Acoustical Monitoring of *Rhyzopertha dominica* (Coleoptera: Bostrichidae) Populations in Stored Wheat

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ABSTRACT Acoustical sensors provided estimates of *Rhyzopertha dominica* (F.) population increases at 27 and 32°C that were comparable with estimates obtained from counts of adults in grain samples. At both temperatures, the number of insect sounds increased in proportion to insect density and averaged twice the number of adult insects. Between 7 and 70 d after eclosion, the number of adult insect sounds did not differ significantly with age. At 22 and 27°C, adults produced >37 times the number of sounds produced by larvae at 27°C. Thus, even though larvae were more numerous than adults, they probably did not contribute many of the sounds heard when adults were present.

KEY WORDS Insecta, stored products, temperature, sampling

ACOUSTICAL SENSORS that automatically alert us to the need for insect control can improve pest management by reducing the chances of an infestation being undetected. Although the feasibility of acoustical detection of insects was demonstrated some time ago (Adams et al. 1953), only recently has acoustical detection of insects in stored grain been studied quantitatively. Vick et al. (1988) showed that, in grain samples, larvae of lesser grain borer (*Rhyzopertha dominica* (F.)), rice weevil (*Sitophilus oryzae* (L.)), and Angoumois grain moth (*Sitotroga cerealella* (Oliver)) produced feeding sounds 61–90% of the 7-d period during which their sounds were recorded. Larvae were detected from 13 to 19 d after oviposition until pupation. Infestation rates in the range of 1–20 infested kernels/100 ml of wheat, corn, or rice were strongly correlated with the number of sounds counted by a frequency counter. Hagstrum et al. (1988) demonstrated that sounds of *R. dominica* larvae can be used to estimate larval population densities without removing grain samples. They found that the probabilities of detection and accuracies of density estimation of larvae with an acoustical sensor were comparable to those obtained by the standard method of counting the number of adults in grain samples.

Here, we demonstrate that acoustical sensors can provide density estimates of growing *R. dominica* populations without removal of grain samples, and that these estimates are comparable to estimates made by counting the number of adults in grain samples. We also examined the effects of temperature, adult age, and population age structure upon estimates made with an acoustical sensor.

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

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Materials and Methods

Populations of *R. dominica* were monitored in six steel drums (0.86 m high, 0.58 m diameter). Each drum contained 160 kg of hard red winter wheat (10% moisture content) and was infested with five male and five female adults. Three were monitored weekly for 21 wk at 27°C and three were monitored for 12–14 wk at 32°C with an acoustical sensor and by counting the numbers of adults in grain samples taken with a grain trier.

The acoustical detection system (Hagstrum et al. 1988) consisted of a piezoelectric sensor mounted on the end of a probe which was pushed into the grain, a battery-operated amplifier, and earphones for listening to insect sounds. The numbers of sounds heard during a 20-s interval at each of nine locations 15, 30, 45, and 60 cm below the grain surface were counted and recorded. For each of the nine locations, the counts for the four depths were summed to give estimates that were more comparable with those obtained with a grain sample. The probe was inserted at two locations near the center and at seven equidistant locations halfway between the center and the edges of the drums.

Trier samples of 350–450 ml, including wheat from the full depth of the drums, were taken from four locations in each drum (two locations in the center and two halfway between the centers and the edges of the drums). The live adults were separated from the wheat with an oblong-hole grain sieve (0.18 by 1.27 cm; Seedburo, Chicago, Ill.) and counted.

The number of insect sounds produced by adults was determined for densities of 2, 5, 10, and 20 adults (1:1 sex ratio)/1.5 kg of wheat (grain mass 10 cm deep, 14 cm diameter) in glass jars at 22 and 27°C. Each glass jar was set in a cylinder (40 cm diameter) of synthetic foam (5 cm thick) to dampen background sound. The number of adult sounds heard 3 cm below the surface of the grain

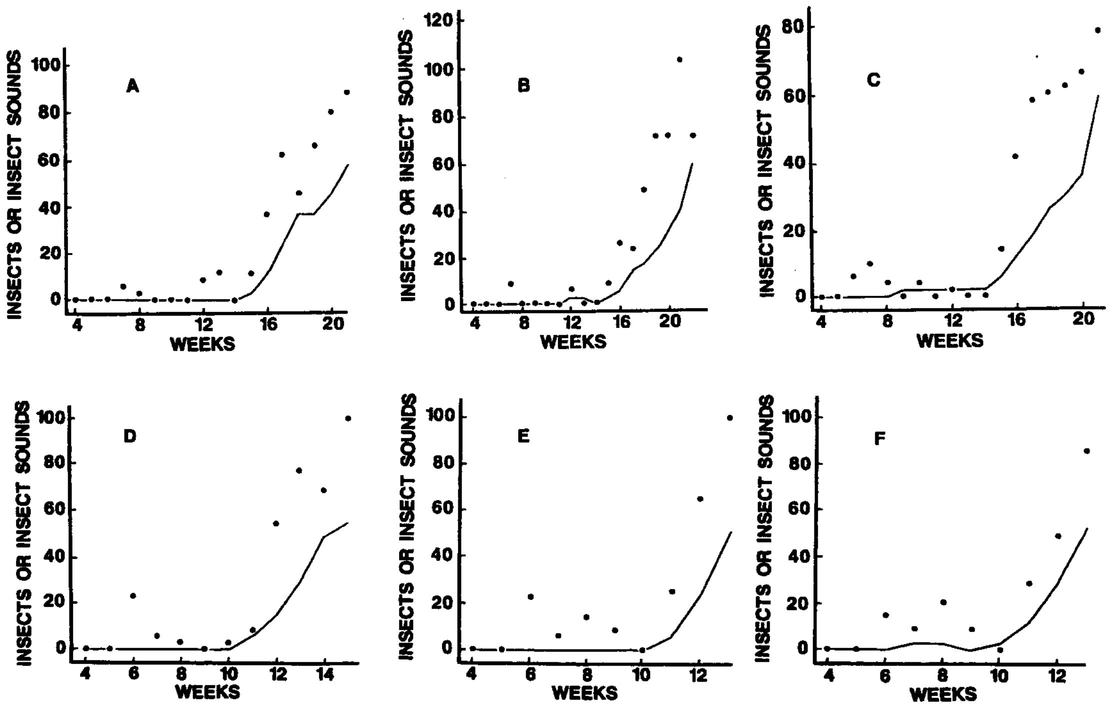

Fig. 1. Comparison of *R. dominica* population estimates in three drums at 27°C (A–C) and in three drums at 32°C (D–F) made with acoustical sensors (•) and by counting the number of adults in wheat samples (——).

was recorded during a 60-s interval as in a previous study on larvae (Hagstrum et al. 1988) so that data for the two stages could be compared. Sounds were recorded at each of nine locations, two near the center and seven equidistant locations halfway between the center and the edge of container. At a density of 10 adults (1:1 sex ratio)/1.5 kg of wheat, the numbers of sounds were recorded in the same manner for 8–15 populations of 7-, 14-, 21-, 42-, and 70-d-old adults.

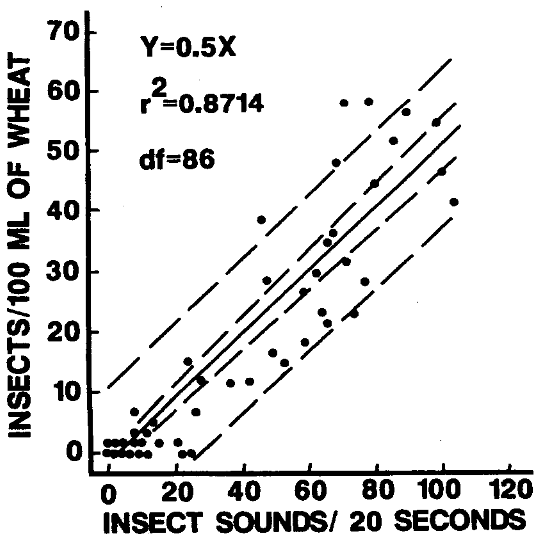

Fig. 2. Prediction of *R. dominica* adult population densities (y) on wheat at 27 and 32°C from the number of insect sounds (x). All four upper and lower 95% prediction and narrower 95% confidence limits are shown as dashed lines.

Population age structure was studied by infesting three 19-kg lots of hard red winter wheat with five male and five female adults per lot. After 6, 8, and 10 wk, four 90-ml samples of wheat were taken from each lot with a grain trier (two samples in the center and two halfway between the center and the edge of the grain mass). Adults were twice separated from each sample with a Seedburo oblong-hole grain sieve (0.18 by 1.27 cm) and counted, once immediately and again after 10 d. Each of these 12 grain samples was spread evenly on an acetate sheet (12.5 by 32.5 cm) and X-rayed immediately and again after 10 d. A General Electric X-ray Grain Inspection Unit (20 kv, 5 ma) and Kodak 36 × 43 cm type M Industrial X-ray Film were used. Exposure time was 1.5 min. The numbers of larvae, pupae, and adults on the two X rays were counted for each sample with a dissecting microscope. Because small larvae were hard to see on X rays, the total number of larvae was calculated using the data from the two X rays taken 10 d apart. The number of larvae equalled the number of larvae on the first X ray plus the difference between the numbers of larvae, pupae, and adults on the two X rays adjusted for the number of adults emerging during the 10-d period.

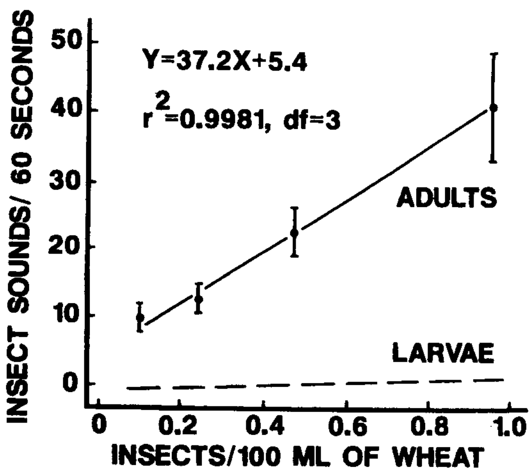

Fig. 3. Comparison of increase with density in the number of sounds produced by *R. dominica* adults and larvae in wheat. The standard errors are given as vertical bars for adults. The data for larval stage are from Hagstrum et al. (1988).

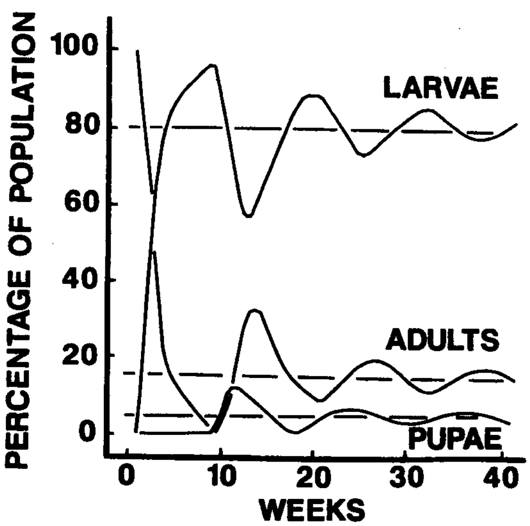

Fig. 4. Changes in the age structure of *R. dominica* populations at 27°C predicted by computer simulation model of Hagstrum & Throne (1989).

Commercial software (SAS Institue 1982) was used to calculate means and standard errors, estimate regressions, calculate prediction or confidence intervals, and plot data. The effect of age and temperature on the relationship between insect numbers and insect sounds was compared using the model comparison procedures of Draper & Smith (1981).

Results

Acoustical sensors provided density estimates of growing *R. dominica* populations at 27 and 32°C comparable to estimates made by counting the number of adults in grain samples (Fig. 1). The regression equation predicting the numbers of insects from the number of insect sounds for data collected at 27°C was not significantly different from the regression equation for data collected at 32°C (F = 0.34; df = 2, 83; P = 0.71). At both temperatures, insect sounds averaged twice the number of insects, and a linear regression equation combining data for both temperatures explained 87% of the variation between estimates (Fig. 2). Although the prediction limits for single samples were wide, the confidence limits for means of several samples were quite narrow.

Acoustical sensors detected adult and larval sounds, and for both stages the number of sounds increased with density (Fig. 3). Comparison of adult and larval sounds indicated that the number of sounds produced by adults was >37 times the number produced by larvae. The increase in the number of sounds with increasing adult density at 22°C was not significantly different from that at 27°C (F = 2.06; df = 2, 6; P = 0.21). Between 7 and 70 d after eclosion, the number of sounds produced did not differ significantly with adult age (F = 0.31; df = 4, 565; P = 0.87).

The contribution of adult and larval stages to the number of sounds heard also depended upon the relative abundance of the two stages. When we omitted the egg stage because of the difficulty of sampling this stage, larvae, pupae, and adults represented means (±SD) of 80.6 ± 19.1, 10.4 ± 18.4, and 9.0 ± 10.2% of the population, respectively. These estimates did not differ significantly among samples taken during the 6th, 8th, and 10th wk of the study for larvae (F = 1.69; df = 2, 34; P = 0.19), pupae (F = 1.64; df = 2, 34; P = 0.21), or adults (F = 0.46; df = 2, 34; P = 0.63). Overall, the 9-fold difference in densities between adult and larval stages was small compared with the 37-fold difference in the number of sounds they produced.

Discussion

In this study, the acoustical sensors provided a reliable method for detection and density estimation of insect populations in grain. However, the background sounds found in commercial grain storage and handling facilities may make detection and density estimation of insect populations using insect sounds less reliable than in the present study. Acoustical sensors permanently installed in grain bins could automatically alert us to the need for insect control. However, because the sounds of different insect species are indistinguishable from one another (Vick et al. 1988), some grain samples will be needed to identify which insect species are present. The sensors would identify the location at which these samples need to be taken.

Density estimates made with acoustical sensors might be expected to be sensitive to variation in insect activity with age of adults and temperature. However, activity of *R. dominica* adults was similar throughout the first 70 d of adult life at 27°C.

This 70-d period represents more than 1½ generations during which a large percentage of lifetime egg production occurs (Birch 1953). Between 22 and 32°C, a temperature range common during much of the grain storage period (Hagstrum 1987), the level of insect activity was apparently the same. This means that density estimates should not need to be adjusted for differences in insect activity within these ranges of temperature and adult age.

The acoustic sensors detect both larval and adult stages, and the sounds of one adult generally equal those of >37 larvae. Examination of population age structure allows further evaluation of the relative contribution of the two stages. A population dynamics computer simulation model (Hagstrum & Throne 1989) can predict changes in population age structure over a 40-wk period at 27°C (Fig. 4). With each additional 6-wk generation, the population age structure moves closer to a stable age distribution at which the larvae are on average 4 times more abundant than adults. In our study, estimates of roughly 9 times more larvae than adults during the 6th, 8th, and 10th wk agree well with predictions of the simulation model. Larvae were not sufficiently more numerous than adults to compensate for adults producing >37 fold more sounds than larvae and probably did not contribute many of the sounds heard when adults were present.

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