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INTRODUCTION

A variety of auditory stimuli have been used for many years as a means of repelling nuisance birds from problem areas (Boudreau, 1968; Bremond et al., 1968; Frings and Jumber, 1954; Langowski et al., 1969; Nelson and Seubert 1966; Pearson and Corner, 1967; Thompson et al., 1966, 1968a, b). This approach to alleviating bird problems is appealing because wild birds are considered very sensitive to sound stimuli of biological origin, and such stimuli are harmless to both target and nontarget species. The harmless aspect is an important advantage in dealing with wildlife related problems because of the increased public concern about the safety and environmental impact of the use of chemicals to alleviate some types of problems.

The major limitation to the use of auditory stimuli to effectively repel birds is that, regardless of the strength of the communication signal, there is a decrement in physiological and behavioral response with repeated stimulation, resulting in habituation and loss of repellent ability. In addition, the effectiveness of sound stimuli is influenced by environmental and behavioral facts such as light intensity and flock behavior (Thompson et al., 1966, 1968a).

Because of these limiting factors there is a need to compare the fright producing ability of different auditory stimuli to identify the strongest stimuli for field application. To facilitate this, we developed laboratory methodology to compare repellency strength of prerecorded sound stimuli. The methodology is illustrated in the present starling study by measuring (1) heart rate (HR) as a second order function of telemetered electrocardiogram (ECG), and (2) keypecking rate (KPR) as an operant response in a switchback experimental design for four treatments. The switchback design was used to minimize error due to between-bird-variation in slope of the habituation curve and also to reduce the number of birds required for sensitive comparisons of stimuli.

METHODS

The four treatments (auditory stimuli) tested in experiment are:

1. Denver Wildlife Research Center standard starling distress call. (Pearson and Corner, 1967)
2. Synthesized sound designed to repel birds. Sound device produced by AV-alarm Corporation, Santa Clara, California.
3. Starling alarm sound recorded by Dr. Werner Keil, Frankfurt, Germany.
4. Starling distress sound recorded by Mr. Gordon Boudreau, Hollister, California.

These were compared using 24 adult starlings in a switchback design as outlined by Lucas (1956). Each treatment was replicated once (Table 1). Treatments were randomly allotted to the numbers shown in the pattern and birds were randomly assigned to treatment sequence within blocks. Training and testing of birds was conducted by blocks. Daily weight, food consumption, and keypeck responses were recorded on each bird. We trained birds to keypeck for food reinforcement (mealworms) in a behavior chamber using standard operant behavior procedures (Ferster and Skinner, 1957). After birds learned to associate keypecking with food reinforcement, they were trained to keypeck at a near constant rate by using a series of variable-interval schedules (VI), whereby the intervals between reinforcement in each schedule varied in a random order. The initial VI schedule averaged 20 seconds between reinforcements, and the final averaged 56 seconds.

Performance of each bird was observed by closed circuit television, and keypecks were counted and printed in minute intervals by an automatic counter. After birds established a stable baseline KPR on a VI 56 schedule, each was instrumented with sensors and a 5-gm FM radio transmitter to continuously telemeter ECG and record HR with a physiological recording system as previously described (Thompson et al., 1966, 1968a,b). After birds adjusted to the transmitter and sensors, as evidenced by a stable KPR on a VI 56 schedule, they were considered ready for testing. Baseline HR and KPR were recorded for about 10 minutes before testing responses to treatment. The instrumentation system was programmed so that the keypeck coinciding with the sixth food reinforcement activated a tape cartridge handler and amplifier to deliver 10 seconds of the assigned sound stimulus at 85 decibels through an audio speaker in the bahavior chamber. Heart beats were counted continuouslyand printed at 15-second intervals from stimulus onset. Keypecks were counted continuously and printed at minute intervals from stimulus onset.

The HR response values (D_1) were calculated for each bird by the equation $D=Y_1—2Y_2+ Y_3$ where Y_1, Y_2, and Y_3 each represent, on experimental days 1, 2, and 3, the number of heart beats in 1 minute following stimulus onset minus the baseline number of heart beats for the minute before stimulus onset. Keypecking suppression (KPS) values (D_2) were also calculated by this equation where Y_1, Y_2, and Y_3 each represent the percentage KPS, which was obtained by dividing the number of keypecks in the 1 minute poststimulus by the number of keypecks in the 1 minute prestimulus.

Differences in HR and KPS responses due to treatements were analyzed as described by Lucas (1956).

RESULTS AND DISCUSSION

The use of radiotelemetry and keypecking for food reinforcement facilitated measurement of physiological and behavioral responses to sound stimuli without restraining or disturbing the birds. To our knowledge, this is the first report where both responses have been simultaneously used to measure response to stress-inducing stimuli.

The audiospectrogram of each sound stimulus is shown in Figure 1. We did not analyze the frequency characteristics of any stimulus. However, each had a different audiospectrogram and sounded distinctively different to the human ear.

Figure 2 shows the mean HR response above baseline following onset of each stimulus. The response pattern was similar to that from our previous studies (Pearson and Corner, 1967; Thompson et al., 1966, 1968a, b); HR increased from prestimulus level to peak level within 3 seconds following stimulus onset. The mean prestimulus HR (beats/min) was 344 ± 56 (SD) for all birds in the study. HR response above treatment baseline to stimulus, 1, 2, 3, and 4, averaged 77.7, 9.4, 73.7, and 63.6, respectively. Analysis of variance revealed significant differences ($P<0.05$) among HR responses to stimuli. Duncan's multiple range test (1951) showed that stimulus 1, 3, and 4 produced a significantly greater response ($P<0.05$) than stimulus 2, but were not different from each other.

Prestimulus KPR averaged 34± 16(SD). With onset of each stimulus, KPR was suppressed and is expressed as percent KPS (Figure 3). Analysis by T-test revealed that each stimulus significantly suppressed ($P<0.01$) prestimulus KPR, but the analysis of variance test showed none of the KPS values was significantly different from any other ($P>0.05$).

The HR response to stimulus 1 is in agreement with previous observations, demonstrating that it is a strong fright-producing agent for starlings (Thompson et al., 1966, 1968a, b) and is an effective repellent in the field (Nelson and Suebert, 1966; Pearson and Corner, 1967). In contrast, the response to stimulus 2 was slight and, in fact, almost in the category of a neutral stimulus. Stimuli 3 and 4 obviously transmitted response information similar to stimulus 1 even though they sounded different and had different audiospectrograms. These results suggest that sound stimuli of biological origin have more potential as bird repellents than synthesized sound stimuli.

The results confirm previous reports (Odum, 1941; Thompson et al., 1966, 1968a, b) showing that HR is an instantaneous and sensitive indicator of physiological condition, and demonstrate that the probable repellency strength of sound stimuli can be assessed in a laboratory environment by telemetering HR response. On the other hand, keypecking behavior appears not to be sensitive enough to rank repellency strength of sound stimuli. However, keypecking behavior appears to be an excellent laboratory technique to minimize non-treatment disturbances on animals and to control time and dosage of chemicals in bioassay studies.

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DISCUSSION

Q: Do you anticipate cardiac measures being of any use in the field assessments?

A: Yes, I think it would be of value. Our problem Is coming up with a transmitter small enough to use for that type of experiment. This type of transmitter that we're working with now is limited to something like 100 feet or so. We do plan to do some work in developing miniaturized transmitters. Perhaps there are some that are available, but we haven't found one that we've been able to use for field studies yet. There is a real need, and I think work in this area is real deserving.

Moderator: One possibility might be to cage your experimental birds, leaving them in the wild, having other birds come around, and then put some sort of a stimulus in to see whether your caged bird gives any type of cue as to how It Is responding.

TABLE 1. Experimental design treatment pattern for one replication of 12 birds.

Experimental day	Block 1 Treatment Sequence	Block2 Treatment Sequence	Block3 Treatment Sequence
1	1 2 3 4	1 2 3 4	1 2 3 4
2	2 3 4 1	3 4 1 2	4 1 2 3
3	1 2 3 4	1 2 3 4	1 2 3 4

Consecutive days. For example, starting with Block 1, the first bird received treatment 1 on day 1, treatment 2 on day 2, and treatment 1 again on day 3.

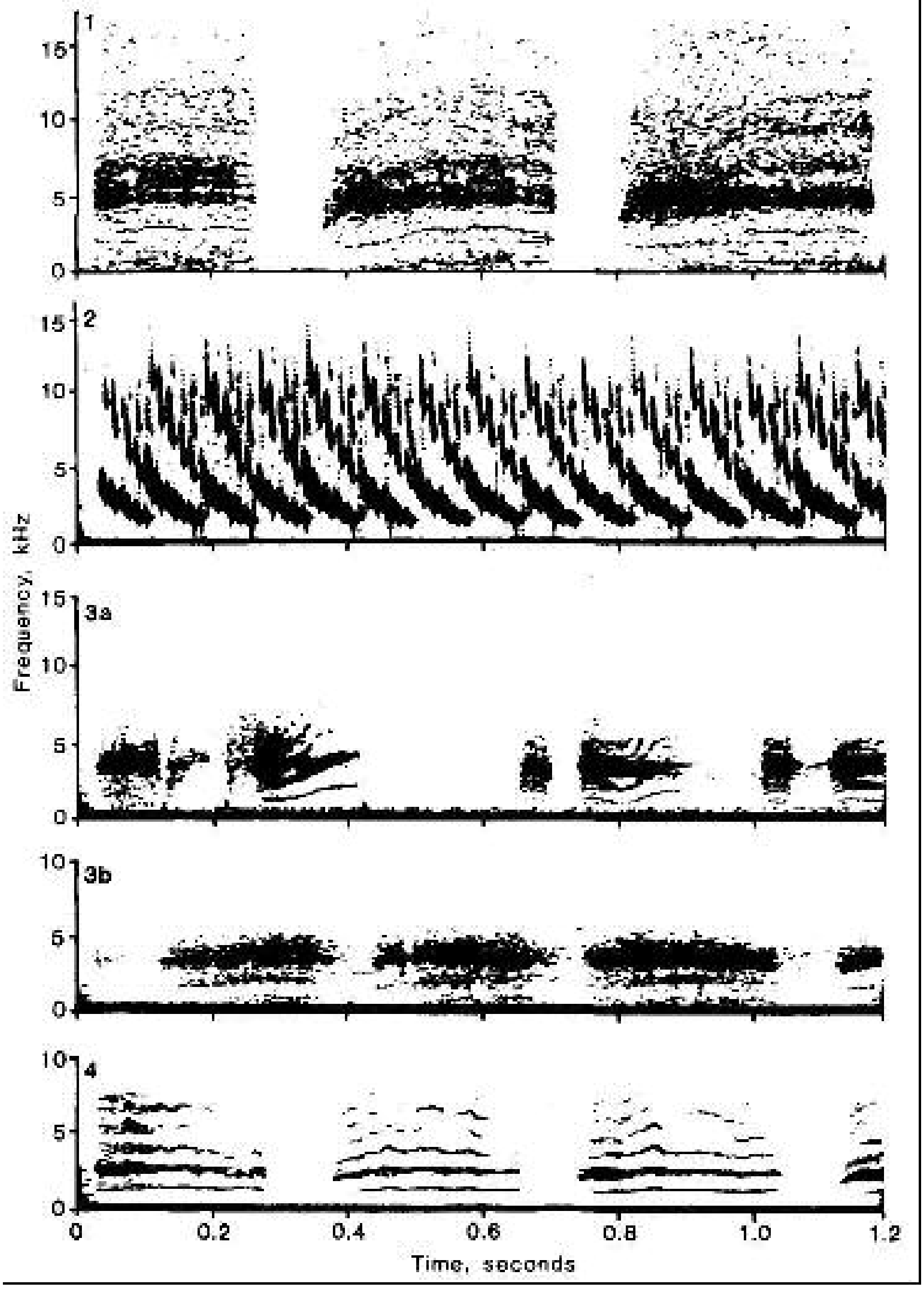

FIGURE 1. Audiospectrogram of sound stimuli:

(1) Denver Wildlife Research Center standard starling distress call;

(2) synthesized sound, AV-alarm Corporation;

(3a) starling alarm sound, Kell, high vocalizations In call;

(3b) low vocalizations In call;

(4) starling distress sound, Boudreau.

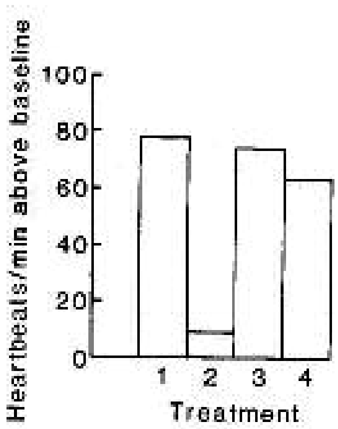

FIGURE 2. Mean heartbeats/minute above baseline for each sound stimulus. Total response time represented is 1 minute.

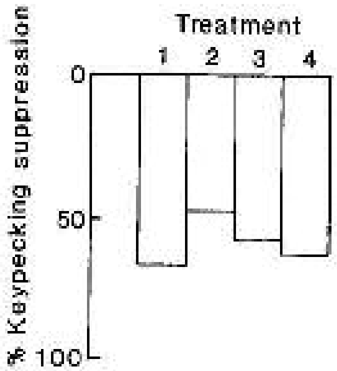

FIGURE 3. Percent keypecking suppression for each sound stimulus. Total response time represented is 1 minute.