

## SINGING BEHAVIOR OF THE FIVE-STRIPED SPARROW

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**ABSTRACT.**—We studied the singing behavior and analyzed spectrographically the songs and calls of the Five-striped Sparrow (*Aimophila quinquestriata*). Its song consists of an introductory note followed by one to six, usually two, note complexes (a group of notes consistently occurring together). The same note complex is usually not repeated more than three times; nor are three different note complexes sung successively within the same song. Note complexes within songs are delivered in a non-random fashion, but the types of note complexes following other note complexes vary among individuals.

Repertoires of three birds consisted of 159, 220, and 237 different songs and 43, 38, and 55 different note complexes, respectively. From 11,845 total songs recorded from all males, 99 different note complexes were recognized. Most note complexes were shared but several were unique to each individual.

Five-striped Sparrows sing their song types many times before introducing others. Consequently, samples of songs as large as 1,000, 1,500, and 3,000 songs are necessary to obtain 90% of a bird's repertoire of note complexes.

Complexity and versatility of song performances were greater when eggs or young were in the nest than when no nest or just the nest was present. In addition, Total Versatility values differed significantly when eggs were present and when eggs were absent. The number of different songs and different note complexes sung by each male also appeared to be related to the stage of nesting.

The specific distinctiveness of a bird's singing performance is based partly on the number of different songs in the repertoire and the manner in which the songs are delivered (Kroodsmma 1975). The singing performance of the Chipping Sparrow (*Spizella passerina*) represents a simple form of singing behavior in that one song type is sung repeatedly with little or no variation (Borror 1959). In contrast, the singing performance of the Brown Thrasher (*Toxostoma rufum*) is considered more complex because many different song types are sung before any are repeated (Borror 1964). Many avian singers, however, lie between these two extremes; they repeat many times a given song type, from a repertoire of several songs, before singing a different song type. Kroodsmma (1975) has described an "intermediate" singing behavior in the Rock Wren (*Salpinctes obsoletus*), which he considered unique to this species. In a series of songs, few song types from a large repertoire are employed, and they are not often repeated successively.

Another factor affecting the quality of a singing performance is the internal complexity of a song, i.e., the numbers of different components (notes) and their organization within the song. For example, the Indigo Bunting (*Passerina cyanea*) sings one particular song type throughout the day (Thompson 1968), as does the Chipping Sparrow, but this former song is

comprised of several different notes varying in pitch and length—in contrast to the Chipping Sparrow's song, which is a series of identical notes. An individual, or a species of bird, then, can exhibit a singing behavior characterized by various-sized song repertoires consisting of simple or complex songs sung in an unvarying or complicated manner (Borror 1961).

A preliminary examination of the singing behavior of the Five-striped Sparrow (*Aimophila quinquestriata*) indicates that it can be classified with the Rock Wren's "unique, intermediate" behavior, yet the within-song components are few in number and uncomplicated. The songs of the Five-striped Sparrow have been briefly discussed in the literature (Borror 1971, Wolf 1977, Groschupf and Mills 1978), but no detailed spectrographic analysis has been performed. We describe here the vocalizations and song patterning of nine Five-striped Sparrows recorded in southern Arizona and northern Mexico. Our study provides substantial information on the singing characteristics of a single species, which may be applied towards future studies of avian singing behavior.

### METHODS

This study is based primarily on the vocalizations of four males (SC5, SC6, SC7, SC8) re-

TABLE 1. Number of different songs and note complexes catalogued from each bird's total number of recorded songs.

Bird	Total songs recorded	Different songs <sup>1</sup>	Different note complexes
Unknown 1	68	15 (27)	8
Unknown 2	71	14 (29)	9
Unknown 3	10	5 (7)	5
Unknown 4	34	10 (12)	5
CB1	772	138 (228)	44
SC1	39	14 (16)	7
SC2	236	57 (79)	22
SC3	108	21 (29)	12
SC4	184	22 (43)	9
SC5	490	67 (110)	30
SC6	1,770	159 (not calc.)	43
SC7	4,160	220 (not calc.)	38
SC8	3,903	237 (not calc.)	55
Total	11,845	not calculated	99

<sup>1</sup> The number in parentheses is the number of different songs catalogued including any introductory notes, if present. The number in front of the parenthesis is the number of different songs catalogued excluding any introductory notes.

recorded southwest of Patagonia, Santa Cruz County, Arizona and one male (CB1) recorded at Cajon Bonito, Sonora, Mexico, between May and August 1976–1978. Songs of four other males (SC1–SC4) and “unknown males” (unbanded birds at the borders of territories, or birds recorded by someone other than ourselves) were also examined, but because these songs were few in number we included them in only a few of the analyses (Table 1). Though not included in this paper, tape recordings made in 1978 of the vocalizations of an additional 29 individuals show similar songs and song patterning.

We identified individuals chiefly by the location of the bird in its territory (see Mills et al. 1980); a few of the birds were banded and color-marked. Identification of the most extensively recorded males (SC5–SC8) can be explained as follows. SC6 was an unmarked, mated bird who occupied a territory in Sparrow Canyon during the summer of 1976. His territory was adjacent to that of SC5 (an unmated male) who was banded in August 1976. In 1977, SC7, a mated, unmarked bird, defended this same area in Sparrow Canyon, but there were no neighboring Five-striped Sparrows. This male was banded and color-marked in August 1977. The following year, 1978, another unmarked, mated male, SC8, occupied this territory. Its mate was the female mated to SC7 the previous year and again, there were no neighboring Five-striped Sparrows. Although SC6 and SC7, or SC6 and SC8 could have been the same individual we treated them as three different birds. At the time SC5, SC6, and SC7 were studied, they

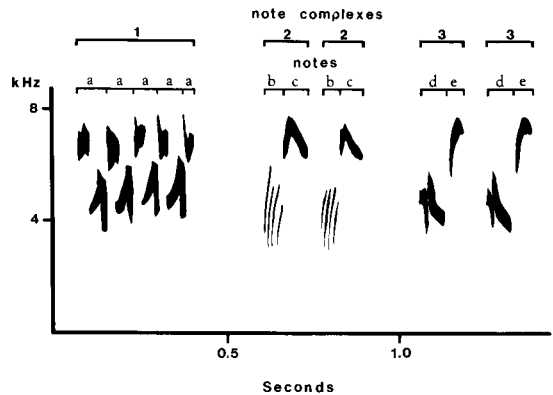


FIGURE 1. Tracing of a sonogram of a representative song which depicts structural terms used in the text.

were the only male Five-striped Sparrows known to occur in the United States. Consequently, for fear of reducing breeding success, we did not mark the birds until late in the season.

We used either a Uher 4000 Report-L tape recorder at a tape speed of 7½ ips with an Electro-voice cardioid microphone (model 666) and a 40-cm parabolic reflector, or a 110 Sony cassette tape recorder with a Gibson EPM microphone. Songs were analyzed using a Kay Elemetrics Company model 6061A Sonagraph at the wide band-pass setting and by listening to playbacks at one-quarter speed (1¼ ips). We also analyzed songs with a Spectral Dynamics Real Time Analyzer (Hopkins et al. 1974) model SD301C-C, with the tapes played on a Nagra III tape recorder at one-half speed (3¾ ips).

#### TERMINOLOGY

In an attempt to standardize bird vocalization terminology, Shiovit (1975) refined the definitions of Bondeson and Davis (1966) and aligned their terminology with the consensus usage of numerous workers. Unfortunately, the classification scheme proposed by Shiovit is not adequate to describe Five-striped Sparrow vocalizations, hence we employed the following terms. A sonogram of song components (Fig. 1) can be used as a reference to clarify the definitions of terms used in the text and to aid an understanding of the analytical methods.

*Note.* “One continuous vocal utterance” (Marler and Isaac 1961).

*Note complex.* A note, or a group of notes consistently occurring together.

*Trill.* A note complex in which the repeated units (notes or note complexes) occur at a rate faster than one per 0.14 s. Any note complex repeated at a slower rate was treated as a repeated note complex. In all cases, we perceived a trill as one continuous sound, whereas a fig-

ure that repeated successively was perceived as two distinct sounds.

*Syllable.* When referred to in the analyses, it is a sound separated from another sound by a silence longer than 0.14 s.

We classified songs according to the types and numbers of note complexes of which they were made. For example, a song consisting of five note-complexes (such as 1-2-2-3-3 in Fig. 1) was classified as different from a song consisting of only four note-complexes (such as 1-2-2-3). Classification of a note complex was nearly always unambiguous even though the number of notes within the complex varied occasionally and slight temporal and frequency modulations occurred. For example, note complex 1 in Figure 1 sometimes consisted of only three notes (aaa) and note e in the last note complex (3) was sometimes absent. Thus, classification was somewhat subjective, but separation of variations in complexes would have resulted in innumerable note complexes and songs.

## RESULTS AND DISCUSSION

### CALLS

In addition to the males' advertising songs, other vocalizations (calls) were recorded (Fig. 2). *Chucks* and *pips* were the simplest calls. As their onomatopoeic names imply, *chucks* are brief notes covering a broad frequency range (1,500 to 7,500 Hz), and *pips* are brief notes extending over a short range of frequency (7,000 to 8,000 Hz). In many cases, one or both types closely preceded a song, and when used in this context, we classified them as introductory notes. Both types were also rendered independently between songs, usually while a bird was foraging or perched. Females uttered *pip* and *chuck* notes in similar situations. Once, we observed a male, which had been singing from an exposed perch, suddenly give a quick series of *pips* then dive for cover as a Cooper's Hawk (*Accipiter cooperii*) flew past (Mills et al. 1980).

"Alarm" calls, given by both sexes, consisted of a rapid series of similar notes and were given during interactions with intruders and during disturbances at the nest. The "chatter" call was similar to "alarm" and "pair bond" calls (see below). This call was given by both sexes during foraging bouts, and we heard one female use it as she approached a nest carrying nest material. Notes constituting "alarm" and "chatter" calls were similar to *chuck* notes.

The *seet* call, which Mills et al. (1980) suggested may be the *tziit* or *tziit* call described by Wolf (1977), was a single, high pitched sound apparently used to advertise an indi-

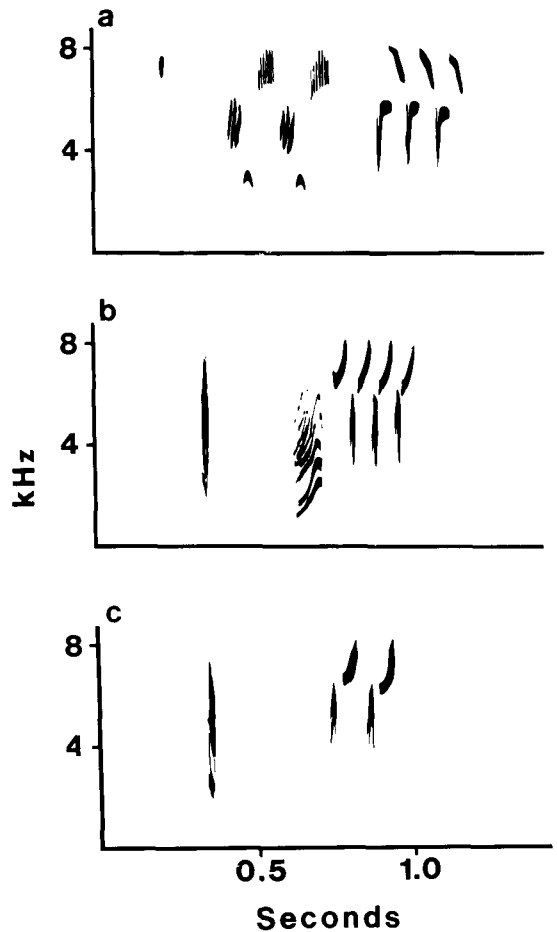


FIGURE 2. Continued on next page.

vidual's location. After a bird uttered a few *seet* sounds, it often flew towards its mate when the latter had responded with the same note. We also heard these *seet* calls during the winter from individuals foraging on the ground.

Of the calls recorded, the "high intensity," or "pair bond" call was the most complex. Wolf (1977) described this as a "warbling song, a continuous outpouring of notes varying markedly in pitch." We heard similar vocalizations from Rufous-crowned Sparrows (*Aimophila ruficeps*) and Black-throated Sparrows (*Amphispiza bilineata*). Male Five-striped Sparrows uttered this call during intense territorial disputes with neighboring males (Mills et al. 1980) or in response to song playback. In addition, paired males and females uttered this call before and during a rendezvous.

"Ticking" and "high peeping" sounds were the only vocalizations we heard from the young. "Ticks" were series of identical notes

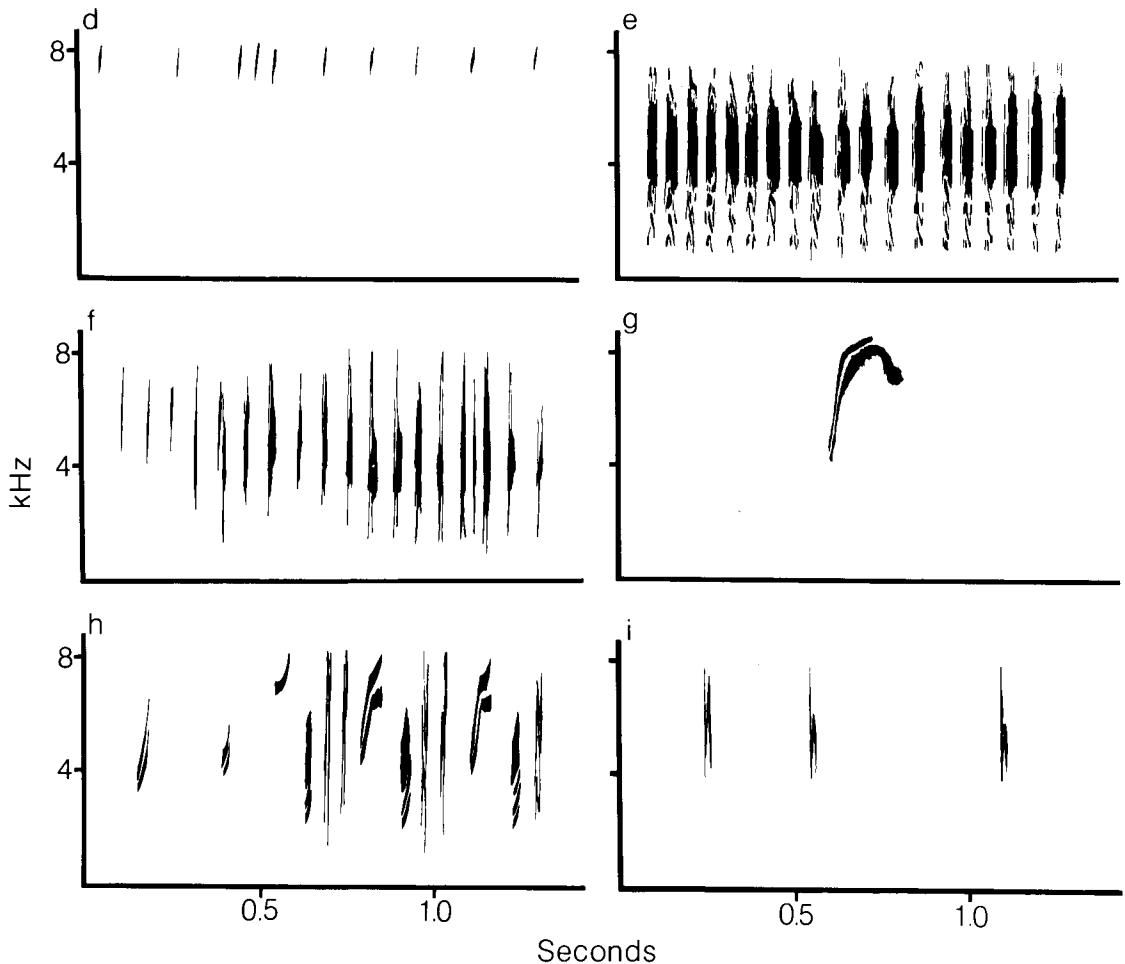


FIGURE 2. Example of a song (a) consisting of an introductory note (*pip*) followed by two identical "standard" note complexes plus a trill; example of a song (b) consisting of an introductory note (*chuck*) followed by an "auxiliary" note complex which immediately precedes a trill; example of a song (c) consisting of a "standard" note complex, which was also employed as a component of the trill illustrated in b; rapid series of *pip* notes (d); "Alarm" call (e); "Chatter" call (f); "Seet" call (g); "Pair bond" call (h); "Ticks" of young (i).

similar to an "alarm" call but uttered more slowly and at a slightly higher pitch.

#### SINGING BEHAVIOR

Mills et al. (1980) described the general singing behavior of territorial males. Songs were sung only by males, most often from exposed perches on steep hillsides covered with dense vegetation 1–2 m high. Males also sang while foraging on the ground or in bushes, sometimes continuing to sing while handling food. The average singing rate was 16 songs per minute. Rate varied with a bird's activity; songs produced while a bird was foraging or concealed in shrubs were delivered more slowly than those produced while a male was on an elevated perch. Playback of the species' songs or calls (either the singer's own or a different male's) often appeared to stimulate a sparrow to sing at a faster initial rate.

Singing bouts consisted of one to several

hundred songs. When males first arrived on their territories, singing bouts were short and infrequent. Rather, the birds often made steady series of call notes (*chucks* and *pips*) while sitting on exposed perches and while foraging on the ground. The frequency and duration of singing bouts were greatest between June and September, gradually waning after the last nesting attempt. Males sang at all hours of the day, with peaks in the early morning and late afternoon.

#### SONG DESCRIPTION AND ORGANIZATION

An individual song of the Five-striped Sparrow is basically simple in structure. Each song is usually comprised of an introductory note (*chuck* and *pip*) followed by one to six (most often two) note complexes. On one occasion, a "flight song" by a male chasing a female consisted of 14 note complexes; all other "flight songs" we heard were like typical songs.

TABLE 2. Syllabication of songs.

Songs without trills								
Syllables	1	2	3	4	5	6		
	204	750	1,514	534	70	4		
Songs with trills (T)								
Syllables	T	T + 1	T + 2	T + 3	T + 4	2T + 1	2T + 2	2T + 3
	40	434	163	55	4	4	3	1

We identified three different classes (Fig. 2a, b, c) of note complexes: 1) "standard" note complexes, 2) trills, and 3) "auxiliary" note complexes. The "standard" note complex, by far the most common, consisted of several different notes arranged into a recognizable group. Trills consisted of varying numbers of similar notes or note complexes that were repeated successively so as to produce a single sound. One "standard" note complex, sung by six birds, was exceptional because it was employed as a component of a trill as well (Fig. 2b, c). "Auxiliary" note complexes were relatively uncommon. When one did occur, it was always in conjunction with other specific complexes—two types preceded trills, one type followed a "standard" note complex. "Auxiliary" note complexes were considered as separate parts of other complexes because complexes with which they occurred also occurred alone.

We catalogued the songs recorded from SC1–SC6, CB1, and the "unknown males" according to the number of note complexes and/or trills comprising the song (summarized in Table 2). Introductory notes were also included; therefore, a song that consisted of a *chuck* or a *pip* and two note complexes (either identical or different), or a song that consisted solely of three note complexes, was classified as trisyllabic. Songs containing trills were treated separately. Of the 3,780 songs analyzed, 3,076 (81.4%) did not include trills, and of these, 1,514 (49.2%) were trisyllabic. Most of the trisyllabic songs consisted of an introductory note and two note complexes, rather than three note complexes. Of the 704 (18.6%) songs that contained trills, 434 (61.6%) were bisyllabic. Most of these consisted of one trill plus an introductory note or one note complex. Songs rarely contained two trills, thus the syllabic patterns involving a trill consisted of one type of trill preceded or followed by zero to four note complexes. These note complexes may have been the same figure repeated or different note complexes. The few songs that contained two trills (8) also contained at least

one other syllable (either an introductory note, one or two note complexes, or one of each).

Within a song, a given note complex was never repeated successively more than three times, nor were three different note complexes sung consecutively. A note complex did not recur in the same song if followed by a different note complex.

Individual note complexes appeared singly, paired, or trebled in a song; the number of times they repeated seemed to be related to the length of the note complex. Twenty-three of the 81 note complexes from the 3,780 songs analyzed always occurred singly, paired, or trebled. The mean length of those note complexes (measured from sonograms) that occurred only singly (11) was 0.27 s ( $n = 22$ ); of those that occurred only paired (11) was 0.16 s ( $n = 18$ ); and of the one note complex that occurred only trebled was 0.11 s ( $n = 1$ ). The average length of individual note complexes constituting the 11 types of trills found in the songs analyzed was 0.10 s ( $n = 27$ ).

The presence of an introductory note appeared to be related to song lengths. Songs that were not preceded by introductory notes were significantly longer than those that did have introductory notes (excluding the introductory note) (Student's *t*-test,  $P < 0.01$ ). Introductory notes occurred in 71% of the songs analyzed. The average duration of the songs that were preceded by a *chuck* note, including the *chuck* note ( $n = 196$ ) was  $0.76 \pm 0.21$  s, and the duration of the songs which were preceded by a *pip* note, including the *pip* note ( $n = 51$ ) was  $0.82 \pm 0.24$  s. Excluding the *chuck* or *pip* introduction, the average duration of the songs was  $0.49 \pm 0.17$  s and  $0.47 \pm 0.19$  s, respectively. Of the songs analyzed that were not preceded by an introductory note ( $n = 100$ ), the average duration was  $0.59 \pm 0.21$  s.

Transition matrices have been used to study the sequential organization of songs for several species of birds (Isaac and Marler 1963, Lemon and Chatfield 1971, Catchpole 1976). In this study, we employed transition matrices in order to determine the within-song orga-

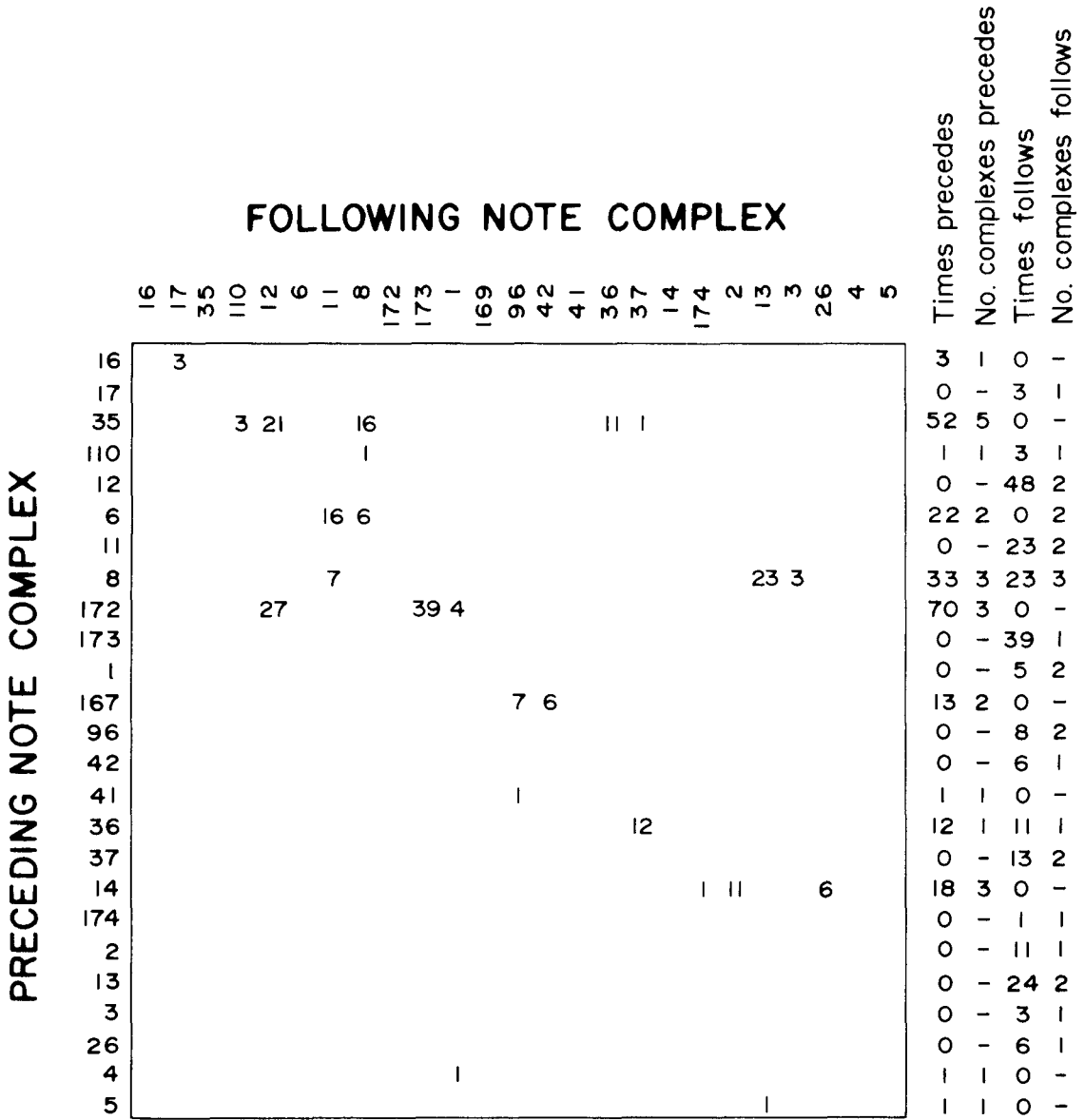


FIGURE 3. Transition matrix of preceding and following note complexes from songs of SC5.

nization of note complexes. For three birds (SC5, SC6, CB1) we counted the number of times note complexes preceded or followed other note complexes. The transition matrices show a dependent relationship between note complexes as indicated by the clustering of points along the diagonal (Fig. 3). If there were no dependency, the points would be scattered randomly within the square (Isaac and Marler 1963). No points lie along the center diagonal because we did not count repeated note complexes within songs, although they often occurred.

Most of the note complexes occurred in a characteristic position in the songs of each Five-striped Sparrow. A note complex either preceded or followed other different note com-

plexes within the same song and rarely occurred in both positions (Fig. 3). Because the individuals did not share all note complexes, the note complexes that were shared often could not precede or follow the same note complexes as in other individuals.

REPERTOIRE SIZE

From the 11,845 songs that were analyzed, we recognized 99 different note complexes, each of which was audibly and spectrographically distinct from the others. We were able to identify each note complex when it was played at one-quarter speed, and sonograms of the note complexes confirmed the identification. Table 1 lists the total number of songs, different note complexes, and different songs recorded from

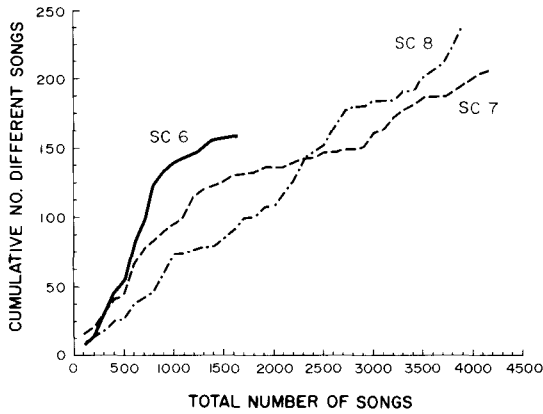


FIGURE 4. Cumulative number of different songs employed by each male during the whole breeding season.

each bird. Many of the figures and songs were shared, while others were unique to each of the males. Sample size undoubtedly affected the degree of sharing—birds with fewer songs recorded had less chance of our finding unique note complexes than those with more recorded songs. The degree of sharing can be illustrated by the songs recorded from SC6, SC7, and SC8 since very large, similar-sized samples were obtained. From the 9,833 songs of these birds, 81 different note complexes were recognized. SC8 shared 1 note complex with SC7 and 3 note complexes with SC6, while 32 were unique to SC8. Males SC7 and SC5 shared 17 note complexes; 4 note complexes were unique to SC7, and 9 note complexes were unique to SC6. Fifteen note complexes were shared by all three males.

A graph of the cumulative number of different songs recorded from SC6, SC7, and SC8 versus the total number of songs recorded for each bird illustrates that the number of different songs increased as the sample size increased (Fig. 4). When the cumulative number of different note complexes was graphed versus total songs, the curves for SC6 and SC7 reached an asymptote near a sample of 1,000 and 1,500 songs, respectively, while the curve for SC8 became asymptotic at approximately 3,000 songs (Fig. 5). The cumulative number of different note complexes for SC8 apparently reached a plateau near a sample of 1,000 songs also, but this pattern did not continue as did the pattern of the curve for SC7. This illustrates the importance of acquiring large samples of songs when investigating avian vocalizations. The cumulative numbers of different songs and note complexes (Figs. 4 and 5) for SC6 increased more rapidly than those for SC7 and SC8. This may reflect the sampling techniques. Relatively few songs of SC6 were re-

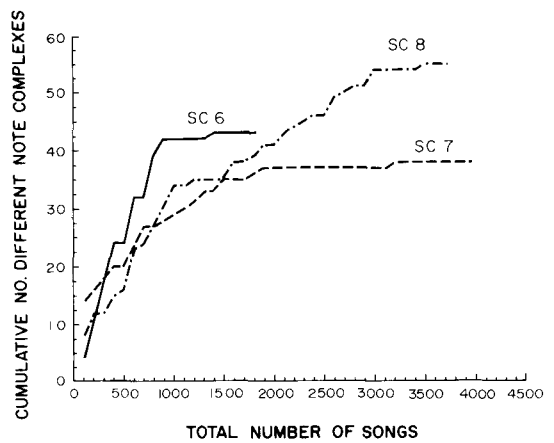


FIGURE 5. Cumulative number of different note complexes employed by each male during the whole breeding season.

corded during the first few days this male was studied, thus spacing the initial 1,000 songs over a relatively long period. On the other hand, the first 1,000 songs for SC8 were recorded on the first two sample days, which were only 11 days apart. Since Five-striped Sparrows sing with eventual versatility, i.e., song types are repeated many times before others are introduced, this could cause the curve for SC6 to have a steeper initial slope.

#### SONG PATTERNING

An examination of the songs of SC5, SC6, and CB1 for the presence or absence of individual types of note complexes showed that few types of note complexes were employed during a singing bout and that a gradual turnover of different note complexes occurred. Note complexes used at the beginning of a series of songs generally were not present in the songs at the end of the series (Fig. 6). The incidence of each note complex depends of course on the number of songs that are considered. For our analysis, we divided the total number of songs sung into successive groups of ten. Note complexes were listed upon their first appearance and were subsequently marked as they occurred within a ten-song series. Complexes employed in one singing bout were often employed in later singing bouts but were not delivered in the same order. Smith et al. (1978) found that male Yellow-throated Vireos (*Vireo flavifrons*) change their song forms in accordance with shifts in an individual's activities. We did not detect similar changes in singing pattern complexity in Five-striped Sparrows because we recorded the same note complexes, as well as songs, during several types of activities.

Diversity of daily song performances varied for each bird. For example, the number of note

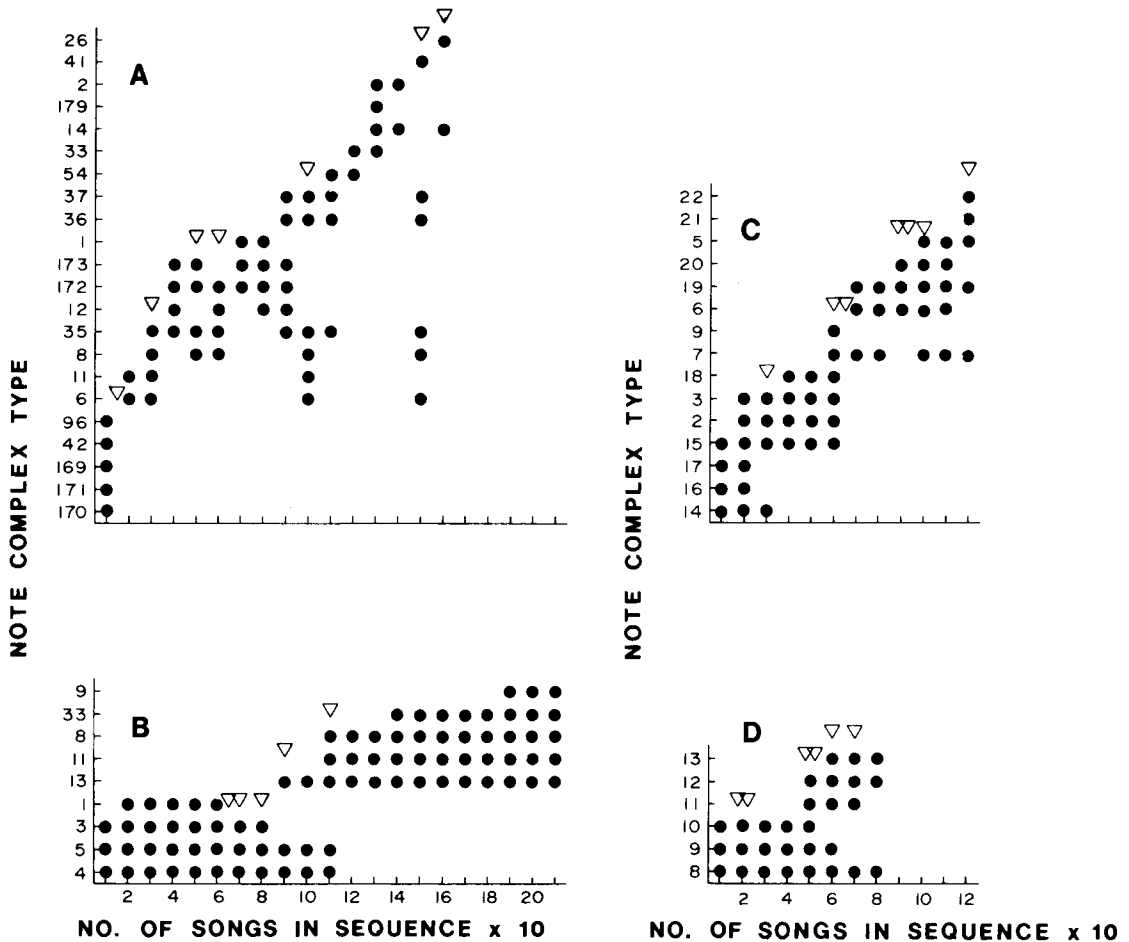


FIGURE 6. Sequences of note complexes used by Five-striped Sparrows. A, SC5 on 22 June 1976; B, SC5 on 27 August 1976; C, SC6 on 9 July 1976; D, SC6 on 20 July 1976. Open triangles indicate end of singing bout. For example in A, the first song bout contained 10 songs which collectively consisted of five note complex types (170, 171, 169, 42, 96). The second song bout contained 18 songs which collectively consisted of four note complex types (6, 11, 8, 35), and the third bout contained 14 songs which collectively consisted of five note complex types (8, 35, 12, 172, 173).

complexes used in the first 100 songs of SC5 on two different dates was 5 and 15. Similarly, the number of note complexes used in the first 80 songs of SC6 on two dates was 6 and 11 (Fig. 6). The slope of the line in the graphs in Figure 6 provides an indication of the diversity of the song performances—the steeper the slope, the greater the diversity.

Some note complexes were used on many of the dates whereas others were used only once. Of 81 different note complexes sung by SC6, SC7, and SC8, 23 were sung on only one date; SC6 sang 8 of these and SC8 sang the other 15 of the note complexes. Usually these note complexes were sung only once on each of these dates. The note complexes that occur on several recording dates were not necessarily the most frequently sung on those dates.

The foregoing results prompted us to determine whether any of the changes in the diversity of the birds' song performances were re-

lated to the stages in the nesting cycle. We divided these stages into four categories: I) no nest present; II) nest present without eggs; III) nest with eggs present; and IV) nest with young, or fledglings present. In some cases the stage in the nesting cycle was calculated from known information on other dates. Note that each pair attempted to nest more than once, and that nesting stage need not correspond with a particular date.

In order to determine whether singing pattern complexity of the Five-striped Sparrow is related to phases of the nesting cycle, we calculated Total Versatility values for numerous 11-song sequences in unbroken singing bouts. "Total Versatility" is the product of Song Type Versatility and Transition Versatility (Kroodsma and Verner 1978). "Song Type Versatility" is defined as the number of different song types in a sequence, and "Transition Versatility" is defined as the number of



TABLE 3. Averages of Total Versatility values during the four nesting stages.

Bird	I		II		III		IV	
	$\bar{x}$	$n^1$	$\bar{x}$	$n$	$\bar{x}$	$n$	$\bar{x}$	$n$
SC6	41.95	58	38.00	2	57.10	40	53.20	30
SC7	35.59	176	51.33	3	45.66	100	43.78	55
SC8	34.72	97	34.14	50	46.37	155	43.64	44
Com- bined	36.45	331	35.22	55	47.58	295	45.92	129

<sup>1</sup>  $n$  = number of 11-song sequences.

transitions that occur between unlike song types in this sequence. For example, in a singing bout where the songs were delivered in the manner: A B A A C C D E B E D F D B G B E D B D E (where different letters represent different songs), the Total Versatility value of the first 10 songs in the 11-song sequence would be calculated as  $5 \times 8 = 40$ . The next 11-song sequence would begin with song D, the eleventh song in the series. The Total Versatility value for this sequence would be calculated as  $5 \times 10 = 50$ . Total Versatility values, then, can range from 0 to 100 with the larger values representing greater versatility. Values of 11-song sequences within singing bouts of all three males were combined and analyzed during all four nesting stages (Table 3).

Versatility of the birds' singing performances varied with the stages of nesting. Total Versatility values when nest and eggs were present (stage III) were significantly higher than values when eggs were not present (nesting stages I, II, and IV combined; two-tailed  $t$ -test,  $P < 0.001$ ). In addition, values were higher when eggs or young were in the nest (stages III and IV) than they were when no nest or just the nest was present (stages I and II; Duncan's test,  $P < 0.01$ ).

Total Versatility is a crude measure of the variability of a bird's singing performances because it deals only with the number of different songs rendered in an arbitrarily chosen sequence of songs and the number of transitions between unlike songs. Thus, an 11-song sequence such as A B C A B C A B C A B would have the same Total Versatility value as a sequence such as A B A B A B A B A B A. Intuitively, a human listener might classify the former sequence as being more versatile than the latter, but it is impossible to test whether a bird experiences the same sensation. Kroodsma and Verner (1978) discussed this problem when they analyzed the singing patterns of *Cistothorus* wrens, and they skirted the difficulties by including two other measures: 1) renditions per song type, and 2) recurrence numbers. These measures helped to

distinguish the variability of similar sequences in the wrens' song performances. Since the song patterning of the Five-striped Sparrow is not as "simple" as the wrens', we did not calculate the renditions per song type and recurrence numbers.

The numbers of different songs and note complexes employed on each recording date also appeared to change according to the nesting stages. Figure 7 illustrates these shifts; other birds showed similar patterns. For example, on 16 June during nesting stage I, we recorded 196 songs from SC6, which contained 10 different song types and 7 different note complexes; on 20 July during nesting stage III, we recorded 121 total songs which included 26 different song types and 17 different note complexes. On 18 August during nesting stage I, this same male sang 11 different song types and 11 different note complexes out of a total of 407 songs recorded; on 13 August during nesting stage IV, 36 different song types and 10 different note complexes were sung in a total of 457 recorded songs. Data for SC8 also showed this same relationship; this bird was recorded on two days during nesting stage I and sang with a daily average of 41.5 different song types. On five different recording dates during nesting stage III it sang with a daily average of 59.8 different song types. On all seven dates the sample sizes (total number of songs sung) were relatively large and approximately the same. Curiously, however, the average number of different note complexes sung by this male differed but little during these two nesting stages. Statistical tests were not applied to these data in Figure 7 because of the unequal sample sizes and the curvilinear relationship between sample size and number of different songs or note complexes sung, both on a daily and seasonal basis (see Figs. 4 and 5).

A Pearson's Correlation using combined data from all three males indicated that the number of different songs sung each day correlated with the number of different note complexes each day ( $r = .82$ ,  $P < 0.01$ ; Fig. 7). This suggests that the birds tended to construct new songs from new note complexes, rather than rearrange old note complexes.

The data presented here show that changes in song complexity and singing pattern versatility of Five-striped Sparrows were related to certain phases of the nesting cycle. Song performances were more complex and versatile when eggs or young were in the nest than when no nest or just the nest was present. The amount and rate of song output in other birds have also been reported to be related to phases of the breeding cycle (Saunders 1948). Al-

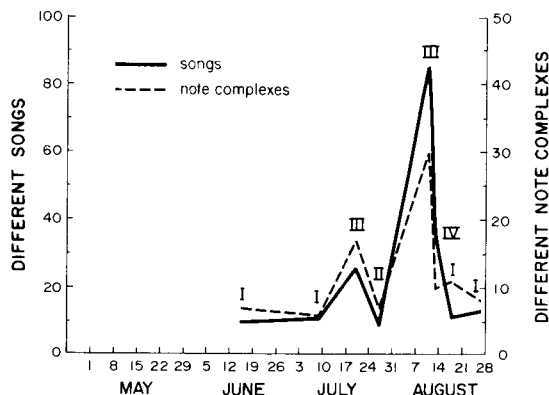


FIGURE 7. Numbers of different songs and different note complexes employed by SC6 on each recording date. I: no nest; II: nest; III: nest and eggs; IV: nest and/or young.

though daily song output and singing rates were not calculated in this study, singing pattern versatility of the Five-striped Sparrow (as measured by the number of different songs in a three-song sequence) previously has been shown to be negatively correlated with intersong interval, or singing rate (Groschupf and Mills 1978). Hartshorne (1956) showed a similar relationship among species, and postulated that this correlation exists because of a temporary inhibition against repeating the same pattern (song) after it has been sung.

Day length, light intensity, weather conditions, etc., may influence versatility of song performances, but behavioral factors could also operate. Kroodsma (1977) found that high singing rates and low repetition rates (i.e., high Transition Versatility) occurred during courtship chases by Winter Wrens (*Troglodytes troglodytes*), House Wrens (*T. aedon*), and Bewick's Wrens (*Thryomanes bewickii*); he suggested that this relationship was influenced by higher motivational states and intensity of display. In the Five-striped Sparrow, the sight of eggs or young in the nest may create a high motivational state during these stages of nesting. Kroodsma (1976) found that female Canaries (*Serinus canaria*) that were exposed to male Canary songs consisting of large numbers of song types were stimulated into reproductive condition faster than females that were exposed to songs consisting of a small number of song types. In the Five-striped Sparrow, stimulation of the female by her mate's song may be necessary in order to induce incubation, to induce further egg-laying, or to maintain the pair bond.

## CONCLUSIONS

The singing behavior of the Five-striped Sparrow is intermediate in complexity between those of species with small repertoires that suc-

cessively repeat one song type, and of species with large repertoires that rarely successively repeat a song type. The Five-striped Sparrow's repertoire is large but only a small proportion is sung in a bout. In a sample of about 4,000 songs each, two individuals whom we recorded throughout a breeding season each used over 200 song types. Before our study, the published repertoire size for Five-striped Sparrows was 13 song types (Borrer 1971), based on a sample of only 113 songs recorded from one individual on one day. Species whose singing behavior resembles this sparrow's especially need prolonged study because small samples may incorrectly assess the repertoire size.

Krebs and Kroodsma (1980) have reviewed the variations in song repertoire sizes of birds and the factors that may affect them. As they pointed out, much information is needed before we can begin to identify the factors that are most important in determining repertoire size. However, they emphasized studies of repertoire size within species, not between species. Both types of studies are needed, and the search for patterns and correlations between repertoire size and habitat or other ecological and ethological variables should be useful in evaluating some of the proposed hypotheses. More basic research on singing behavior is needed to provide the data for such evaluations.

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## LITERATURE CITED

- BONDESEN, P., AND L. I. DAVIS. 1966. Sound analysis within biological acoustics. *Natura Jutlandica* 12:236-239.
- BORROR, D. J. 1959. Songs of the Chipping Sparrow. *Ohio J. Sci.* 59:347-356.
- BORROR, D. J. 1961. Intraspecific variation in passerine bird songs. *Wilson Bull.* 73:57-78.
- BORROR, D. J. 1964. Songs of the thrushes (Turdidae), wrens (Troglodytidae), and mockingbirds (Mimidae) of eastern North America. *Ohio J. Sci.* 64:195-207.
- BORROR, D. J. 1971. Songs of *Aimophila* sparrows occurring in the United States. *Wilson Bull.* 83:132-151.
- CATCHPOLE, C. K. 1976. Temporal and sequential or-

- ganisation of song in the Sedge Warbler (*Acrocephalus schoenobaenus*). *Behaviour* 59:226–246.
- GROSCHUPF, K., AND G. S. MILLS. 1978. Intersong interval and song pattern variability of the Five-striped Sparrow. *Auk* 95:758–760.
- HARTSHORNE, C. 1956. The monotony-threshold in singing birds. *Auk* 83:176–192.
- HOPKINS, C. D., M. ROSSETTO, AND A. LUTJEN. 1974. A continuous sound spectrum analyzer for animal sounds. *Z. Tierpsychol.* 34:313–320.
- ISAAC, D., AND P. MARLER. 1963. Ordering of sequences of singing behavior of Mistle Thrushes in relationship to timing. *Anim. Behav.* 11:179–188.
- KREBS, J. R., AND D. E. KROODSMA. 1980. Repertoires and geographical variation in bird song, p. 143–177. In J. S. Rosenblatt, et al. [eds.], *Advances in the study of behavior*. Vol. 11. Academic Press, New York.
- KROODSMA, D. E. 1975. Song patterning in the Rock Wren. *Condor* 77:294–303.
- KROODSMA, D. E. 1976. Reproductive development in a female songbird: different stimulation by quality of male song. *Science* 192:574–575.
- KROODSMA, D. E. 1977. Correlates of song organization among North American wrens. *Am. Nat.* 111:995–1008.
- KROODSMA, D. E., AND J. VERNER. 1978. Complex singing behaviors among *Cistothorus* wrens. *Auk* 95:703–716.
- LEMON, R. E., AND C. CHATFIELD. 1971. Organisation of song in Cardinals. *Anim. Behav.* 21:28–44.
- MARLER, P., AND D. ISAAC. 1961. Song variation in a population of Mexican Juncos. *Wilson Bull.* 73:193–206.
- MILLS, G. S., J. SILLIMAN, K. GROSCHUPF, AND S. SPEICH. 1980. Life history of the Five-striped Sparrow. *Living Bird* 18:95–110.
- SAUNDERS, A. A. 1948. The seasons of bird song: the cessation of song after the nesting season. *Auk* 65:19–30.
- SHIOVITZ, K. A. 1975. The process of species-specific song recognition by the Indigo Bunting, *Passerina cyanea*, and its relationship to the organization of avian acoustical behavior. *Behaviour* 55:129–175.
- SMITH, W. J., J. PAWLUKIEWICZ, AND S. T. SMITH. 1978. Kinds of activities correlated with singing patterns of the Yellow-throated Vireo. *Anim. Behav.* 26:862–884.
- THOMPSON, W. L. 1968. The songs of five species of *Passerina*. *Behaviour* 31:261–287.
- WOLF, L. 1977. Species relationships in the avian genus *Aimophila*. *Ornithol. Monogr.* 23.

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## RECENT PUBLICATIONS

**Birds of a Feather. Unpublished letters of W. H. Hudson.**—Edited and introduced by Dennis Shrubbsall. 1981. Moonraker Press, Bradford-on-Avon, Wilts., Great Britain. 108 p. \$16.00. Source: Buteo Books, P.O. Box 481, Vermillion, SD 57069. Hudson left Argentina for England in 1874, when he was 33, and lived there for the rest of his long life. (For an introduction to his history, see the bibliography by J. R. Payne, noticed in *Condor* 79:510.) Published here for the first time are his letters to J. R. Harding, Mrs. Emma Hubbard, and Mrs. Eliza Phillips. Hudson replied to their questions about birds, thanked them for proffered information, and related his own thoughts and doings. His letters are helpfully annotated here by Dennis Shrubbsall, a Hudson scholar. They do not disclose any important new details about him, yet nevertheless help to show why he was so favored as an English country writer. The book is beautifully illustrated with wood engravings by Marcus Beaven. Index.

**The Peregrine Falcon in Greenland/Observing an Endangered Species.**—James T. Harris. 1981. University of Missouri Press, Columbia. 254 p. Paper cover. \$8.95. A fine piece of nature writing, this account of peregrine studies during a Greenland summer combines personal observations and feelings with scientific background. This paperback edition of a book first published in 1979 (noticed in *Condor* 81:389) carries a new preface with updated information about the status of the species.

**The History of the Federation of Alberta Naturalists and Its Corporate Member Clubs.**—Edited by Martin K. McNicholl. 1981. Alberta Naturalist, Special Issue No. 1. 152 p. Paper cover. \$7.00 Can. (\$6.00 if picked up personally at any corporate member club). Source: Federation of Alberta Naturalists, Box 1472, Edmonton, Alberta T5J 2N5, Canada. The natural history of the Alberta region has been studied scientifically since the early 19th century, and has attracted much attention from professionals and amateurs. Natural history clubs arose just before the turn of the century, and in 1970, six of them collaborated in forming the Federation of Alberta Naturalists. This book is a fully detailed history of the FAN, its corporate member clubs, its officers and patrons during its first decade. The chapters and sections are written by many individual members of the clubs. It is good to have these names and events recorded accurately while there are still people who remember them. Photographs.

**Bird Banding in Alberta.**—Edited by Martin K. McNicholl. 1981. Alberta Naturalist, Special Issue No. 2. 73 p. Paper cover. \$3.50 Can. (\$3.00 if picked up personally). Source: as above. Banding has been carried out in Alberta since the 1920's, starting with ducks and Rowan's work with gulls, crows and juncos. In recent years, attention has been directed especially toward hawks and owls. This booklet reviews the history of bird banding in Alberta, reprints a 1928 article by Rowan and offers several papers on the results of banding studies in the province. Much of this research appears to be well-focussed and informative. Photographs, maps, diagrams.