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TESTS OF HEARING ABILITY

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ABSTRACT.—Hearing tests taken by 274 people at the symposium indicated large differences in hearing ability among active birders. Simulation of the detectability of birds for observers with hearing thresholds of 10, 20, 30, and 40 dB indicated differences in area effectively surveyed as large as an order of magnitude.

In order to increase the comparability of observers, we recommend testing all potential observers for hearing ability using pure tone tests from .5 to 8 kHz and eliminating all those with uncorrectable hearing thresholds of 20 dB or greater in the frequencies emitted by the species being surveyed.

The importance of hearing to birders has long been recognized (Saunders 1934; Mayfield 1966; Cyr 1981). Because of the great reliance placed on aural observations during bird counts (Kepler and Scott 1981), we felt it would be informative to determine the variation in hearing ability in active birders. Thus, we offered hearing tests to participants in this symposium. Two hundred seventy-four people took advantage of this opportunity.

METHODS

The test was a standard industrial type in which the hearing threshold—the lowest detectable volume in decibels (dB) of each ear—was determined for frequencies ranging from 0.5 to 6.0 kilohertz (kHz). Information was obtained on age, sex, number of years' birding experience, and the number of bird surveys conducted in the last year. Unfortunately, the question on numbers of bird surveys conducted was imprecisely phrased, so we were unable to fully use that information.

RESULTS

The hearing thresholds for six different age classes are shown in Figure 1. The decline in hearing ability with age, especially at higher frequencies, is clearly shown. The frequency distribution of hearing thresholds for these same individuals without regard to age class is shown in Figure 2. Mayfield (1966) considered a hearing loss of 0–15 dB insignificant; 15–30 dB, slight; 30–45 dB, mild; 45–60 dB, marked; 60–80 dB, severe; and 80 dB, extreme. Below 2 kHz, more than 90% of all individuals tested have a hearing threshold of 20 dB or less. Emlen and DeJong (1981) have suggested 20 dB as deficient hearing ability for counting birds.

As we mentioned, the question on number of bird surveys conducted was stated in such a way that several of the 274 participants reported conducting 300 or more bird surveys in the previous year. This indicates that the respondents misunderstood the question, but we still consider it an indicator of trouble that two-thirds of the surveys reported were conducted by observers with hearing thresholds of 20 dB or greater. The loss of information with reduced area surveyed is shown for one day's field effort using stations (Table 1) and transects (Table 2).

AN EXAMPLE

To appreciate the effect that hearing loss can have on an observer's ability to count birds, consider this simplified example. Assume that a bird is a directional sound source; i.e., the intensity of the sound pressure of its song concentrates in the direction the bird faces, as in Figure 3. The actual variation we use in this model assumes the intensity $I(\theta)$, at an angle of θ from the source direction is

$$(1) \qquad I(\theta) = E \times 10^{-.198\theta^2}/C, \quad -\pi < \theta < \pi,$$

$$\text{where } C = \int_{-\pi}^{\pi} 10^{-.198\theta^2}\, d\theta, \text{ and}$$

where E is the total energy in the sound wave. We assume further that this total energy ($E = 1.24 \times 10^{-10}$ watts) would provide an average intensity of 50 dB within a one meter cylinder surrounding the bird.

A general equation describing sound attenuation with distance is (Urick, Ch. 2 and 4)

$$(2) \quad N(x) = N(1) - 10 \log_{10}(x^s) - ax - bx.$$

Here N(x) is the number of dB at a distance of x meters from the bird. The number s is a spreading factor, and the term in which it occurs describes the spreading of the total energy over increasingly large areas as distance increases. With spherical spreading, $s = 2$; whereas $s = 1$ with cylindrical spreading, as might occur in a closed canopy situation. In practice, the spreading factor would be somewhere between 1 and 2, and we arbitrarily assumed it to be $s = 1.5$ for this example. With this choice, each doubling of distance results in a loss of 4.5 dB sound pressure. Martin and Marler (1977) arrived at a loss figure of 6 dB with each doubling of distance, which is a figure also used by Bowman (1979). The 6 dB figure corresponds to $s = 1.99$,

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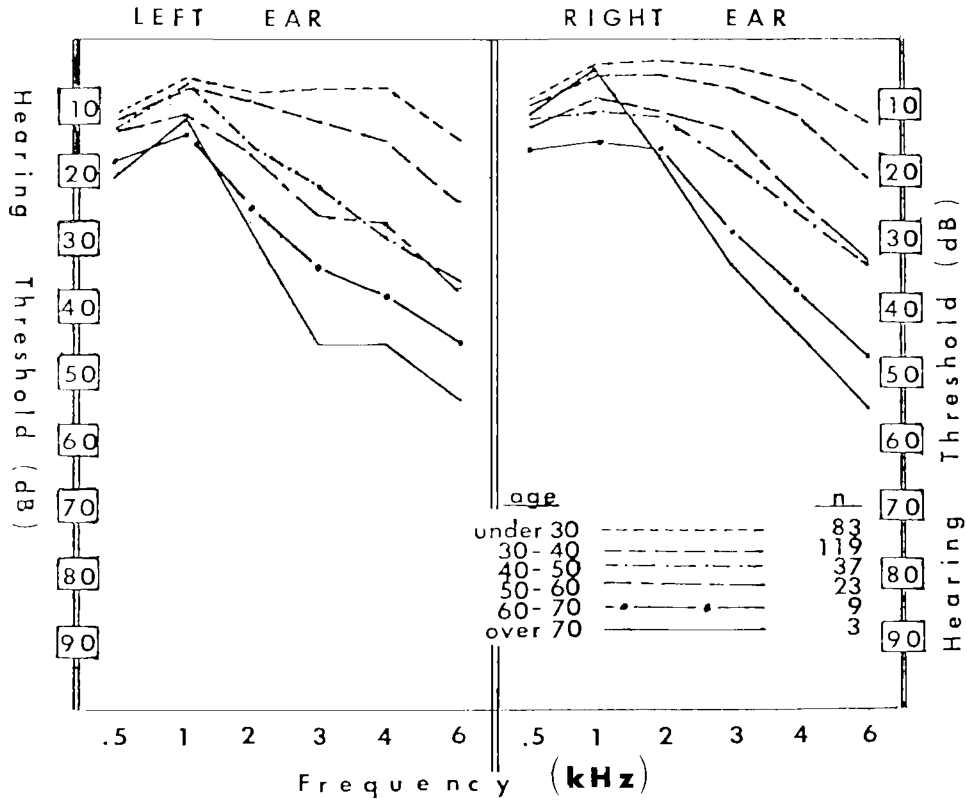

FIGURE 1. Age profiles of average hearing thresholds over the frequency range 0.5 to 6.0 kHz.

or virtually spherical spreading. Thus using s = 1.5 produces a model which is optimistic in that sound carries farther and hearing loss has less effect than it might have in practice. The final two terms in equation (2) describe absorption of energy by the medium and by vegetation, respectively. The constants a and b increase as the square of the frequency of the bird's song. However for the sake of generality we have made the model independent of frequency by taking a = b = 0.

With intensity spread as in equation (1), the actual sound intensity reaching the observer depends on the angle θ of the bird's orientation with respect to the bird-observer line. Taking this into account, we arrive at this simplified condition for song detection:

$$N(x) = 50 + 10 \log_{10}C - 1.98\theta^2 - 15 \log_{10}x \geq DT, \quad (3)$$

where DT is the observer's dB detection threshold, such as that measured on the standard hear-

TABLE 1
NUMBER OF BIRDS DETECTED WITH VARYING DENSITIES AND VARYING AREAS SURVEYED USING 15 CIRCULAR PLOTS AND ASSUMING PERFECT DETECTABILITY WITHIN EACH PLOT

Radius of area surveyed (m)	Area (km^2)	Density (birds/km^2)						
		25[a]	50	100	200	400	800	1600
5	.001	0.3	0.6	.1	.2	.5	1	2
10	.005	.1	.2	.5	1	2	3	6
20	.019	.5	1	2	4	8	15	30
40	.075	2	4	8	15	30	60	120
80	.302	8	15	30	60	120	241	483
160	1.210	30	60	120	241	483	965	1930

[a] Numbers are rounded to nearest tenth below 1 and to the nearest whole number above 1.

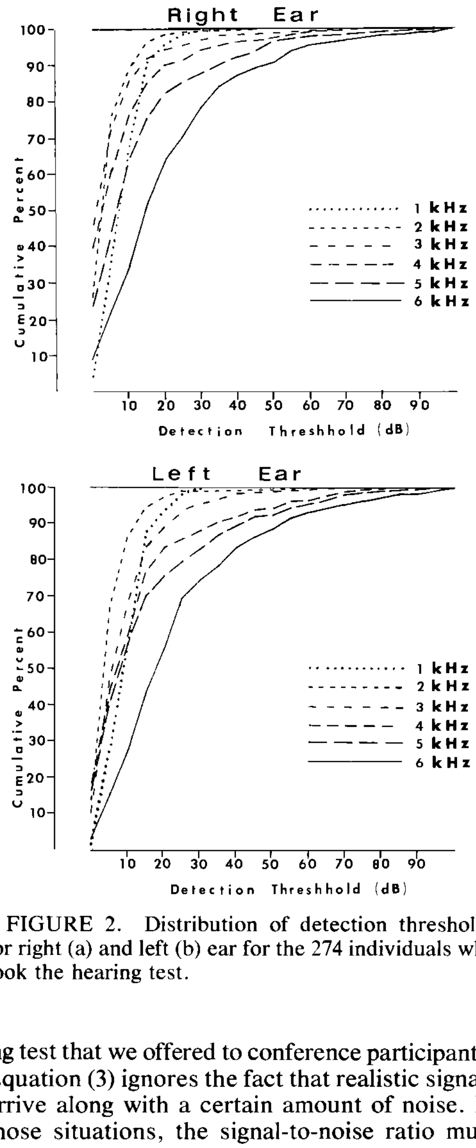

FIGURE 2. Distribution of detection thresholds for right (a) and left (b) ear for the 274 individuals who took the hearing test.

ing test that we offered to conference participants. Equation (3) ignores the fact that realistic signals arrive along with a certain amount of noise. In those situations, the signal-to-noise ratio must be greater than the observer's DT for that observer to make a detection. Thus, equation (3) represents an ideal situation with no noise.

Finally, we assume that the orientation angle θ has a uniform probability distribution on the angles $(-\pi, \pi)$. The resulting situation is this: letting

$$(4) \quad \psi(x, DT) = (1/\pi)\sqrt{28.69 - 7.58 \log_{10} x - DT/1.98},$$

then the probability of an observer with detection threshold DT being able to detect this bird at a distance of x meters is

$$(5) \quad \Pr\{\text{Detection} \mid x\} = \begin{cases} 0; & \text{if } \psi(x, DT) \leq 0 \\ \psi(x, DT); & \text{if } 0 < \psi(x, DT) \leq 1 \\ 1; & \text{if } \psi(x, DT) > 1 \end{cases}$$

Several of these song detection curves are plotted in Figure 4, using observer detection thresholds of 10, 20, 30, and 40 dB. An observer with DT $\geq$ 50 dB will be virtually deaf to this bird and must rely exclusively on visual detections during a survey.

DISCUSSION

The numbers of birds recorded by an observer in a survey are proportional to the effective area surveyed by the observer (Tables 1 and 2) (Ramsey et al. In press). We cannot use the results of the previous example to judge effective area surveyed without making further assumptions about the bird's song rate, the duration of the survey's count periods, the density of vegetation, background noise levels, and the form of the observer's visual detectability curves. However, it is reasonable to conclude from Figure 4 that hearing differences can result in differences as large as an order of magnitude in areas effectively surveyed. (In a hypothetical line transect survey where each bird sings once as the observer passes, the observer's effective area sur-

TABLE 2
NUMBER OF BIRDS DETECTED WITH VARYING DENSITIES AND VARYING WIDTHS ALONG A 1 KM TRANSECT

Area surveyed		Density (birds/km²)						
Area (km^2)	Width (m)	25[a]	50	100	200	400	800	1600
.01	5	.3	.5	1	2	4	8	16
.02	10	.5	1	2	4	8	16	32
.04	20	1	2	4	8	16	32	64
.08	40	2	4	8	16	32	64	128
.16	80	4	8	16	32	64	128	256
.32	160	8	16	32	64	128	256	512

[a] Numbers are rounded to nearest tenth below 1 and to the nearest whole number above 1.

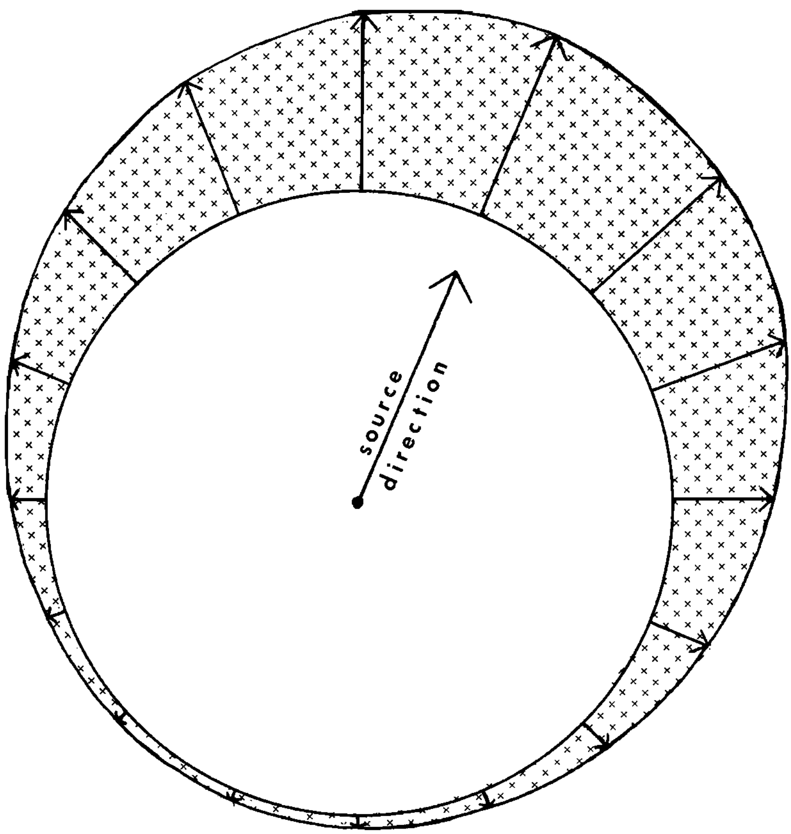

FIGURE 3. Idealized representation of sound transmission from a directional source.

veyed is the area under their detectability curve in the figure.) Surveys of terrestrial passerines typically record high percentages of audio only detections (Kepler and Scott 1981), thus differences in hearing ability will be reflected directly in the total number of detections.

The use of fixed area counts or simple counts may result in biased results when two observers of differing hearing ability are used. Hearing attenuation is not the same for all frequencies and is greater at higher frequencies. Thus with greater detection thresholds at higher frequencies, the high frequency emitters will be undersampled relative to low frequency emitters. This phenomenon could be very important and should be looked for. The use of variable area survey techniques such as the line transect or variable circular plot theoretically adjusts raw counts so that two observers with different hearing can still produce unbiased density estimates. However, the precision of the observer with the larger area is greater. Additionally, the numbers of species should increase as the hearing threshold decreases and the area surveyed increases.

SOLUTIONS

There is a tendency for observers as they grow older to become deficient in the higher frequencies first. Examination of the audiospectograms in Robbins et al. (1966) for the species listed by O'Meara et al. (1981) indicate that they have sounds ranging across at least 2 kHz and those with higher songs in the higher frequencies may range from 1 to above 6 kHz, e.g., white-eyed vireo (*Vireo griseus*). Thus, as observers lose their ability to perceive the higher frequencies, they may still be able to hear the lower pitched song portions. Their ability to identify these songs depends more on their field experience and the portion of the song which is discernable to them. Thus, field experience is an important variable to consider when evaluating (potential) observers. Also, differential attenuation of the high frequencies (Morton 1975) by the environment may make them relatively unimportant to all observers in detection and identification of distant songs. The noise level in some field situations may be sufficiently high to

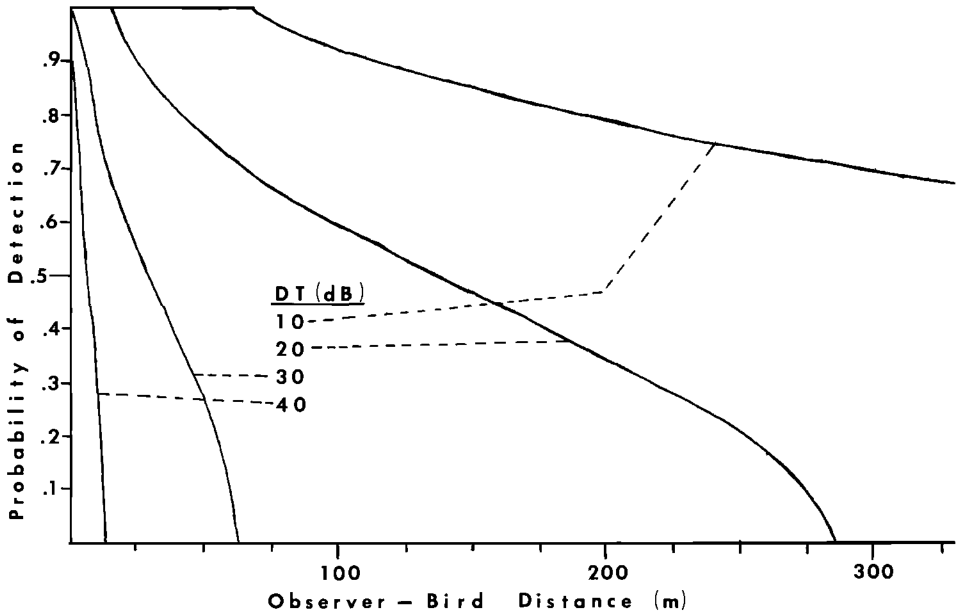

FIGURE 4. Detection curves for observer detection thresholds of 10, 20, 30, and 40 dB. Intensity of sound was 50 dB 1 m from the source.

mask songs until it is well above the thresholds of most observers. These effects combined with the long experience of older observers may act to reduce the disadvantage of hearing losses in the higher frequencies for at least some species.

One of the individuals we tested had his hearing threshold decrease by 20–30 dB when tested with a hearing aid. This suggests that one possible way for standardizing experienced observers with hearing problems would be to have them wear hearing aids which had been individually calibrated for a hearing threshold of say 10 dB within the frequencies emitted by the birds being counted.

In order to achieve the greatest possible coverage of an area at the lowest possible cost and increase the comparability and accuracy of observers, we recommend testing all potential observers for hearing ability using pure tone tests from .5 to 8 kHz (Kepler and Scott 1981). Observers who have hearing thresholds of 20 dB or greater in the frequencies emitted by the species of interest should be eliminated from the program (Emlen and DeJong 1981) or have their hearing corrected to 10 dB. All observers should then be tested for their ability to correctly identify species using simultaneous counts (Kepler and Scott 1981) and randomly presented sequences of song and calls at low sound levels (Cyr 1981; D. Richards, Pers. Comm.). Intensive field and laboratory training should then be used to correct any deficiencies (Kepler and Scott 1981).

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