Comparison of Baited Jug-trap and Spot Cards for Sampling House Fly, *Musca domestica* (Diptera: Muscidae), Populations in Poultry Houses¹

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Environ. Entomol. 14: 815-819 (1985)

ABSTRACT The relationship between known densities of house flies, *Musca domestica* L., and fly-abundance indices obtained with baited jug-traps and white spot cards in a caged-layer poultry house was determined. Baited jug-traps hung from the ceiling and spot cards fastened to feed troughs gave fly-abundance indices most sensitive to changes in house fly density; spot cards fastened flush against the rafters were slightly less sensitive, and spot cards hung vertically from the rafters were least sensitive. With increasing mean daily temperature (range, 22 to 34°C), estimates of fly-abundance density obtained with baited jug-traps, spot cards fastened to the feed trough, and spot cards fastened hanging from the rafters increased, while the estimates obtained with spot cards fastened flush against the rafters decreased. The relationship between fly-abundance indices obtained with baited jug-traps and spot cards (in different locations) was determined by linear regression. Equations are given for calculating the numbers of sampling devices required at different fly-abundance thresholds for obtaining indices with a desired coefficient of variability.

A BAITED JUG-TRAP has been used for sampling house fly (*Musca domestica* L.) populations in poultry houses (Rutz and Axtell 1979, 1981, Rutz 1981). The baited jug-trap consists of a 3.8-liter white translucent plastic milk jug baited with 25 g of commercial fly bait containing muscamone and methomyl (Burg and Axtell 1984). The trap is suspended from the ceiling or rafters, and flies enter the trap through four (5 cm diam) holes cut in the side. The number of flies captured per unit time is used as an index of house fly abundance.

Axtell (1970) used the number of fecal and vomit spots on white paper file cards (8 by 13 cm) (spot cards) fastened flush to the rafters as an index of fly activity (abundance implied). Pickens et al. (1972) and Beck and Turner (1985) suggested that abundance indices obtained with spot cards are not sensitive to changes in house fly density, but used larger (13 by 20 cm) cards hung vertically from the rafters. The spot card's principal advantage is that it is a simple and economical means of obtaining an index of house fly abundance.

Neither the numbers of flies caught per baited jug-trap nor the numbers of spots per card have been related to actual densities of flies in a confined livestock system. Therefore, an experiment was conducted to determine if spot card and baited jug-trap indices are related to actual changes in house fly density and the effect of temperature and location of the spot cards on this relationship. In addition, the relative precision of house fly abundance indices obtained with these sampling methods was compared.

Materials and Methods

The experiment was conducted in a screen-sided (14 mesh) narrow caged-layer poultry house (see Fig. 2 of Burg and Axtell [1984]) divided by cross partitions into three separate sections (4.9 by 3.1 m) (each ca. 38 m²). The sides of the house were 2 m high, and the roof rose to a peak 3 m above the center concrete walkway. On each side of the walkway were two tiers of 10 standard commercial cages containing a total of 80 White Leghorn laying hens. Manure accumulated beneath the cages for 3 weeks before the experiment and for the duration of the experiment (May to October 1983). The screens on the sides of each section were removed and cleaned at ca. 2-week intervals to assure adequate airflow.

The experiment was conducted in six week-long time periods ca. 2 weeks apart during the summer. In each time period six fly densities were used in two groups of three each assigned at random to the screened sections. The fly densities were obtained by weighing out groups of 1,000, 2,500, 4,000, 5,500, 7,000, or 8,500 pupae, holding for adult fly emergence in screened cages with food, and releasing the 2- to 3-day-old flies in the poultry house sections. The number of house flies emerging in each group was calculated from the proportion emerging in an aliquot of 300 pupae. The released flies were reared from a colony of house flies started with wild flies collected in the poultry house the previous summer.

The procedure used in each 1-week period was

Table 1. Results of multiple regressions of house fly density and temperature with indices of house fly abundance obtained with BJT and spot cards (on TSC, FSC, and VSC)

Sampling device	Parameter estimate ^a			r^2 (b_1b_2)	r^2 (b_1)	r^2 (b_2)
	b_0 (intercept)	b_1 (density)	b_2 (temp)			
BJT	0.517 (0.311)	0.0048a (0.0006)	0.0300a (0.0109)	0.68	0.60	0.07
TSC	-0.364 (0.321)	0.0044a (0.0006)	0.0300a (0.0113)	0.64	0.56	0.08
FSC	1.451 (0.241)	0.0028b (0.0005)	-0.0188b (0.0085)	0.54	0.48	0.07
VSC	0.777 (0.153)	0.0021b (0.0003)	0.0140a (0.0054)	0.63	0.54	0.08

^a All nonintercept parameters significantly different from 0 at $P < 0.05$. Numbers in parentheses are standard errors of estimates. Numbers in same column followed by different letters are significantly different at $P < 0.05$. General form of regression is $y = b_0 + b_1x_1 + b_2x_2$ where $y = \log_{10}(\text{mean index})$, $x_1 = \text{flies/m}^3$, $x_2 = \text{mean temp } (^{\circ}\text{C})$.

as follows. On day 1, all wild house flies present in the screened sections of the poultry house were killed by misting with pyrethrins synergized with piperonyl butoxide. On day 3, known numbers of house flies were released into each of the three sections. Jug-traps and spot cards were installed in each section 1 h later and left in position for 24 h, after which the numbers of trapped flies and numbers of spots were counted (day 4). The mean temperature in each section during the sampling period was calculated from temperatures recorded at 3-h intervals in four locations in each section. The house flies left in the section after sampling were killed by misting with synergized pyrethrins. On day 6 house flies at the remaining three densities were released and the sampling and temperature-recording procedures repeated.

The following sampling devices were installed in each section: 1) two baited jug-traps (BJT) hung 1.5 m above the ground at diagonal corners of each section; 2) four spot cards attached by a clip to the outside of the lower feed trough (TSC), two on each side of the center aisle; 3) three spot cards attached flush to the rafters (FSC) 2 m above the floor; and 4) three spot cards hung vertically from the rafters (VSC). The BJT were similar to those used by Burg and Axtell (1984) and Rutz (1981), except we used 2.5-liter white plastic pails (Fisher Scientific, Pittsburgh, Pa.) with three holes (3.5 cm diam) cut in the side. The bait was 25 g of Improved Golden Malrin, containing 1.0% methomyl (*S*-methyl *N*-[methylcarbamoyl] oxy thioacetimidate) and 0.025% (*Z*)-9-tricosene (Zoecon Industries, Dallas, Tex.).

The mean number of flies caught per BJT, and the mean number of spots per card for the TSC, FSC, and VSC were calculated within each section for each density of house flies, transformed to $\log_{10} \bar{x}$ and regressed against house fly density (flies per m^3) and average daily temperature ($^{\circ}\text{C}$). Multivariate multiple regression was used since the same predictor variables were present for each type of response (Johnson and Wichern 1982). The slopes for density and temperature were compared be-

tween each sampling method using linear combinations of the parameter estimates and the MTEST statement of PROC REG of SAS (Ray and Sall 1982).

Sampling Precision. House fly populations were monitored throughout the summer of May to October 1984 in each of three two-story high-rise caged-layer poultry houses in Chatham County, North Carolina (see fig. 3 of Burg and Axtell 1984). The houses were located within 0.5 km of each other and were of a similar design. Each house was ca. 14 by 170 m with the birds housed in the upper story in eight rows of two-tiered cages (three birds per cage) separated by five walkways. The manure accumulated on the ground ca. 4 m below the cages. Six BJT, TSC, and FSC were placed in each house. VSC were not used because they were least sensitive to changes in house fly density in the first experiment. The sampling devices were arranged in groups consisting of one BJT, one TSC, and one FSC within 2 m of each other. The groups were placed at the front, center, and rear of the house along each outer walkway. At 7-day intervals, the number of dead flies per BJT and spots per TSC or FSC were counted and new bait and cards were installed. The mean, sample variance, and coefficient of variability, $\text{SE}/\bar{x}$ (Karandinos 1976) of the counts for each sampling method were calculated on a weekly basis for each house.

Results and Discussion

Fly Density Versus Indices. The results of the multiple regressions of the fly abundance indices against fly density and temperature are shown in Table 1. Plots of the data with the regression equations solved at 22–34 $^{\circ}\text{C}$ are shown in Fig. 1–4. The general form of the regression equation for each monitoring technique is

$$y = b_0 + b_1X_1 + b_2X_2 \quad (1)$$

where $y = \log_{10}(\text{mean index})$, $X_1 = \text{house fly density (flies per } \text{m}^3\text{)}$, $X_2 = \text{average daily temperature } (^{\circ}\text{C})$, $b_0 = \text{the } y \text{ intercept}$, $b_1 = \text{the change in the}$

Fig. 1. Relationship between mean number of flies caught in 24 h in BJT and house fly density (flies per m^3). Circles are observed points, solid lines are regression equation solved at 34, 31, 28, 25, and 22°C (upper to lower line).

Fig. 2. Relationship between mean number of spots per trough card in 24 h and house fly density (flies per m^3). Circles are observed points, solid lines are regression equation solved at 34, 31, 28, 25, and 22°C (upper to lower line).

abundance index per unit change of house fly density, and b_2 = the change in abundance index per unit change of temperature. The slopes for house fly density (b_1) and temperature (b_2) for each monitoring method were all significantly different from 0 ($P < 0.05$).

The slopes with respect to density (b_1) for BJT and TSC were not significantly different from each other ($P > 0.5$) but were significantly higher than b_1 for either the VSC or FSC ($P < 0.01$). Thus, for a given change in house fly abundance, the indices obtained with BJT and TSC changed more than indices obtained with VSC or FSC (i.e., BJT and TSC are more sensitive to changes in house fly density). Beck and Turner (1985) and Pickens et al. (1972) found that large (13 by 20 cm) spot cards hung vertically from the rafters were not sensitive to changes in house fly density. Our results indicated that smaller (8 by 13 cm) spot cards hung vertically were not sensitive to changes in house fly density but were sensitive to density changes when placed flush against the feed troughs or rafters.

House fly density was the most important variable influencing the abundance indices. Density alone accounted for 60% of the variation in number of flies caught per BJT and 56, 48, and 54% of the variation in number of spots per TSC, FSC, and VSC, respectively. Temperature had a significant positive effect on the indices obtained with

BJT, TSC, and FSC. The slopes with respect to temperature (b_2) for these sampling methods were not significantly different from each other ($P > 0.2$), but were significantly higher than b_2 for FSC. The slope for FSC was negative; as temperature increased there was less of a tendency for flies to land and spot on these cards. Temperature accounted for only 7–8% of the variation in indices obtained with any of the methods, so inclusion of temperature in a model does not add greatly to the precision of the model. However, b_2 was large in all cases; therefore, temperature influences the accuracy of the models. To use these sampling methods most accurately to detect changes in house fly abundance, there should be an estimate of mean temperature during the sampling period.

Care must be taken when interpreting relative estimates of abundance. Commonly, the ratio of two indices obtained at different points in time is used to estimate the change in population density during that time period. Different sampling methods may provide different estimates of changes in density even though the samples may have been taken at the same place and time (Anderson and Poorbaugh 1964). Thus, changes in actual density may not be interpreted as such by comparing indices. For example, at 28°C and 50 house flies per m^3 , we would expect 39.5 flies per BJT or 5.0 spots per TSC. At the same temperature, but at 4-fold the density, our equations predict 207.5 flies per

Fig. 3. Relationship between mean number of spots per flush card in 24 h and house fly density (flies per m^3). Circles are observed points, solid lines are regression equation solved at 34, 31, 28, 25, and 22°C (lower to upper line).

Fig. 4. Relationship between mean number of spots per hanging card in 24 h and house fly density (flies per m^3). Circles are observed points, solid lines are regression equation solved at 34, 31, 28, 25, and 22°C (upper to lower line).

BJT and 22.7 spots per TSC. The real change in density was 4-fold, but our indices would have indicated a change of 5.2- and 4.5-fold, respectively. The equations in Table 1 can be used to calibrate indices obtained with different methods, so if the mean daily temperature during a 24-h sampling period is known, the density of house flies during that time period can be approximated by

$$\text{flies per } m^3 = (y - b_2 X_2 - b_0) / b_1 \quad (2)$$

where $y = \log_{10}$ (mean abundance index), b_0 , b_1 , and b_2 are the regression coefficients from Table 1 for a particular sampling method.

Our results are based on 24-h sampling periods. If the sampling interval is longer, estimates may be converted to daily estimates. This requires the assumption that the increase in an index is a linear function of the duration of the sampling interval. This assumption is reasonable for BJT and spot cards if the sampling interval is a week or less. During a longer sampling interval, the bait loses its attractiveness and the cards become soiled and the spots difficult to count. The sampling period should be a multiple of a day to eliminate subtle behavioral effects due to the flies' diurnal cycle.

Sampling Precision. The CV for each sampling method was used in an analysis of variance and their means compared with Duncan's (1955) multiple range test. The mean CV for BJT (0.06) was

significantly lower ($P < 0.01$) than the mean CV for TSC and FSC (0.14 for both), but all three methods had an acceptable level of precision for routine house fly monitoring.

The relationship between the mean and variance of the indices obtained with BJT, TSC, and FSC was determined separately for each method by least squares regression. The model for each sampling device was

$$y = a + bx \quad (3)$$

where $y = \log_{10}(\text{variance of index} + 1)$ and $x = \log_{10}(\text{mean index} + 1)$. The model for the BJT was

$$y = 0.082 + 1.519x, \text{ SE}(b) = 0.1251, \\ r^2 = 0.73, P < 0.01. \quad (4)$$

The model for the TSC was

$$y = -0.141 + 1.607x, \text{ SE}(b) = 0.0511, \\ r^2 = 0.95, P < 0.01. \quad (5)$$

The model for the FSC was

$$y = 0.222 + 1.372x, \text{ SE}(b) = 0.0872, \\ r^2 = 0.83, P < 0.01. \quad (6)$$

Since the r^2 values are high for each model, the mean of an abundance index can be used to estimate its variance. Karandinos (1976, equation 3) provided the following formula for calculating the number of samples required to obtain a fixed level

of precision based on the mean and variance of an index:

$$n = \frac{s^2}{\bar{x}^2 (CV)^2} \quad (7)$$

where n = sample size required to obtain a fixed CV at a given mean and variance. By substituting an arbitrary value for the CV into equation 7, and by estimating the variance of a mean for a particular sampling device using equations 4-6, the number of samples by each method required for a fixed level of precision was calculated. Rutz (1981) suggested that a treatment threshold of 350 house flies per BJT per week be used for routine monitoring. At that density, four traps would be required to obtain an index with a CV of 0.15 and eight traps for a CV of 0.10.

To determine equivalent treatment thresholds for the TSC and FSC, least squares regression was used to estimate the relationship between the number of spots per TSC and flies per BJT. This was

$$y = -1.628 + 1.159x, SE(b) = 0.1255, \\ r^2 = 0.61, P < 0.05 \quad (8)$$

where $y = \log_{10}(\text{mean spots per TSC} + 1)$ and $x = \log_{10}(\text{mean flies per BJT} + 1)$. Solving this with $x = 350$ gives a value of 20 spots per TSC (95% CL = 14.8 - 27.1) as the number of spots per TSC expected at the same house fly density as 350 house flies per BJT. For this treatment threshold, 11 TSC would be required for a CV of 0.15 and 24 for a CV of 0.10.

The relationship between BJT indices and FSC indices was

$$y = -1.356 + 1.150x, SE(b) = 0.1493, \\ r^2 = 0.55, P < 0.05. \quad (9)$$

where $y = \log_{10}(\text{mean spots per FSC} + 1)$ and $x = \log_{10}(\text{mean flies per BJT} + 1)$. Setting $x = 350$, the expected number of spots per FSC at the treatment level is 38.1 (95% CL = 29.2 - 49.5). Applying equation 7, eight FSC would be required to obtain a CV of 0.15 and 17 for a CV of 0.10. If different treatment thresholds or precision levels are required, the variance of this threshold for a particular sampling method can be calculated using equations 4-6 and equation 7 can be used to calculate the required sample size.

In summary, the BJT and TSC provided estimates of house fly abundance that were sensitive to real changes in house fly density. FSC were less satisfactory but could be used when BJT or TSC were not practical. VSC were not satisfactory due to their lower sensitivity to real changes in fly density. All sampling methods were influenced by temperature, so an estimate of average daily temperature should be used to correct this bias. The

number of samples required to obtain estimates of fly abundance with a fixed level of precision at suggested treatment thresholds can be calculated with equations given above. For commonly used treatment thresholds of 350 flies per BJT per week, 20 spots per TSC and 38 spots per FSC per week, 4 BJT, 11 TSC, and 8 FSC are required for a CV of 0.15.

Acknowledgment

This is Paper No. 9769 of the Journal Series of the N.C. Agric. Res. Serv.

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Received for publication 18 March 1985; accepted 8 August 1985.