from one individual during a single season. There must be hundreds of different song patterns in this species.

SUMMARY

This study is based on 58 tape recordings of Carolina Wren songs made in six states; these recordings contained 71 song series and a total of 753 songs; 18 of the recordings, containing 24 song series, were of a single individual. Samples of each song series were analyzed by means of an audiospectrograph.

The singing rate varied from 4.8 to 13.3 songs per minute in one individual, and from 4.3 to 24.0 per minute in all the recordings; the average rate was 11.4 songs per minute. The singing rate averaged slightly higher in Florida birds than in Ohio birds.

The songs varied in length from 0.51 to 2.43 sec., averaging 1.66 sec. The songs of Ohio birds averaged slightly shorter than those of Florida birds.

The song of a Carolina Wren consists of a series of similar phrases. In most of the songs all the phrases were complete, but nearly a third had the last phrase incomplete, and in a few songs the first and/or last phrases were incomplete. Songs with the last phrase incomplete occurred more often in the recordings of northern birds than in those of Florida birds. In about four song series out of five all the songs were alike in phrase completeness. The variation in phrase completeness was approximately the same in the songs of one individual as in the songs of different individuals.

The recorded songs contained from 2 to 12 phrases, averaging 5.20 phrases, and the songs of one individual contained from 3 to

10 phrases. The songs of Florida birds contained, on the average, more phrases than those of Ohio birds.

The phrases varied in length from 0.169 to 0.620 sec. (from 0.195 to 0.480 sec. in the songs of one individual) and averaged 0.363 sec. On the average, the phrase length varied inversely with the number of phrases in the song. The phrases of Florida songs averaged shorter than those of the Ohio songs.

The phrases contained from 2 to 8 notes, averaging 4.58 notes. The Florida songs contained, on the average, somewhat fewer notes per phrase than the Ohio songs. In general, the longer the phrase the more notes it contained.

Most of the notes in the songs studied were slurred; a few contained portions that were steady in pitch and portions that were slurred. Some notes were musical and little or not at all slurred; a few were noise-like, containing a relatively broad band of frequencies. The songs of northern birds contained a higher proportion of slurred notes than the songs of Florida birds.

About one-fifth of the songs contained instances of two or more notes being uttered simultaneously; in most cases this resulted from one note continuing for a short time after the following note began, one of the notes usually being steady in pitch and the other slurred. A few notes contained steady and slurred elements simultaneously. At one point in each phrase of one song a steady note and two down-slurred notes were uttered simultaneously.

The frequencies in these songs varied from 1300 cps (approximately equivalent to the third E above middle C on the piano) to 7000 cps (approximately equivalent to the first A beyond the upper limit of the piano); this range occurred in the songs of one individual. The pitch range in individual songs varied from 10 to 25 musical intervals, and this range was not significantly different in the songs of birds from different localities.

The patterns of the wren songs studied were classified into four major groups on the basis of the pitch trend of the notes in an individual phrase of the song; each major group was further subdivided. The phrases of the songs in group I begin with a down-slurred note and have the pitch rising in the notes later in the phrase; in group II the general trend in pitch through the phrase is downward; in group III the pitch rises at the beginning of the phrase and falls later in the phrase; in group IV the phrase begins with a down-slurred note followed by an up-slurred note, the two notes covering a similar range in pitch. Of the 71 song series studied, 55 fell in group I, 3 in group II, 7 in group III, and 6 in group IV. There was little geographic variation in the song patterns of this species.

There were four instances in the 71 song series where two or more different birds sang songs that were identical or nearly so: (1 and 2) two birds in Florida, (3) a bird in Kentucky and one in Ohio, and (4) two birds in central Ohio. In five other instances the songs of two or three different birds were extremely similar but not identical. There were 22 different song patterns in 24 series sung by a single bird. There is evidently a tremendous variation in the song patterns of this species.

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