TWO-VOICE PHENOMENON IN BIRDS: FURTHER EVIDENCE

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ABSTRACT.—Maternal calls of 11 wood duck (*Aix sponsa*) hens were recorded at nest sites in the field. Audiospectrographic analyses revealed that most of the hens uttered calls containing two (or more) temporally overlapping, nonharmonically related tones, thereby implicating two or more independent sound-producing sources in the syrinx. Evidence for the "two-voice" phenomenon has heretofore come mainly from songbirds. The present report presents the first evidence of this vocal phenomenon in waterfowl.—*Psychology Laboratory, North Carolina Department of Mental Health, Dorothea Dix Hospital, Raleigh, North Carolina 27611. Present address: Department of Ethology, University of Bielefeld, P.O. Box 8640, D-4800 Bielefeld 1, West Germany.* Accepted 22 December 1975.

THE vocalizations of certain avian species contain two separate, nonharmonically-related tones. As these tones are uttered simultaneously and are not harmonically related, it is likely that two independent sound sources are operating simultaneously in the vocal tract of these species. The two-voice phenomenon was first described by Potter, Kopp, and Green (1947: 410–412). They noted a "double tone" in the sound spectrogram of a Brown Thrasher's (*Toxostoma rufum*) song. Subsequently, other investigators of bird vocalizations have found two voices in other species, almost always oscines (Borror and Reese 1956, Thorpe 1961: 112–113, Greenewalt 1968: 55–78, Stein 1968, Nottebohm 1971). Thorpe (1961: 112–113) interpreted sound spectrograms of songs of a Gouldian Finch (*Chloebia gouldiae*) and a Wood Thrush (*Hylocichla mustelina*) as portraying three and four simultaneous voices, respectively. The present report describes the first evidence suggesting the presence of multiple voices in waterfowl (nonoscines).

The vocalizations of birds are generated by air passing across certain vibratile membranes in the syrinx, the vocal apparatus located at or near the tracheobronchial junction. Greenewalt (1968: 55–78) and Stein (1968) independently presented models of avian sound production incorporating the capability of sounds being produced by two independent acoustical sources within the syrinx. In actuality, the syringes of many species have up to four membranes (two on each side of the syrinx) that could be involved in sound production. The best anatomical evidence for two independent acoustical sources in birds comes from Nottebohm (1971). He sectioned either the left or right root of the hypoglossus nerve, which innervates the muscles controlling the membranes on each side of the syrinx, and found that adult Chaffinches (*Fringilla coelebs*) no longer produced one of two nonharmonically-related tones in their species-typical song, depending on which root was sectioned.

Nottebohm's results increase the validity of the two-voice phenomenon, for, prior to his research, the only evidence for this phenomenon was based solely on sound spectrograms of the voices of intact birds. The question remains how general the two-voice phenomenon is in nonoscine species. For example Greenewalt (1968: 56–78) found spectrographic evidence for two voices in 12 species of oscines but only in 7 nonoscine species: Eared Grebe (*Podiceps nigricollis*), American Bittern (*Botaurus lentiginosus*), Greater Yellowlegs (*Tringa melanoleucus*), Common (Red-shafted) Flicker (*Colaptes auratus cafer*), Broad-winged Hawk (*Buteo platypterus*), American Golden Plover (*Pluvialis dominica*), and Bare-throated Bellbird (*Procnias*

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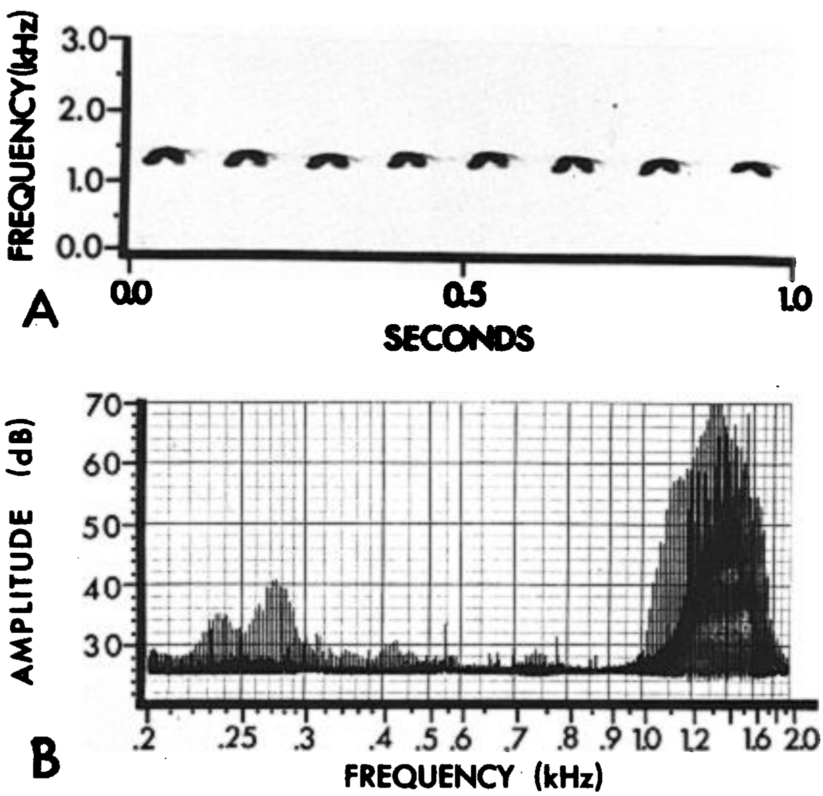

Fig. 1. A, narrow-band spectrogram of Wood Duck maternal call. The notes of this call are single tones (i.e. "singlets"). B, narrow-band frequency analysis of all of the notes in A. The singlets have most of their energy around 1.4 kHz.

nudicollis). I could find no reports of the two-voice phenomenon in any species of Anatidae (waterfowl). Although the calls of waterfowl have a simpler structure than the complex songs of most oscines, they, nevertheless, have social communicative value. For example, it has been shown that a characteristic frequency modulation in the notes of the maternal Wood Duck (*Aix sponsa*) call is the acoustic basis of species identification in Wood Ducklings (Gottlieb 1974).

To gain insight into the structure and function of waterfowl vocalizations, I recorded Wood Duck calls. Incidental to my other aims (see Miller and Gottlieb 1976), I discovered evidence for two voices in some Wood Duck females. For this purpose I examined in detail the maternal calls of 11 Wood Ducks recorded at nest sites in the field near Raleigh, North Carolina over the past 14 years. These are the calls that the hens utter while brooding their young (i.e. pre-exodus call) and while calling them out of the nest within 2 days after hatching (i.e. exodus call). Most of the recordings were made with a Nagra III-B tape recorder and an AKG directional microphone. The microphone was placed in a supporting cradle attached to the undersurface of artificial wood duck hole-nest boxes.

Sound spectrograms were made of each call using a Kay Electric Sonagraph (Model 6061-B). Unfortunately certain problems associated with sound spectrographs make it risky to judge the presence (or absence) of two or more voices solely on

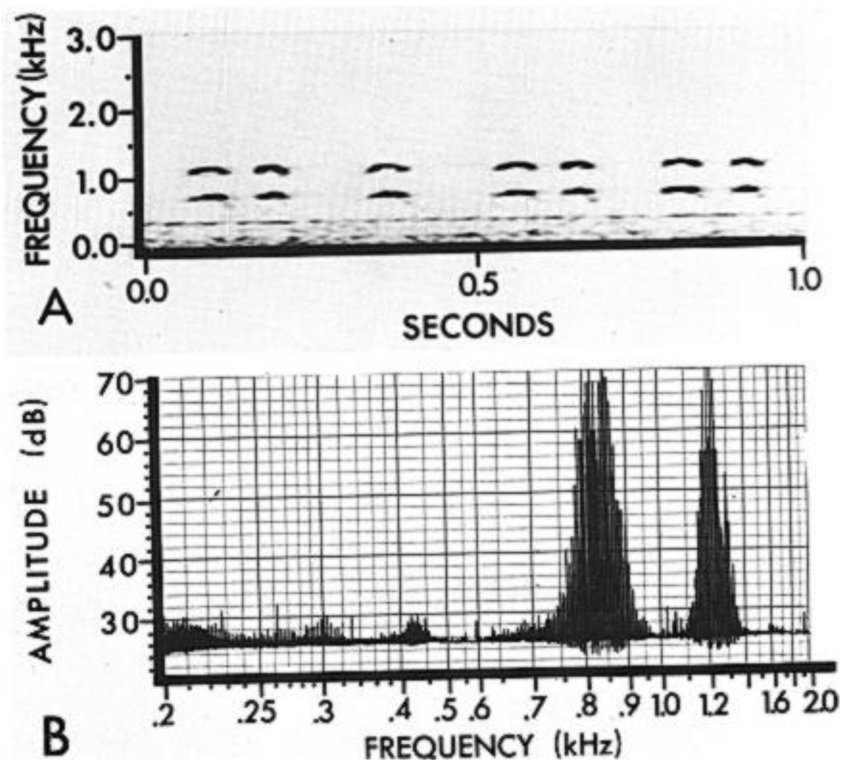

Fig. 2. A, narrow-band spectrogram of Wood Duck maternal call in which each note is comprised of two nonharmonically-related tones (i.e. "doublets"). B, narrow-band frequency analysis of all of the notes in A. The energy of the notes of the doublets is around 0.85 kHz for the lower tone and 1.2 kHz for the upper tone.

the basis of the spectrogram (cf. Watkins 1967). First, as shown by Greenewalt (1968: 9), spectrograms sometimes depict energy that does not actually exist on the tape recording. Second, because of the limitations imposed by the dynamic range of the sound spectrograph, energy that does exist on the tape recording may sometimes not be depicted on the spectrogram. Third, without a scale magnifier, one cannot specify precisely the exact frequencies of the signals from the compressed frequency scale of the spectrogram. To overcome these difficulties, I also analyzed each call on a Brüel & Kjaer Type 2107 Frequency Analyzer, which was connected to a Brüel & Kjaer Type 2305 Level Recorder to produce the resulting amplitude-frequency charts. As the narrow-band frequency analyzer does not omit or add energy and gives a precise frequency reading (i.e. better than ±1% degree of accuracy), it provides a very useful and important adjunct to the sound spectrograph, especially in the present context.

Spectrograms and corresponding frequency analyses of representative Wood Duck maternal calls are shown in Figs. 1–4. As can be seen, the hen of this species is capable of producing two nonharmonically-related tones simultaneously (Fig. 2), as well as single tones (Fig. 1). The frequency analyses (Figs. 1B and 2B) corroborate the spectrograms (Figs. 1A and 2A), verifying the presence of two distinct peaks that are not harmonically-related to one another (i.e. the upper tone is not at a frequency that is a multiple of the lower tone). In addition, it is essential to rule out the

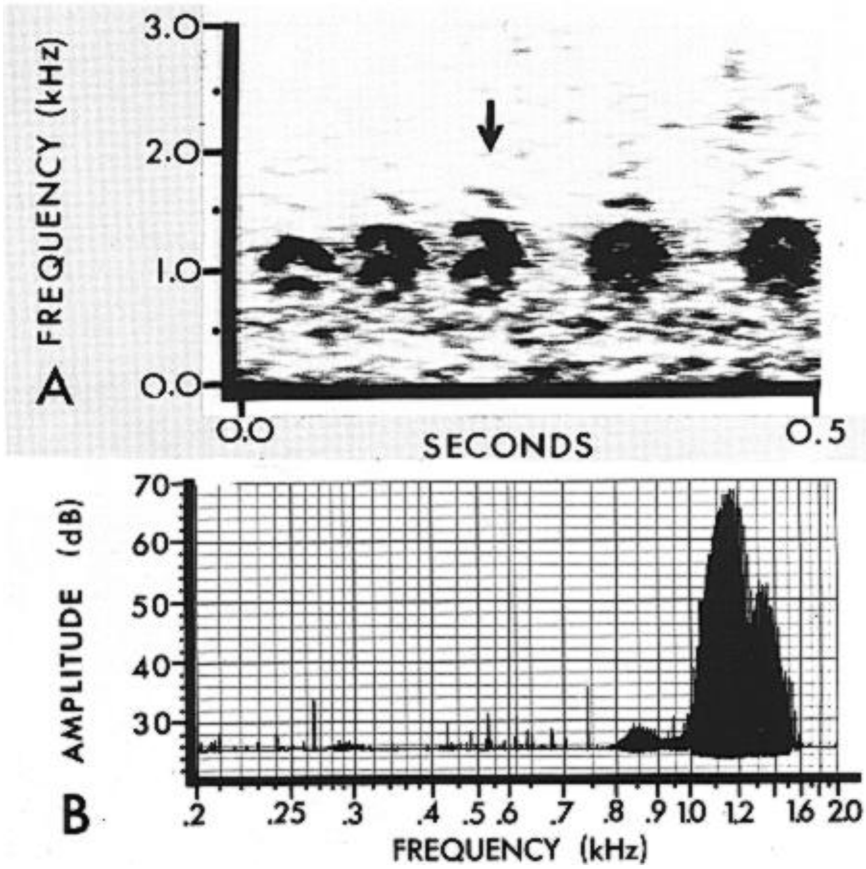

Fig. 3. A, narrow-band spectrogram of a Wood Duck maternal call consisting of one doublet followed by four notes containing three nonharmonically-related tones (i.e. "triplets") plus a less pronounced harmonic. B, narrow-band frequency analysis of the third note in A (see arrow). The energy peaks for each component of the triplet are around 0.85, 1.15, and 1.35 kHz.

possibility that the two voices are not in fact harmonics of any lower frequencies. In Fig. 2B, for example, low-amplitude peaks occur at 0.3 and 0.43 kHz. As there is a 40 dB difference between these peaks and the peaks at 0.85 and 1.2 kHz, it is highly unlikely that the latter two are harmonics of the former. Nevertheless, I subjected the contents of the two low-amplitude peaks to a finer-grain analysis. Using the frequency analyzer as a low-pass filter, I portrayed only the energy around 0.3 and 0.43 kHz on the spectrograph. The resulting spectrograms contained only background noises at these respective frequencies and no Wood Duck notes (i.e. the energy at these lower energy bands, resembling "white noise," was not modulated like the higher energy bands); thus the peaks at 0.85 and 1.2 kHz are not harmonics of the low-amplitude peaks at 0.3 and 0.43 kHz. By applying this same procedure to the low-frequency peaks (<0.6 kHz) in Figs. 1B and 4B, I found these energy bands also to be strictly background noises.

The distribution of two voices among the hens in the present sample suggests this phenomenon to be a somewhat general feature of Wood Duck maternal calls. Of the 11 Wood Duck hens, one uttered only "singlets," two uttered only "doublets," six

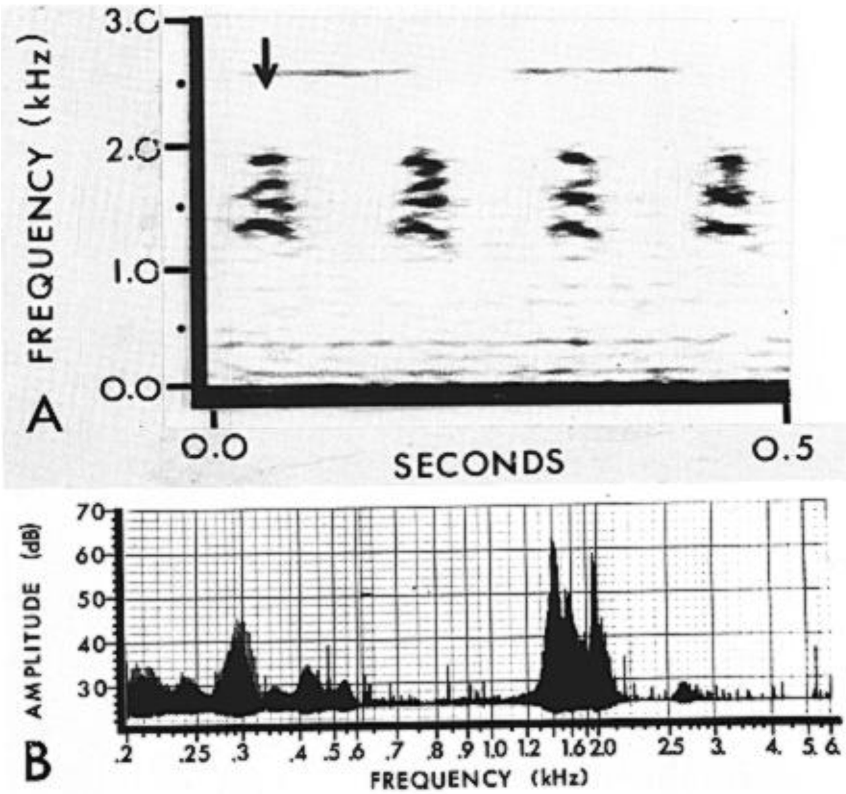

Fig. 4. A, narrow-band spectrogram of a Wood Duck maternal call in which the first note is comprised of four nonharmonically-related tones (i.e. "quadruplets"). The second note may also be a quadruplet, and the third and fourth notes are probably triplets. B, narrow-band frequency analysis of the first note in A (see arrow). The energy peaks of the quadruplet are around 1.4, 1.55, 1.75, and 1.9 kHz. The peak at 1.75 kHz is relatively small and somewhat difficult to see because of the compression of the frequency scale at the particular point where the peaks are located.

uttered singlets and doublets, one uttered singlets, doublets, and "triplets" (i.e. three nonharmonically-related tones), and one uttered doublets, triplets, and "quadruplets." Examples of triplets are shown in Figs. 3A and B, and examples of quadruplets are shown in Figs. 4A and B. As the nonharmonically-related components of the triplet and quadruplet are at closely-spaced frequencies, the peaks on the frequency analyses (Figs. 3B and 4B) appear to be continuous rather than discrete. Even at the fastest writing speeds, the recording pen of the level recorder is not mechanically capable of returning to baseline between these closely-spaced tones. The discreteness of the tones is better portrayed by the spectrograph (Figs. 3A and 4A). It should also be noted that because of the pronounced descending component of the darkest upper two tones of the triplet (see arrow in Fig. 3A), the terminations of the three components impinge on each other. It will be noted that the beginning of each tone is discrete and nonoverlapping.

The anatomical basis of doublets, triplets, and quadruplets poses an intriguing problem. It is not yet known which membranes are involved (or how) in the multiple voices of Wood Duck hens, or any other species for that matter.

Bird vocalizations are modulated (i.e. change over time) with respect to both frequency and amplitude. I found that the two independent sounds can be modulated either similarly or differently in both frequency and amplitude. Also in the case of doublets, the tones at one frequency tend to have a greater amplitude than the tones at the nonharmonically-related frequency. At least one of the Wood Duck hens showed a shift in relative amplitude from the upper tones to the lower tones and vice versa within a given call (i.e. burst of notes).

While the present study is restricted to a single species of duck, a preliminary analysis of other calls on hand in the laboratory suggests that the two-voice phenomenon is present in other waterfowl species as well (e.g., Mallard (*Anas platyrhynchos*), Muscovy Duck (*Cairina moschata*), Mandarin Duck (*Aix galericulata*)). The functional significance of uttering two or more tones simultaneously remains obscure. As the frequency modulation of the maternal Wood Duck call has been shown to be an essential parameter of species identification by Wood Ducklings (Gottlieb 1974), one may speculate that independently-modulated voices increase the information content with respect to frequency modulation. Two voices may increase the attractiveness of the maternal call to the young, and individual differences in this parameter could provide a possible basis for individual parent recognition as well.

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LITERATURE CITED

BORROR, D. J., AND C. R. REESE. 1956. Vocal gymnastics in Wood Thrush songs. Ohio J. Sci. 56: 177–182.

GOTTLIEB, G. 1974. On the acoustic basis of species identification in Wood Ducklings (*Aix sponsa*). J. Comp. Physiol. Psychol. 87: 1038–1048.

GREENEWALT, C. H. 1968. Bird song: acoustics and physiology. Washington, D.C., Smithsonian Institution Press.

MILLER, D. B., AND G. GOTTLIEB. 1976. Acoustic features of Wood Duck (*Aix sponsa*) maternal calls. Behaviour 57: 260–280.

NOTTEBOHM, F. 1971. Neural lateralization of vocal control in a passerine bird. I. Song. J. Exp. Zool. 177: 229–261.

POTTER, R. K., G. A. KOPP, AND H. C. GREEN. 1947. Visible speech. New York, D. Van Nostrand Co.

STEIN, R. C. 1968. Modulation in bird sounds. Auk 85: 229–243.

THORPE, W. H. 1961. Bird-song. Cambridge, Cambridge University Press.

WATKINS, W. A. 1967. The harmonic interval: fact or artifact in spectral analysis of pulse trains. Pp. 15–43 *in* Marine bio-acoustics, vol. 2 (W. N. Tavolga, ed.). New York, Pergamon Press.