ACOUSTICAL DETECTION AND ESTIMATION OF *RHYZOPERTHA DOMINICA* (F.) LARVAL POPULATIONS IN STORED WHEAT

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ABSTRACT

The possibility of using insect-produced sounds to estimate insect populations without removing grain samples was investigated. The number of insect-produced sounds, heard with a piezoelectric microphone pushed into the grain, increased as the number of lesser grain borer, *Rhyzopertha dominica* (F.), larvae increased. The probabilities of detection and the accuracy of estimation of insect densities with the acoustical method were comparable to those obtained with a standard grain trier.

RESUMEN

Se investigó la posibilidad de usar sonidos producido por insectos para estimar las poblaciones de insecto sin tener que remover muestras de granos. El número de sonidos producido por insectos, oidos con un micrófono piezoeléctrico empujado dentro del grano, aumentó a medida que el número de larvas de *Rhyzopertha dominica* (F.), aumentó. Las probabilidades de detección y la exactitud del estimado de la densidad de insectos con el método acústico fue comparable a aquellos obtenidos en un probador patrón de grano.

Nondestructive methods of detecting insects feeding inside kernels of grain during storage include x-ray of insects within the grain (Milner et al. 1950), and measurement of insect-produced carbon dioxide (Bruce et al. 1982) or sounds (Vick et al. 1988). The initial cost of the x-ray machine and the ongoing cost of the x-ray film and chemicals to develop the x-ray film are high and examination of each of the individual grains on the x-ray film for insects is labor intensive. While the cost and labor might be lower for carbon dioxide and acoustical methods than for the x-ray method, x-ray has the added advantages of 1) detection of both live and dead insects (although live insects cannot be distinguished from dead insects) and 2) identification of the species and stage of insect detected. However, eggs and small larvae are generally difficult to distinguish from denser portions of the grain. Also, not all carbon dioxide or sound detected in grain are produced by insects. Adams et al. (1953) suggested that the acoustical method might be used to monitor ". . . grain within storage bins for infestation without sampling or removing the grain from the bins in much the same manner as permanent thermocouple systems are now used for checking the heating of grain in storage." This potential for automation of insect monitoring with the acoustical method may be a major advantage over the carbon dioxide and x-ray methods.

We investigated whether the insect-produced sounds, heard with a piezoelectric microphone pushed into grain, can be used to detect insect infestations and to estimate insect densities as efficiently as other methods.

MATERIALS AND METHODS

The acoustical system shown in Figure 1 was used for discovery and estimation of the densities of lesser grain borer, *Rhyzopertha dominica* (F.), larvae detecting the feeding sounds they produce. The system was composed of a durable piezoelectric microphone (#9D0576 BNF Enterprises, Peabody, Mass.) mounted on the end of a probe which was pushed into the grain, a battery operated amplifier (Insecta-scope, Sound Technologies Inc., Kilgore, TX) and earphones for listening to insect-produced sounds. A Krohn-Hite model 3700 filter (not shown in Figure 1) was used between the amplifier and earphones to remove frequencies below 1000 hz and above 3000 hz. Feeding sounds were recorded on a Technics magnetic tape recorder, Model RS-B16, equipped with dBx. Magnetic tape recordings of these sounds were analyzed later with a Fast Fourier Transformation (FFT) instrument (Nicolet Model 660A) and a Hewlett Packard vectra computer to compare earphone with instrument counts. The FFT determined the frequency content of the sounds, whereas instrument counts with the Hewlett Packard Vectra computer coupled through a Hewlett Packard universal counter Model 5316A

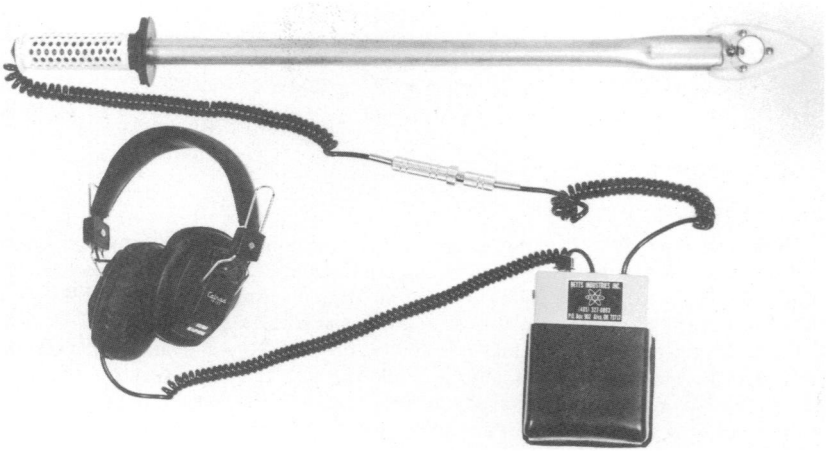

Fig. 1. Acoustical insect detection system including a probe with piezoelectric microphone (Top), battery operated amplifier (Bottom Right), and earphones (Bottom Left).

determined the number of voltage spikes in a predetermined time interval (Webb et al. 1988).

Insect populations of several densities were prepared by diluting lesser grain borer cultures with clean wheat. The actual densities and age structure of the lesser grain borer populations were determined at each density level by x-raying 90 ml samples of wheat. The acoustical system was used 1) to estimate insect densities by counting the number of sounds per unit of time produced by insects at each of nine locations during a one minute interval in a grain mass (10 cm deep by 14 cm diameter) in a four-liter jar or 2) to determine the probability of detection from the fraction of nine locations in a grain mass (10 cm deep by 30 cm diameter) in a 20-liter can at which sounds were heard during 20-s intervals. Both containers were set on 10 cm thick synthetic foam inside a 40 cm diam cylinder of 5 cm thick synthetic foam to dampen background sound. The acoustical probe was inserted 3 cm deep in the grain at the centers and at eight equidistant locations halfway between the centers and edges of the containers. A series of 1:1 dilutions was repeated four times in each size of container.

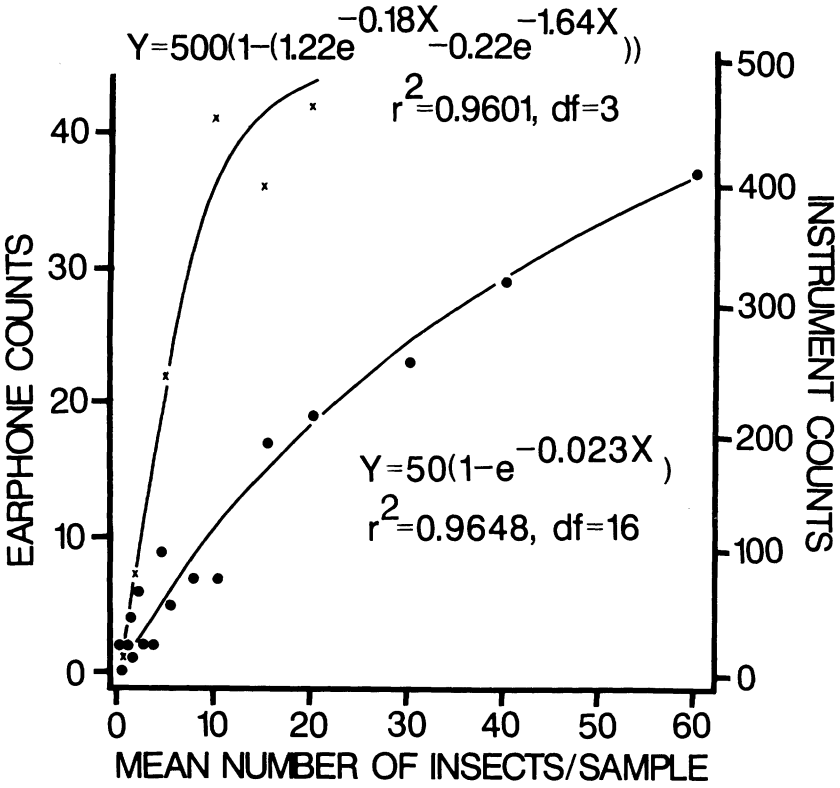

Fig. 2. Relationship between insect density and the number of insect-produced sounds counted with instrument (x) by Vick et al. (1988) or heard in the present study with earphones (.).

Results and Discussion

The number of sounds heard with the piezoelectric microphone pushed into the grain increased as the density of lesser grain borer larvae increased (Fig. 2). This is consistent with the results of Vick et al. (1988) using an acoustical system which required that grain samples be taken. In both studies, the relationship between the number of sounds or voltage spikes counted and the number of lesser grain borer larvae present was not

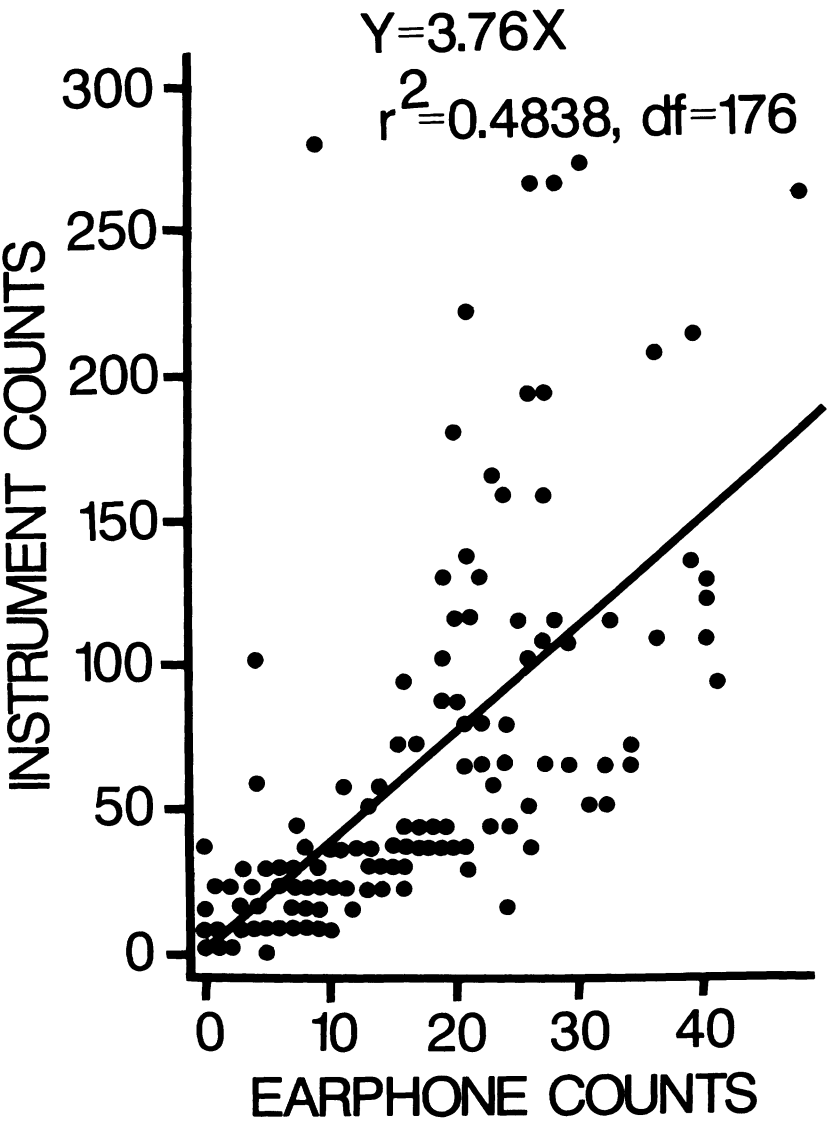

Fig. 3. Relationship between earphone counts of insect-produced sounds and instrument counts of insect-produced sounds in the present study.

linear. The nonlinear increase in insect-produced sounds is probably the results of an increased simultaneous occurrence of sounds of insects which cannot be distinguished as separate sounds.

In the present study, the positive correlation between the number of insect-produced sounds counted with earphones and the number counted with the instrument indicates that our use of earphones instead of instrumentation has not altered the relationship observed between insect sounds and insect density (Fig. 3). The slope of the regression indicates that each insect-produced sound counted with the earphones was actually composed of an average of 3.76 instrument counts. This means that the instrument counts from Vick et al. (1988) must be divided by 3.76 in comparing the two data sets. Even with this adjustment, the counts in this earlier study increased much more rapidly as insect density increased than in the present study. In Vick's earlier study, the number of counts per insect increased rapidly between 0 and 10 insects per 100 ml sample of wheat, but the counts increased more slowly as insect density increased from 10 to 20 insects per sample. Because we are estimating increases in the number of insects by increases in the number of sounds counted, insect densities are estimated

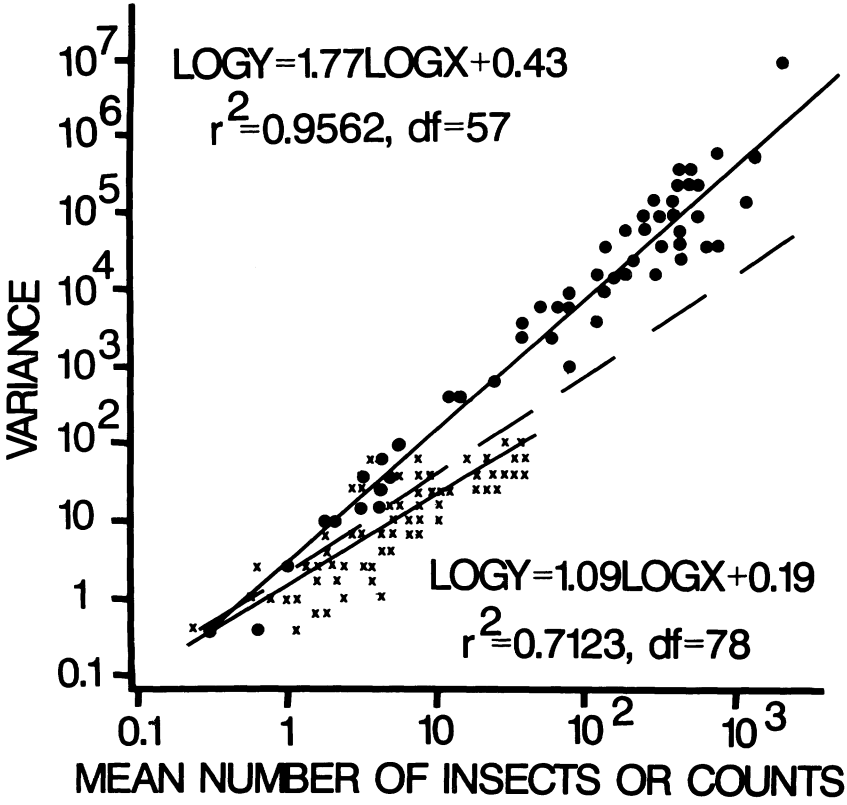

Fig. 4. Regressions of the logarithm of variance in the number of counts or insects (Y) against logarithm of mean (X) number of counts or insects are given for present study (.) and an earlier study (x) by Vick et al (1988). Regression line for other insect sampling methods from Hagstrum et al. (1988) is shown as dashed line for comparison.

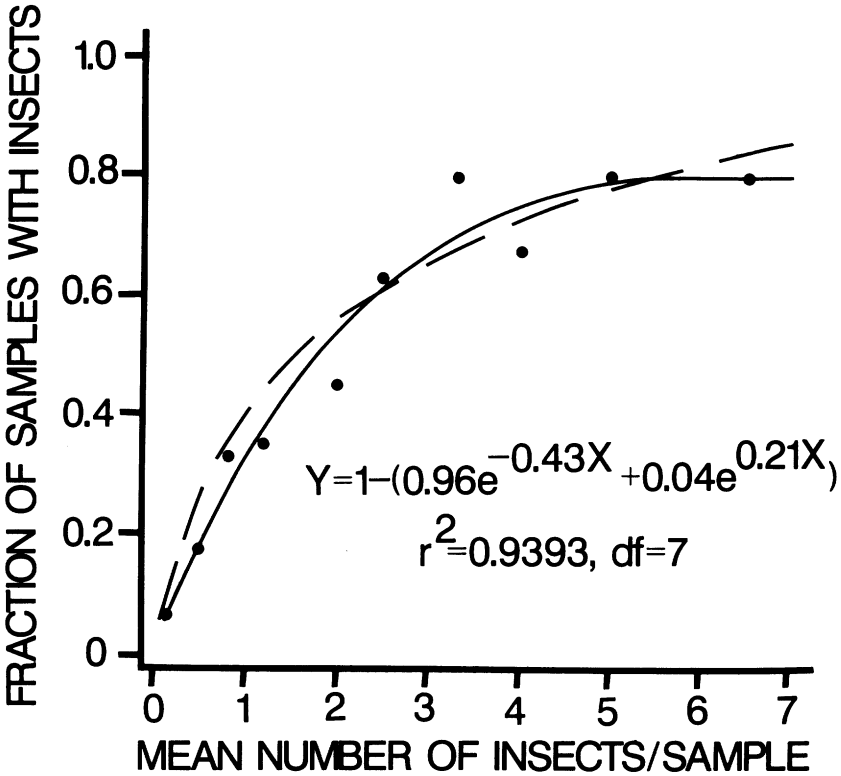

Fig. 5 Regression of the fraction of samples with insects or sounds against mean number of lesser grain borer larvae per sample. The regression line for other sampling methods from Hagstrum et al. (1988) is given as dashed line for comparison.

better between 1 and 10 insects per 100 ml sample of grain than at higher densities. In the present study, over a much broader range of 0 to 60 insects per 100 ml sample of grain, the rate of increase in counts for each increase in insect density was intermediate between rates observed for the 0 to 10 and 10 to 20 density ranges in the earlier study.

The relationship between the mean number of insects or insect-produced sounds per sample and the sample-to-sample variance (Fig. 4) provides a measure of insect distribution and a means of calculating the accuracy of estimation of insect populations (Hagstrum 1987). The relationship between the variance and mean for the acoustical method are very similar to the relationship between variance and mean for other insect sampling methods. Such similarities indicate that the accuracies of the acoustical method will be similar to accuracies for other methods.

We also determined the fraction of samples with insect-produced sounds because this represents the probability of detection. The increase in the fraction of samples with insect-produced sounds as insect density increased is described by the double logarithm model (Fig 5). The similarity of relationship between probability of detection and insect density for acoustical method to that for other insect sampling methods is also shown. Because it is simpler to record the number of locations at which insect-produced sounds are are heard (presence or absence sampling) than to count the number of insect-produced sounds at each location, these curves may also be useful in estimating insect densities from the fraction of sample locations with insects.

These studies suggest that with further development the acoustical method might provide a quick and easy way of detecting and perhaps even estimating insect populations in stored grain. In our laboratory studies, the probability of detection and accuracy of estimation with an acoustical method appear to be quite similar to those for other methods.

END NOTE

Mention of a commercial or proptietary product in this paper does not constitute endorsement by the USDA.

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ACOUSTIC STUDIES OF *DENDROCTONUS* BARK BEETLES

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ABSTRACT

The utility of recording, monitoring, and manipulating acoustic signals of destructive bark beetles and some methods of bioassay and analysis related to pheromone research are discussed. J. A. Rudinsky and his research group at Oregon State University utilized particular chirps of males and females to acoustically stimulate pheromone release, for bioassays of odors as possible pheromones, and as indicators of the behavior of beetles hidden under the bark. A summary of the acoustic signals of five species of *Dendroctonus*, *D. pseudotsugae*, *D. ponderosae*, *D. brevicomis*, *D. valens*, and *D. frontalis*, is presented.

RESUMEN

Se discuten la utilidad de grabar, chequear, y manipular las señales acústicas de escarabajos destructores de cortezas y algunos métodos de bio-ensayos y análisis re-