low-pressure system formed off the east coast of Yucatan. Winds in Florida and the Gulf were generally E and NE, while in the Caribbean they were E and SE at 15–20 mph.

At 0100 on 11 October the front reached the southern tip of Florida and by 1300 it was stationary over Cuba. It subsequently disappeared by 0100 on 12 October. Its passage on 9–11 October was followed by NE winds of 9–14 mph. The Yucatan low remained stationary through 11 and 12 October. By 13 October, it intensified and became hurricane Isabel and began moving ENE. On 11 October at 1300, the wind directions at Jamaica, Hispaniola, and Venezuela were easterly and southerly at 9–20 mph, whereas at Panama they were SE at 4–9 mph. This same general situation prevailed into 12 October.

Thus for the 36 to 48 hours immediately preceding encounter of the birds and the ship, the Caribbean wind direction averaged SE at 9–20 mph at the start and tended toward E at 4–9 mph at the time of encounter. Whether these birds originated their flight with the assistance of favorable NE winds accompanying the cold front over Florida or Cuba on 10 or 12 October, or whether they were drifted by easterly winds from one of the more easterly land masses of the Greater Antilles is not known. Their position at sea and their physical condition at the time of encounter suggest they must have flown through the night. Had they been migrating normally during the day of 11 October and been forced to fly through the night for lack of a suitable landing site, they could have been airborne for up to 30 hours at the time of encounter. The nearest northerly land masses of significant size are Jamaica (550 miles almost due north) and Hispaniola (650 miles northeast). Under normal circumstances the Barn Swallow is considered a diurnal migrant and is not known to cross the Caribbean. In this case these birds did not survive an attempt to do so.

I wish to acknowledge the loan of meteorological data from Raymond Falconer of the Atmospheric Sciences Research Center of the State University of New York at Albany.—R. P. YUNICK, *1527 Myron Street, Schenectady, New York.* Accepted 5 Sep. 75.

Audiospectrograms with pitch scale: a universal "language" for representing bird songs graphically.—Dissatisfaction with the frequency scale of conventional sonagrams prompted me to portray songs of brown towhees (*Pipilo*) by hand-tracing the graph onto a logarithmic scale of frequency, to equalize the intervals of pitch (Marshall 1964, Condor 66: 347). By pitch I mean position in the do-re-mi sequence or on the musical staff. Later I despaired at the labor of eye-fitting these graphs and used the linear scale audiospectrograms just as they came from the analyzing machine (Marshall 1967, Western Found. Vert. Zool. Monogr. No. 1). Meanwhile manufacturers inserted into newer machines a small, inexpensive device that automatically makes a logarithmic display. Yet ornithologists never use the log scale! Herewith I offer reasons for abandoning the linear scale—because it resembles nothing in the real world—and for adopting the log scale because it is reproducible and, like a musical score, constitutes a universal "language" or symbolism by which sounds can be recognized visually by their shapes on a graph.

The conventional sonagram paper displays notes or a theme as black smudges reading from left to right on a horizontal scale of equal time intervals. The equal intervals of frequency, in vibrations per second, on the vertical axis are not faithful to the intervals that we hear in natural sounds. The latter are stretched apart in the upper levels of the graph, whereas near the bottom they are so condensed that pitch differences cannot be detected. The shorter the time length of the theme displayed (which depends on the speed of rotation of the turntable relative to tape speed of the incoming signal), the flatter it becomes (Fig. 1), as if it were a wax model melting down into a puddle at the bottom of the paper. A single theme can take an infinite number of shapes when rendered at different speeds and on different analyzers. Results can be duplicated only if the machine model, speed at which it accepts the song, the horizontal scale, *and* the vertical scale are all specified and adhered to. Musicians read themes by their shape; they would rebel at having to decipher such distortions if the frequency scale were used on the musical staff.

On the other hand, Fig. 2 shows the same theme on the log scale. Musical intervals of pitch are the same throughout the vertical axis. They are based on the musical octave of doubling frequency. As pitch ascends we experience the recapitulation of a sequence of sounds (do, re, mi, etc.) at double, quadruple, etc., frequencies. Indeed it is much easier for the human ear to assign bird sounds to pitch values on the scale of do-re-mi than it is to discover in what octave of the pianoforte they lie. (For unfamiliar sounds the only way to tell the latter is to make a spectrogram of them with a calibration tone included on the graph. This difficulty is due to the marked similarity of any two tones an octave apart in pitch because of their possession of several harmonics in common.) Thus the log scale reflects the true relationship among sounds in nature. A given note, phrase, or theme has one and only one shape. If greater resolution is desired, the analyzer is speeded to accept only a short portion of the theme (or the tape speed is reduced), and the result is a tracing of the same shape as before, but beautifully enlarged. Results can be duplicated by any kind of analyzing machine at any speed, anywhere. The theme will always have the same shape (being subject
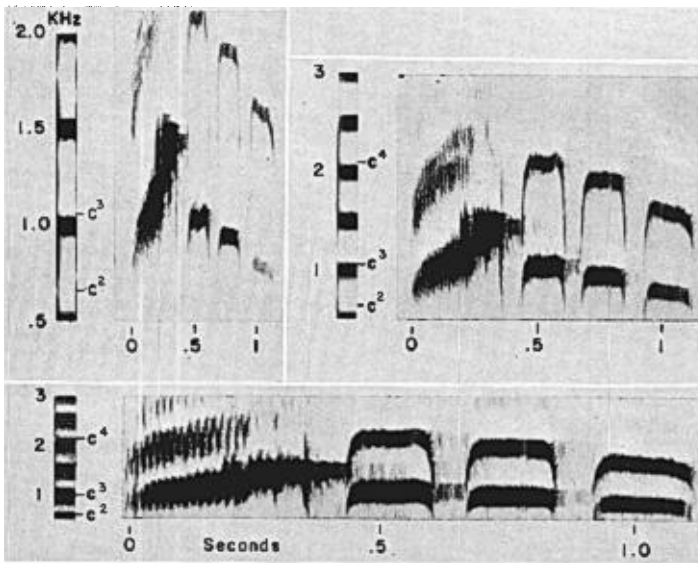
Fig. 1.   Theme of female Javan Frogmouth, *Batrachostomus javensis continentalis*, Thailand. On the vertical axis are equal intervals of frequency—the so-called "linear scale." Different sizes and shapes correspond to different speeds at which the analyzing machine accepted the signal. On the particular analyzer that was used, these speeds were actuated by setting a control knob to render the spectrogram within a range of 20–2000 Hz lasting 9.6 seconds for the first display, 40–4000 Hz lasting 4.3 seconds for the second, and 80–8000 Hz lasting 2.4 seconds for the bottom display. The resulting graphs are all 4 × 12 inches but the superfluous parts have been cropped in this figure.
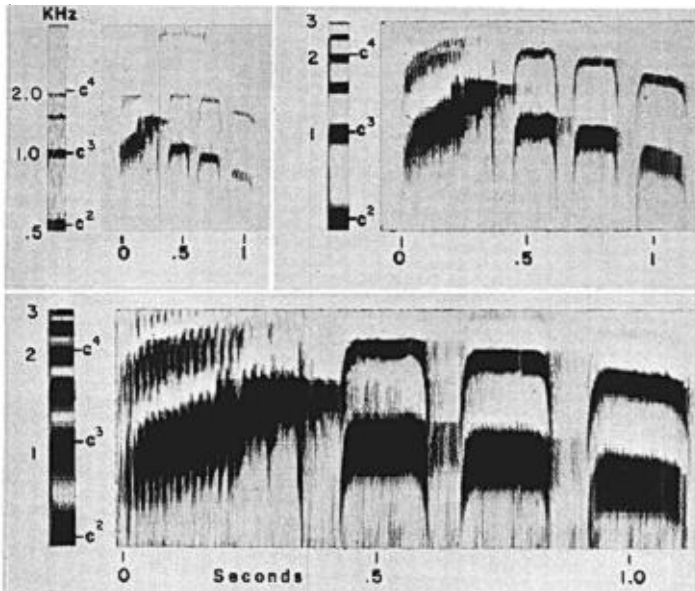

Fig. 2.   Same theme as in Fig. 1. On the vertical axis are equal intervals of pitch—the so-called "log scale." Different sizes of the three displays result from different speeds at which the analyzing machine accepted the signal, but the shapes are all the same.

only to slight stretching or condensing along the time axis according to what sort of analyzer is being used). If the tones are pure, a violinist can read the spectrogram, because it corresponds to notation on the musical staff, and play the theme on his instrument. Most bird songs, and those of gibbons, are pushed to the upper part of the graph, where "wide band" tracings become narrow enough to give the good pitch resolution of "narrow band" combined with excellent temporal definition characteristic of the "wide band" setting. Moreover the page can be inverted to receive a second tracing on the other half.

For all the above reasons I recommend the acceptance of the log scale in displays of natural sounds for ordinary purposes. The linear scale might be reserved for special studies of harmonics, some of which appear at equal vertical intervals at this setting.

I thank Luis F. Baptista and J. W. Hardy for making the spectrograms and the following persons from the fields of music, mathematics, and physics: James R. Anthony, Robert Exell, Rafael Ronkin, Rolf M. Sinclair, and Carl T. Tomisuka for criticizing this note.—JOE T. MARSHALL, JR., *Fish and Wildlife Laboratories, National Museum of Natural History, Washington, D.C. 20560.* Accepted 7 Aug. 75.

The role of the sternotrachealis muscles in bird song production.—Greenewalt (1968) integrated much of what was known about song production in birds and combined it with acoustical data to produce a predictive model of avian song production. Greenewalt's theory can be separated into two models: 1) "The Passive Closure Model" and 2) "The Active Closure Model" (Gaunt et al. 1973). These models assume that the muscles of the syrinx act to regulate tension on the paired internal tympaniform membrane and possibly to position the paired external labia (see Fig. 1). There is good evidence from physiological studies of the syrinx in dead birds that the syringeal musculature is capable of influencing the tension applied to the internal tympaniform membrane and the external labia (Miskimen 1951; Gross 1964; Chamberlain et al. 1968). With the exception of Gross' (loc. cit.) studies of the Domestic Fowl (*Gallus domesticus*), there have been no attempts to determine the precise function of the syringeal muscles in living vocalizing birds.

This paper reports the results of experiments that attempt to define the role of the sternotrachealis muscles in song production of four species of birds representing two orders and three families of birds.

The four species investigated were: Rock Pigeon (*Columba livia*), Red-winged Blackbird (*Agelaius phoeniceus*), White-throated Sparrow (*Zonotrichia albicollis*), and Song Sparrow (*Melospiza melodia*). Two male individuals each of Red-wings, White-throats, and one Song Sparrow were captured on their
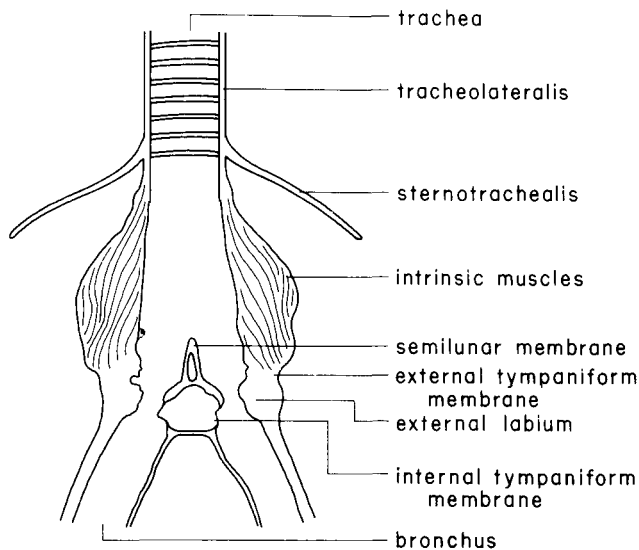

Fig. 1. A schematic representation of structures in the avian syrinx. A longitudinal section of the syrinx exposes the bronchial lumen, external and internal tympaniform membranes, external labia, and location of intrinsic musculature. The tracheolateralis and the sternotrachealis muscles are shown on the outer lateral surfaces of the trachea.