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# Interpretation of Trap Catch for Detection and Estimation of Stored-Product Insect Populations

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ABSTRACT: Methods available for interpretation of trap catches of stored-product insects are discussed. Trap efficiency must be determined to convert trap catches into absolute densities. Much of the variation in trap catch may be attributable to variation in trap efficiency in response to environmental factors rather than to actual changes in insect population density. Therefore, regression equations for calculating trap efficiency over a range of environmental conditions may be needed to convert the number of insects caught to absolute densities. Calculating the probability of detection or the accuracy of estimation insures that trap catches are not extrapolated beyond the limits of their resolution. Insect population dynamics models are useful in predicting future insect population densities from trap catches and in relating trap catches to developmental stages not trapped. Interpretation of trap catch must begin with careful planning of a trapping program if these three methods of interpreting trap catch are to be fully utilized to provide correct conclusions in research programs and appropriate decisions in management programs.

Traps exploit insect behavior to detect insect populations with less effort than more absolute sampling methods. However, this exploitation of behavior may result in large variations in trap catch. Much of this variation in trap catch may be attributable to variation in trap efficiency in response to environmental factors rather than to actual changes in population density. Trap efficiency is defined as the portion of total population per unit volume that is captured during a sampling period. We will consider here, methods available for interpretation of trap catches of stored-product insects in research studies or in pest management programs. Trap efficiency can be used to convert the number of insects caught to absolute insect density by dividing trap catch by trap efficiency. The resolution that is possible in the detection or estimation of insect density can be determined by calculating the number of traps needed based on changes in the probability of detection or the accuracy of estimation with insect density (Hagstrum et al., 1988). In some cases, density estimates for the stage captured (adults) can be used to estimate the densities of the other stages (larvae and pupae). This is often important when we are not trapping the stage causing economic losses. These estimates of population density can also be entered into population growth models to predict future changes in insect population densities. Careful planning of a trapping program is the first step to fully utilize these techniques and to better interpret trap catch. Even the best statistical analyses cannot compensate for

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deploying too few traps or not collecting data on environmental factors that affect trap efficiency.

One of the first considerations in planning a trapping program is the estimation of trap efficiency so that the number of insects caught can be converted to absolute density of insects in or around stored commodities or a storage facility. Even detection implies some measure of population density in that lower densities are detected with increases in the number of traps, with longer trapping periods or with environmental conditions more favorable for insect activity. Management decisions based on detection alone assume that the probability of detection is directly related to insect density. Studies of adult stored-product insects have used a wide variety of methods for determining trap efficiency. Hagstrum and Stanley (1979) used the release-recapture method to estimate the percentage of the almond moths, *Ephestia cautella* (Walker), captured by suction traps in a peanut warehouse. Over a broad range of insect densities from just a few to 400,000, six traps recovered an average of 7% of females and 20% of males during the first day after release. With a closely related pyralid moth, the Indianmeal moth, *Plodia interpunctella* (Hubner), at densities of 50 to 75 adults per 89 $m^3$, Mankin et al. (1983) directly observed that 29.7% of males were captured by pheromone-baited sticky traps. However, only 61.7% of males observed approaching the traps were actually captured. In Australia, Sinclair and Haddrell (1985) used a truck trap to show that the densities of the lesser grain borer, *Rhyzopertha dominica* (F.), and the red flour beetle, *Tribolium castaneum* (Herbst), averaged 23 and 29 insects per $mm^3$ of air, respectively, in an area where unbaited sticky traps caught an average of only 0.6 *R. dominica* and 0.7 *T. castaneum* per trap. The truck trap was a fine mesh funnel tapering from 1.5 × 0.6 m at mouth to a 25 cm diameter collecting bag. It is mounted on top of a truck and the volume of air sampled for insects is calculated from the distance the truck is driven. For a warehouse population of *R. dominica*, Leos-Martinez et al. (1986) found a good correlation between the catch per hour for two pheromone-baited Lindgren funnel traps and estimates of the number of adults per 985.6 $m^3$ of air made using a calibrated Johnson-Taylor suction trap. With regression analysis, Leos-Martinez et al. (1986) found that estimated adult densities per volume of air explained 67 and 88% of the variation among pheromone-baited Lindgren funnel traps. In farm-stored wheat, Lippert and Hagstrum (1987) found that the average densities of adult rusty grain beetles, *Cryptolestes ferrugineus* (Stephens), caught in probe traps averaged from 1 to 17 as the average densities of *C. ferrugineus* in a 0.265-kg grain sample increased from 0.2 to 1.8 adults. With regression analysis, Lippert and Hagstrum (1987) found that estimated trap efficiency explained 37% of the variation among probe traps. With a density of 40 adults per 27.2 kg-lots of wheat in the laboratory, Fargo et al. (1989) demonstrated with probe traps that the catch of four species, *R. dominica, T. castaneum, C. ferrugineus* and rice weevil, *Sitophilus oryzae* (L.), varied from 1 to 25% over a 10 to 32°C temperature range. At 23°C, from 1 to 14% of the insects were captured as the duration of trapping increased from 1 to 7 days. White and Loschiavo (1986) also reported differences in the percentage of populations of *T. castaneum* and *C. ferrugineus* captured with probe traps in two temperature ranges. Wright and Mills (1984) reported differences in the percentage of flat grain beetles, *Cryptolestes pusillus* (Schonherr), captured with probe traps in maize, wheat, sorghum and millet.

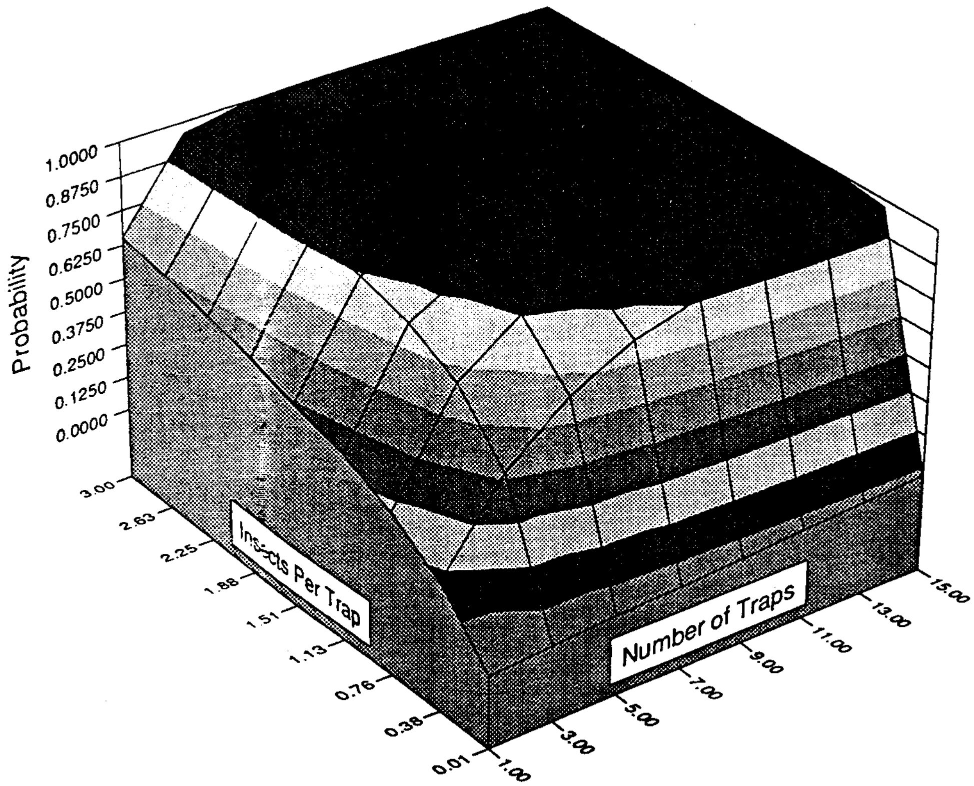


Fig. 1. Variation in the probability of detection with the number of traps and insect density based on equation from Hagstrum et al. 1988.

If we are to routinely use these estimates of trap efficiency to convert trap catches to absolute density in trapping programs, we will need to consider the most important factors influencing trap catch over a broad range of conditions, and possible interactions among these factors, using regression analysis. In an ideal calibration study, multiple regression is used with absolute density as the dependent variable, and trap catch and environmental factors as the independent variables. Only environmental factors that explain a high percentage of the variation should be included in the final regression equation used to convert trap catches to an absolute density.

Another step in planning a trapping program is to calculate the minimum number of traps needed to detect the lowest density of insects that is of interest, or to estimate densities of insects with the desired accuracy. Such calculations are generally based on fewer samples being required for uniformly distributed populations than aggregated populations, because the variation among traps in the number of insects captured decreases as the distribution of the population becomes more uniform. Hagstrum et al. (1988) demonstrated that the distribution of insects among samples was similar for several species of stored-product insects in a number of diverse situations. Thus, the calculated minimum numer of samples would be the same. This similarity suggests that the results of this study may be generally useful in providing an initial estimate of the minimum number of traps needed in a new trapping program. Figure 1 shows the typical increase in the

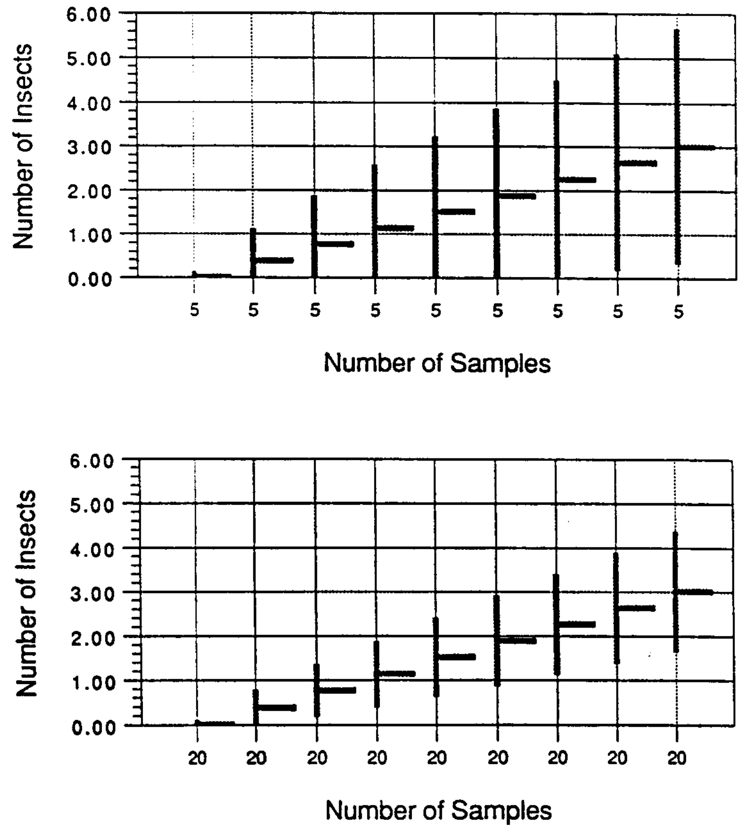


Fig. 2. Variation in the accuracy of estimation with insect density using 5 or 20 traps based on equation from Hagstrum et al. 1988. The mean insect densities are shown as horizontal bars and the vertical bars represent the expected range of estimates with 5 or 20 traps.

probability of detection with increasing numbers of traps and with increasing density of insects present. With one probe trap in the grain for 2 days, the probability of detection increases from close to zero when insect density is 0.01 per 0.5 kg of wheat to greater than 60% when insect density is 3 per 0.5 kg. Similarly, at a density of 0.38 insects per 0.5 kg of wheat, the probability of detection increases from ca. 25% with one trap to ca. 90% with nine traps.

Estimation of absolute population density requires more information about a population than simply determining whether a population has reached or exceeded a detectable level, and thus, requires more traps. Figure 2 illustrates how the accuracy of estimation varies with the number of traps. The range of estimates (vertical bars) remains closer to the actual mean insect density (horizontal bars) with 20 traps than with 5 traps. The less the vertical bars overlap the more likely two means are different. Thus, with 5 traps, we are only 95% confident that a mean of 0.01 insects is significantly different from a mean of 3 insects. However, with 20 traps we are 95% confident that a mean of 0.4 insects is significantly different from a mean of 1.8 insects and a mean of 0.8 insects is significantly different from a mean of 2.8 insects. In addition to using these calculations in planning, such calculations can also help decide whether the insect infestation has really reached a level at which control is needed. The study of Subramanyam and Harein (1990) is an example of the application of these techniques.

Interpretation of trap catch must also be based on an understanding of the population dynamics of pest species. Most management programs are not aimed at eradication, but at maintaining populations below unacceptable levels. Trapping programs not only indicate when current populations have exceeded acceptable levels, but trap catches can also provide the estimates of population density needed for population growth models to predict when populations will exceed acceptable levels (Hagstrum and Throne, 1989) or to predict the consequences of control measures (Flinn and Hagstrum, 1990; Hagstrum and Flinn, 1990). When the developmental stage captured is not the stage causing economic losses, management decisions must be based on predictions from trap catches about present and future densities of another stage. A population model can also be used to predict changes in the age distribution of population and sex ratio of adults over time (Hagstrum et al., 1990). With each generation, the number of lesser grain borer larvae increases and they temporarily become a larger portion of the population. However, once these larvae begin to pupate and emerge as adults, larvae again become a smaller portion of the population. The amplitude of this fluctuation in age distribution decreases each generation and the population approaches a stable age distribution of about four larvae per adult.

Whether we are concerned with the developmental stage captured or another stage, interpretation of trap catch involves relating the number of insects caught to the absolute density of insects in or around the stored commodity or the storage facility. To do this, trap efficiency, and perhaps trap efficiency as a function of environmental factors affecting trap catch, must be known. As with any estimate, the more traps used, the more likely the estimate is to approximate the actual population density. Population growth models are important to the interpretation of trap catch because projected future populations, or populations of other developmental stages, are often more important in making management decisions than current population levels of the stage captured.

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