# NOTES ON SONG STRUCTURE IN THE TOWNSEND'S SOLITAIRE

Donald J. Borror and K. C. Halafoff

Studies of bird song structure with a sound spectrograph are generally based on sonagrams made with a wide-band filter; such sonagrams exaggerate the frequency spread of a sound, but reveal minute features of tempo. Sonagrams made with a narrow-band filter are seldom used because they exaggerate the timewise spread of a sound, even though they reveal details of frequency more precisely than wide-band sonagrams. Most song structure studies have been concerned primarily with temporal patterns and only general features of frequency, which are best shown by wide-band sonagrams.

Songs of the Townsend's Solitaire (*Myadestes townsendi*), like the songs of many other birds, contain elements that appear in wide-band sonagrams to be abrupt slurs, sometimes ranging over half an octave or more in less than 0.01 second. Since the mark on the sonagram is continuous, the assumption is that the abrupt rise or fall in pitch is continuous, hence the term *slur* appears to be appropriate for such a sound.

In the course of graphing Solitaire songs we made some sonagrams using a narrow-band filter, and it was noticed that some of the slurs had a banded appearance in these sonagrams; this suggested that the abrupt pitch change was stepwise rather than continuous—in the nature of a glissando.[1] Repeated graphing of these "slurs" and studies of the resulting sonagrams have revealed some interesting things about song structure in this bird.

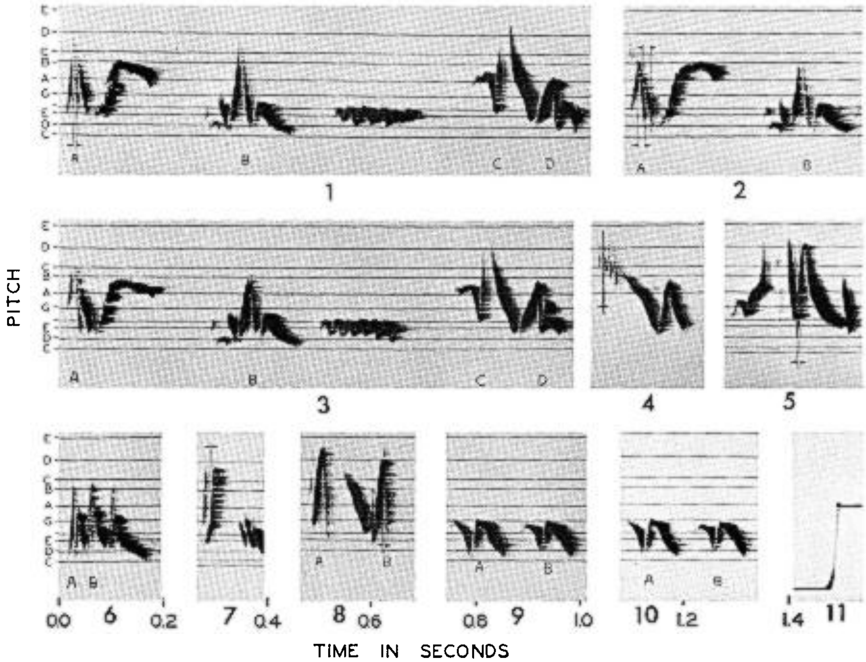
## METHODS

This study was made of the songs in a single recording (with 14 songs), OSU recording no. 7931, made on the north rim of Crater Lake, Oregon, 24 July 1965; the recording was made by D. J. Borror, using a Nagra III recorder, a tape speed of 15 ips, and a D33 American microphone mounted in a 24-inch parabolic reflector. The sonagrams were made with a Vibralyzer sound spectrograph.[2]

We have been particularly interested in the elements of these songs in which there is a rapid and stepwise change in pitch. Since our analyses are based on the banded character of these elements, one may well wonder how accurately the sonagrams portray the true character of the sound. If the pitch change is actually stepwise rather than continuous, this fact would be revealed to the ear in a playback at a reduced tape speed. With our equipment a reduction in tape speed is accompanied by a corresponding

[1] Webster's dictionary defines a glissando as "a rapid series of consecutive notes played on a piano, harp, or other similar instrument by sliding one or more fingers across adjacent keys or strings."

[2] A tape copy of one of the songs in this recording was sent to the Kay Electric Company, Pine Brook, N. J. (manufacturers of the Vibralyzer); their study of a glissando in this song showed the same things our studies did. We wish to thank Mr. George Smith, of the Kay Electric Company, for their study of this tape.




FIGS. 1–10. Sonagrams of portions of Townsend's Solitaire songs, made with a narrow band filter from songs in OSU recording No. 7931 (Crater Lake, Oregon, 24 July 1965). The lowest *C* in the pitch scale has a frequency of 2093 cycles per second, except in Fig. 7; in Fig. 7 the lowest *C* has a pitch of 1046.5 cycles per second, and the time scale is twice that shown at the bottom of the figure. TF, tonal fraction; I, average time interval between the start of successive steps in the glissando; letters indicating pitch are in italics.

FIG. 1. Four phrases from song 5. Each of the glissandos marked (A, B, C, and D) is immediately preceded by a continuous slur in the opposite direction. In the glissandos at A and B TF decreases with the fall in pitch, from about 1/3 above *C* to 1/6 between *F* and *E* in A, and from about 1/5 between *C* and *B* to 1/6½ between *A* and *G* in B; in C TF decreases with the rise in pitch, from about 1/2½ between *F* and *G* to about 1/4½ between *G* and *A*. The glissando at A is 0.00456 sec in length, with I = 0.00022 sec.

FIG. 2. Two phrases from song 4 (the same phrases as the first two in Fig. 1, but from a different song); note the continuous upslur immediately preceding the downward glissando in B and the first one in A. There are two glissandos at A, the first 0.0123 sec in length, and the second 0.0158 sec; TF between *A* and *G* is 1/5 in the first glissando, and about 1/3½ in the second. TF in the glissando at B varies from about 1/6 to 1/8.

FIG. 3. A portion of song 3, showing the same phrases as Fig. 1; the first two phrases here are the same as those in Fig. 2. The steps in A are fairly distinct between *A* and *C*, a little less so between *G* and *A*; TF between *A* and *C* is about 1/6, and between *G* and *A* is about 1/7. At C there are 4½ steps between *G* and *A* (TF = 1/4½). TF in D

reduction in pitch, and at tape speeds lower than 1/32 normal the sounds are unintelligible; only the slowest of the "slurs" studied (e.g., that shown in Fig. 7) appear stepwise to the ear when played at 1/32 normal speed. Many are preceded or followed by a slur that in narrow-band sonagrams *does* appear continuous; if there is horizontal banding in one of two adjacent "slurs" and not in the other, the two must be different. Sonagrams of a fast shift in frequency of an oscillator tone (Fig. 11) show a continuous mark, with no banding. All of these slurlike passages have been graphed a number of times, forward and backward, and over intervals of several months, and the banding remains the same (see Figs. 9 and 10). We therefore believe that this banding is not an artifact; some of the rapid pitch changes in these songs appear to be glissandos, in which successively higher or lower frequencies are initiated in a stepwise fashion.

We have been primarily interested in two features of these stepwise "slurs" or glissandos, the tonal fractions of successive steps, and the rates at which successive steps appear. Data on tonal fractions were obtained by superimposing on the sonagrams horizontal lines representing notes of the musical scale (omitting, for the sake of clarity, the black notes of the piano); such lines have been put on the sonagrams in Figs. 1–10. Data on step rate were obtained by measuring the time interval between the beginning of the first step and the beginning of the last one (shown in Figs. 1-A, 2-A, 4, 5, 7, and 8-B) and counting the steps it contained. We have obtained some data on step duration from wide-band sonagrams (since the duration of a sound is exaggerated in narrow-band sonagrams), measuring at about the middle of the passage (see legend of Figs. 3 and 4).

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decreases with the fall in pitch. The duration of the steps in A is about 0.003 sec, and about 0.010 sec for those in B.

FIG. 4. A phrase from song 4. Of the four downslurs at the beginning of this phrase, the first is continuous and the other three are stepwise. The uniform spacing of the steps in the glissando marked means an increase in the TF with decreasing pitch; this glissando is 0.00193 sec in length, with 12 steps; I = 0.00016 sec (the shortest found). The step duration is about 0.002 sec.

FIG. 5. A portion of song 6, with an upward glissando immediately preceded by a continuous downslur. TF decreases with a rise in pitch, from about 1/3 between *F* and *G* to 1/9 between *B* and *C*. I = 0.00021 sec.

FIG. 6. A phrase from song 4; note that the first upward glissando (at A) is preceded by a continuous upslur. TF in the glissando at A is about 1/5 between *E* and *A*, and between *F* and *G* in the first glissando at B it is about 1/3½.

FIG. 7. A portion of song 2; note the continuous upslur immediately preceding the glissando. I = 0.00078, with 9 steps; TF is constant at about 1/3 tone. This was the slowest of the glissandos examined. (The pitch in this sonagram is an octave lower than in the other sonagrams, and the time scale is twice that of the others.)

FIG. 8. A portion of song 5. Each of the two downward glissandos is immediately preceded by a continuous upslur. TF in both A and B decreases with the fall in pitch, from about 1/6 to 1/9 in A, and 1/6 to 1/7 in B. B is 0.00386 sec in length; I = 0.00024 sec.

FIGS. 9 and 10. A portion of song 6, the two sonagrams made several months apart; note the similar banding in the glissandos marked. In A and B TF decreases with the rise in pitch, but the steps in the two (which appear to be renditions of the same sound) are not quite the same.

FIG. 11. Sonagram of a fast shift in frequency of an oscillator tone (from the Kay Electric Company). Note that there is no indication of banding in this abrupt slur.

## TONAL FRACTIONS

Most early analyses of bird songs (e.g., Mathews, 1921; Arlton, 1949), which were based solely on aural observations, consisted of musical scores; some modern analyses, based on audiospectrographic studies as well as aural observations (e.g., Hall-Craggs, 1962), have also used musical scores. These scores all use our half-tone musical scale,[3] with the implication that the tonal fractions used by birds were the same as those in this musical scale. Some workers (e.g., Howard, 1952) have suspected that smaller tonal fractions are sometimes used by birds, but little attention has been given this point by modern workers using audiospectrographic methods of song analysis.

Our studies of Solitaire songs have yielded numerous instances of tonal fractions less than a half-tone; some examples are shown in Figs. 1–10 (tonal fraction is abbreviated TF in the figure legends). These fractions varied from about 1/2 to 1/9, and usually changed in size through a given glissando. Increases or decreases in the tonal fractions occurred during both rises and falls in pitch, but as a rule there was no reversal of the direction of the change in a given glissando; a diminishing tonal fraction continued to diminish, and an increasing one continued to increase, until the end of the passage. Only rarely did the tonal fractions remain constant through a passage (e.g., at 1/3 tone in Fig. 7). The fractions often differed in different renderings of what appeared to be the same phrase or figure—in different songs, and in different parts of the same song (cf. A in Figs. 1, 2, and 3; and A and B in Fig. 9). The tonal fractions in two or more glissandos uttered in succession usually differed. In parts of these songs where the pitch was sustained for a short period it was not constant; at the end of the figure in Fig. 3, for example, the pitch falls about 1/4 tone.

## STEP RATES IN THE GLISSANDOS

Data on step rates in four of the glissandos shown in the figures are given in Table 1. The time intervals (I) between the beginning of successive steps (the horizontal bands in a narrow-band sonagram) varied from 0.00078 to 0.00016 second; these figures correspond to rates of 1282 to 6211 per second, and represent the rates at which successive steps in the glissandos appear. Measurements of the duration of the steps ranged from 0.002 to 0.010 second; these figures, and the configuration of the steps in narrow-band sonagrams, indicate that successive steps overlap in time—producing a sound with a complex frequency content, but with the successive frequencies beginning in a stepwise fashion rather than all at the same time. It should be noted that our figures on the duration of the steps necessarily includes the reverberation

[3] American Standard Pitch, in which the *A* above middle *C* has a frequency of 440 cycles per second, and there are 12 half-tone steps (tonal fraction = 1/2) in an octave.

TABLE 1

DATA ON SOME SOLITAIRE GLISSANDOS

| Glissando in Fig. | Length (sec) | Steps No. | Steps Pitch Limits | I* | Steps Initiated per sec. |
|---|---|---|---|---|---|
| 1A | 0.00456 | 21 | E–C# | 0.000217 | 4608 |
| 4 | 0.00193 | 12 | B–D# | 0.000161 | 6211 |
| 7 | 0.00702 | 9 | G–D | 0.000780 | 1282 |
| 8B | 0.00386 | 16 | G–C | 0.000241 | 4149 |

* I is the average length of time between the start of one step and the start of the next.

time, which cannot be separated from the actual duration of the sound (as emitted by the bird) once the recording has been made. On the other hand, the values of the time intervals between the start of adjacent steps in a glissando are free from reverberation, as none occurs at the very start of a sound.

Published sonagrams of bird songs do not show note rates higher than about 200 to 250 per second; compared with such figures, our rates of the steps in Solitaire glissandos—up to several *thousand* per second—are fantastically high. The Solitaire is initiating sounds of successively higher or lower pitch at extremely rapid rates; we do not know how the bird is able to produce sounds at these rates.

To date we have found similar glissando-like passages in songs of the Wood Thrush (*Hylocichla mustelina*); it is probable that some abrupt slurs in songs of other birds are also stepwise rather than continuous.

## PROBLEMS OF MUSICAL NOTATION

Our musical scale is based on a half-tone musical interval as the smallest tonal fraction. It is possible to modify this scale, using some other fraction (e.g., 1/3 or 1/4 tone), but all such modifications would presume that the minimum tone unit is constant; it is impossible to do this if the tonal fraction is variable, as it is in these Solitaire glissandos. The only way to write down such fractional-tone bird music would be to indicate each note by its frequency figure (attempts to use such notation in modern music have been made), but such a score would be so difficult to read tonally that it would hardly make sense, and no musician would be able to play it.

Time intervals between adjacent sound units in a bird song can be measured with considerable precision, but it is questionable whether these irregular intervals could be indicated accurately in a musical score, even with the smallest musical units. The time between successive steps in Solitaire glissando passages is extremely short, and it would be very difficult to exactly indicate this time in a musical score. Thus the prospect of the universal use of conventional musical notation, even in an amended form, for writing down bird song must be ruled out.

With our present electronic tools, a sonagram with notes of our musical scale superimposed on it (as in Figs. 1–10) is probably the closest to a musical representation of a song that can be obtained. Such a graph could easily be read, both tonally and along the time scale (provided the overtones can be recognized—by their harmonic relation to the basic notes, and by checking through retarded replay and thus separating them from the melody itself); it contains all the sound elements, including loudness (indicated by the darkness of the mark) and timbre (indicated by the harmonics).


## SUMMARY

Sonagrams made with a narrow-band filter of abrupt slurs in songs of the Townsend's Solitaire (*Myadestes townsendi*) show some of the slurs to have a characteristic banding, indicating that the pitch change is stepwise (a glissando) rather than continuous. Tonal fractions in these glissandos varied from about 1/2 to 1/9 tone; they usually decreased toward the end of a glissando, and often differed in different renderings of the same phrase or figure, and in two or more glissandos uttered in succession. Measurements of the time intervals between the start of successive steps indicated that these steps were begun at rates of 1282 to 6211 per second. Conventional musical scores are inadequate for representing such elements of a bird's song; a sonagram with notes of the musical scale superimposed on it is probably the closest to a musical representation of a song that can be obtained.


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DEPARTMENT OF ZOOLOGY AND ENTOMOLOGY, OHIO STATE UNIVERSITY, 1735 NEIL AVE., COLUMBUS, OHIO 43210, AND 12 JOHN ST., UPPER FERNTREE GULLY 3156, VICTORIA, AUSTRALIA, 17 NOVEMBER 1967.