136

Field Evaluation of Three Methods for Monitoring Populations of House Flies (*Musca domestica*) (Diptera: Muscidae) and Other Filth Flies in Three Types of Poultry Housing Systems

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ABSTRACT Analysis of field data collected over several years in three poultry housing systems (narrow caged-layer houses, high-rise caged-layer houses, and broiler-breeder layer houses) indicated that the baited jug-trap was a reliable method of sampling house flies, *Musca domestica* L.; sticky ribbons provided additional information on two other fly species. Relative frequency of house fly capture indicated that this fly was present in all poultry systems in North Carolina from May to October, while *Fannia canicularis* (L.) and *Ophyra* spp. were present in low numbers after July. Sticky ribbon indices were correlated with baited jug-trap indices for all three fly species in all poultry systems. Spot card indices were correlated with house fly abundance indices, but appeared to be influenced by other fly species in narrow and high-rise caged-layer houses. The relationship between the mean and variance of house fly abundance indices was used to determine the number of samples required to obtain estimates of house fly abundance with a fixed level of precision (CV = 0.10, 0.15, and 0.20) in each poultry housing system.

THREE SPECIES of filth flies are common in poultry production systems. These are the house fly, *Musca domestica* L., the little house fly, *Fannia canicularis* (L.), and "black garbage flies," *Ophyra* spp. (*O. aenescens* [Wiedemann] and *O. leucostoma* [Wiedemann], which are difficult to distinguish). Flies are often abundant and constitute a pest problem in poultry production systems, especially in chicken broiler-breeder layer houses, high-rise caged-layer houses, and narrow caged-layer houses, due to their ability to disperse to neighboring communities (for discussion of fly control and poultry housing, see Rutz [1981] and Axtell [1985]).

The simplest methods for monitoring fly populations in poultry houses are sticky ribbons (Anderson and Poorbaugh 1964), baited jug-traps (Burg and Axtell 1984), and spot cards (Axtell 1970). Based on experiments conducted in an enclosed narrow poultry house where the house fly was the sole species present, Lysyk and Axtell (1985) found that fly catches in baited jug-traps and spot card indices change proportionally with real changes in house fly density, and proposed that these methods be used to monitor house fly populations in poultry houses. Legner et al. (1973) found that sticky ribbon catches of house flies and other species of flies were correlated with the numbers of flies emerging from poultry manure in narrow caged-layer poultry houses in California. Anderson and Poorbaugh (1964) found that sticky ribbons were a favorable method of surveying house fly and little house fly populations in narrow caged-layer poultry houses in California.

This study was undertaken to evaluate these three monitoring methods under field conditions in three types of poultry production systems in North Carolina, particularly to determine 1) the seasonal abundance of the three fly species, 2) if baited jug-traps and sticky ribbons captured flies of each of the three major species in all poultry systems, 3) if spot card indices were related to abundance indices of the three fly species, and 4) the number of samples needed to obtain precise relative estimates of house fly abundance.

Materials and Methods

An extensive data base was developed for simultaneous observations of the performance of sticky ribbons, baited jug-traps, and spot cards for monitoring filth fly populations in three poultry housing systems. Fly populations were sampled weekly for 6 months per year, the period of substantial fly abundance in North Carolina, with sticky ribbons, baited jug-traps, and spot cards in three types of poultry housing systems. Nineteen narrow (California style) caged-layer houses were sampled during a 2-year period, 10 high-rise houses were sampled during a 4-year period, and 12 broiler-breeder layer houses were sampled for 1 year. This data base allowed comparisons of sampling methods under a wide range of conditions. Due to the difficulty in distinguishing between *O. aenescens* and *O. leucostoma*, the black garbage flies were designated *Ophyra* spp.

Narrow Caged-layer Houses. Narrow houses were open-sided structures ca. 70–100 m long by 3 m wide with one row of two-tiered wire cages (two to three birds per cage) running the length of the house on either side of a cement walkway. The cages were suspended 1.5 m above a dirt floor, and manure accumulated underneath the cages.

Thirteen narrow houses (Duplin and Chatham counties, N.C.) were monitored from May to October 1977. Fly abundance was monitored in each house with 8 ribbons suspended on the roof supports along the center of the house and 10 spot cards (7.5 by 12.5 cm white file cards) positioned flush against the rafters along the length of the house. The ribbons were left in position for 1 week, after which they were removed and the numbers of house flies, little house flies, and black garbage flies were counted and the ribbons discarded and replaced with fresh ones. The number of fecal and vomit spots per card were counted weekly, and the old cards discarded and replaced with fresh ones.

Six narrow houses (Craven and Lenoir counties, N.C.) were monitored from May to October 1978. Sticky ribbons (8 per house) and spot cards (10 per house) were used to monitor fly populations. In addition, five baited jug-traps (Burg and Axtell 1984) were used in each house. These were 3.8-liter white translucent plastic milk jugs with four holes (5 cm diam) cut equally spaced in the side in the upper one-third of the jug. The traps were hung from the rafters and baited with 25 g of commercial fly bait containing 1.0% methomyl and 0.025% (Z)-9-tricosene (Improved Golden Malrin, Zoecon). The number of dead flies in the trap after a period of time was used as an index of fly abundance. Spot cards were left in position for 1 week while ribbons and traps were left in position for 2 days. The counts obtained with ribbons and traps were multiplied by 3.5 to standardize counts to a weekly sampling interval.

High-rise Caged-layer Houses. High-rise houses (sometimes called "deep-pit") were two-story open-sided structures ca. 125 m long by 9 to 12 m wide. Birds were housed on the upper story in eight rows of two- or three-tiered cages (three birds per cage) separated by five walkways. The manure accumulated on the ground ca. 4 m below the cages.

Three high-rise houses (Chatham County, N.C.) were monitored from May to October 1977. Ten sticky ribbons and spot cards were positioned in each house, three each at equal intervals at both ends of the house and two each at equal intervals along both sides of the house. Counts of the number of house flies, little house flies, and black garbage flies caught per ribbon were made on a weekly basis; the number of fecal and vomit spots per spot card were also counted weekly.

Four high-rise houses (Chatham County, N.C.) were monitored from May to October 1978 using 10 sticky ribbons, spot cards, and jug-traps per house. Ribbons and cards were placed as before, and six traps were hung on the upper level of the house, three on each side of the house, and four were hung from the walkway into the pit, two at each end of the house. Counts of the number of spots per card were made weekly; ribbon and trap counts were made after 2 days and were standardized as previously described.

Three high-rise houses (Chatham County, N.C.) were monitored from July to October 1982 with four sticky ribbons, spot cards, and jug-traps per house, two each at either end of the house, and weekly counts were made. The same houses were monitored from June to October 1984 with six traps and cards per house positioned at equal intervals, three each on either side of the houses.

Broiler-breeder Houses. Broiler-breeder layer houses were open-sided structures, 90–120 m long by 9–12 m wide with slatted wood platforms 3–4 m wide and 0.8 m high along the length of the house adjacent to each outside wall. Feeders and waterers were positioned over the slats beneath which the manure accumulated. The center third of the house constituted a scratch area and was a dirt floor covered with wood chips (15 cm deep). Nests were suspended from the ceiling 1 m above the dirt floor. Twelve broiler-breeder houses were monitored from May to October 1978 with five sticky ribbons, spot cards, and jug-traps hung from the rafters along the center of the house; counts were made weekly.

Data Analysis. The average number of house flies, little house flies, and black garbage flies caught per ribbon and trap per week and the average number of spots per spot card per week were calculated and transformed to $\log_{10}(\bar{x} + 1)$ before analysis by simple linear regression and stepwise multiple regression using SAS PROC REG and PROC STEPWISE (SAS Institute 1982).

Results and Discussion

Fly Capture and Seasonal Abundance. Overall averages for house flies, little house flies, and black garbage flies caught per sticky ribbon and baited jug-trap in each poultry system are shown in Table 1 along with the average index of fly activity obtained with spot cards. The house fly was the most abundant species in all three systems; the little house fly was second most abundant except in the high-rise houses where considerably more black garbage flies than little house flies were caught with the baited jug-trap. Overall, fly abundance was lowest in the broiler-breeder houses. Large numbers of house flies were caught in all systems with ribbons and traps and fewer little house flies and black garbage flies were caught with traps than with ribbons. The only exception was in the high-rise houses, where more black garbage flies were caught with traps than with ribbons. The average number of spots per card per week was highest in the narrow houses and lowest in the broiler-breeder houses.

If traps and ribbons were both effective in mon-

Table 1. Average number of house flies, little house flies, and black garbage flies, caught per week with two sampling methods (sticky ribbons and baited jug-traps) and index of fly activity obtained with spot cards (no. spots per card per week) in three poultry housing systems

Housing system	House fly		Little house fly		*Ophyra* spp.		Activity	
	n	$\bar{x}$ (SE)	n	$\bar{x}$ (SE)	n	$\bar{x}$ (SE)	n	$\bar{x}$ (SE)
Narrow								
Ribbon	3,640	264.7 (15.2)	3,645	55.4 (7.6)	3,642	8.7 (1.0)		—
Trap	739	281.7 (32.6)	738	2.1 (0.8)	738	0.6 (0.2)		—
Card		—		—			4,405	80.5 (3.8)
High-rise								
Ribbon	2,807	166.3 (19.9)	1,923	125.2 (19.9)	1,923	84.8 (13.4)		—
Trap	1,459	312.2 (23.1)	1,289	29.5 (7.8)	1,289	162.1 (28.8)		—
Card		—		—		—	2,377	33.5 (3.5)
Broiler-breeder								
Ribbon	1,164	45.1 (4.0)	1,165	26.2 (3.1)	1,164	2.2 (0.3)		—
Trap	977	177.2 (18.8)	977	16.2 (2.8)	977	0.9 (0.3)		—
Card		—		—		—	1,167	16.7 (1.2)

itoring species abundance, a positive correlation should exist between abundance indices of each species obtained with each method at the same place and time. The average number of flies caught per house in a week was used as an abundance index for that species, and the relationship between ribbon and trap indices for each species was determined using linear regression of the form:

$$Y = a + bX \quad (1)$$

where $Y = \log_{10}$(mean number of flies per ribbon per week + 1), $X = \log_{10}$(mean number of flies per trap per week + 1), b = slope, and a = intercept. The results are shown in Table 2. There was a significant correlation ($r = 0.60$–0.85) between indices of house fly abundance obtained with ribbons and traps in all poultry systems. The regressions were tested (Steel and Torrie 1980) for common slope and intercept and were significantly different ($P < 0.01$) between systems for house fly indices. Fewer house flies were caught per ribbon relative to the number caught per trap in the broiler-breeder systems than in the other systems. This may reflect inhibition of ribbon catches by dust in the broiler-breeder houses as suggested by Rutz and Axtell (1981). More house flies per ribbon were caught relative to the number caught per trap in narrow houses than in high-rise houses, suggesting that the traps were less effective in the narrow houses. This may be due to the proximity of the manure to the traps in narrow houses, which may compete with the attractant chemicals in the bait for flies. The traps were placed farther from the manure in the high-rise houses, and, thus, might have been relatively more attractive to flies above the walkway than they were in the narrow houses.

Table 2. Relationship of index of abundance of three species of filth flies obtained with sticky ribbons to index obtained with baited jug-trap in three poultry housing systems[a]

Housing system[b]	n	Intercept	Slope	SE (slope)	r^2
House fly					
Narrow	150	1.29	0.62	0.032	0.72
High-rise	137	0.11	0.75	0.087	0.36
Broiler-breeder	196	−0.55	0.91	0.046	0.67
Little house fly					
Narrow	150	0.16	0.81	0.102	0.30
High-rise	95	0.52	0.79	0.086	0.47
Broiler-breeder	196	0.25	0.77	0.054	0.51
Ophyra spp.					
Narrow	150	0.28	1.09	0.127	0.33
High-rise	95	0.24	0.83	0.051	0.74
Broiler-breeder	196	0.15	0.89	0.065	0.49

[a] Model is $Y = a + bX$ where $Y = \log_{10}$(mean no. flies per ribbon per week + 1), $X = \log_{10}$(mean no. flies per trap per week + 1), b = slope, a = intercept.
[b] Slopes (b) significantly different from 0 at $P < 0.01$ (PROC REG, SAS Institute [1982]).

The relationships between indices of little house fly abundance obtained with ribbons and traps are also shown in Table 2. Significant correlations were observed in all systems ($r = 0.55$–0.71), but few little house flies were caught using traps in the narrow houses. There were significant correlations between indices of black garbage fly abundance obtained with ribbons and traps in all three systems ($r = 0.57$–0.86), but capture of black garbage flies was low using traps in the narrow and broiler-breeder systems.

The higher numbers of black garbage flies caught with ribbons and traps in the high-rise houses may have reflected higher populations of black garbage flies in this system. Anderson and Poorbaugh (1964) found that black garbage flies (*O. leucostoma*) rested outside narrow-style poultry houses, and only entered to visit the manure. This species' movement out of the high-rise houses may be more

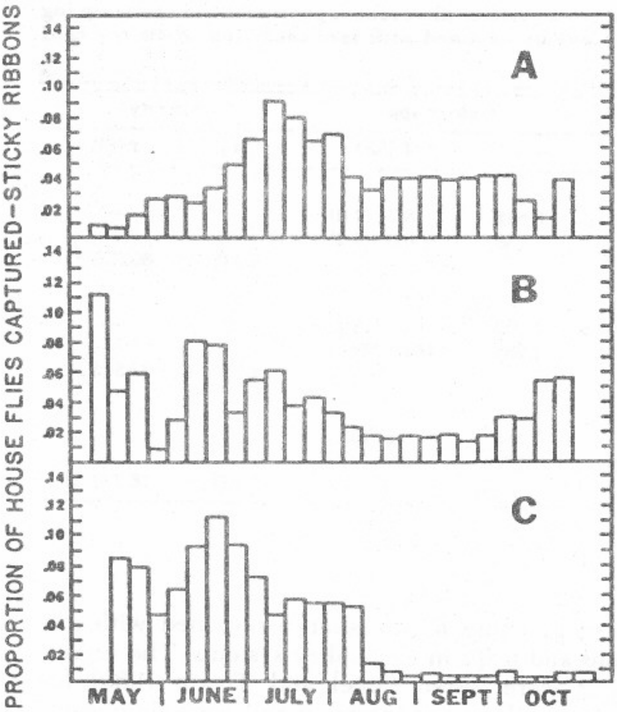

Fig. 1. Relative frequency of house fly capture with sticky ribbons from May to October in three poultry systems: (A) narrow caged-layer houses, (B) high-rise houses, (C) broiler-breeder layer houses.

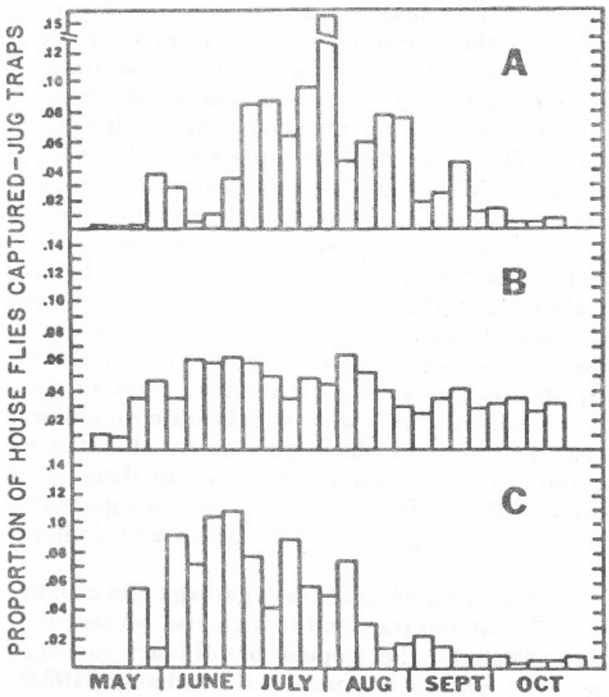

Fig. 2. Relative frequency of house fly captures with baited jug-traps from May to October in three poultry systems: (A) narrow caged-layer houses, (B) high-rise houses, (C) broiler-breeder layer houses.

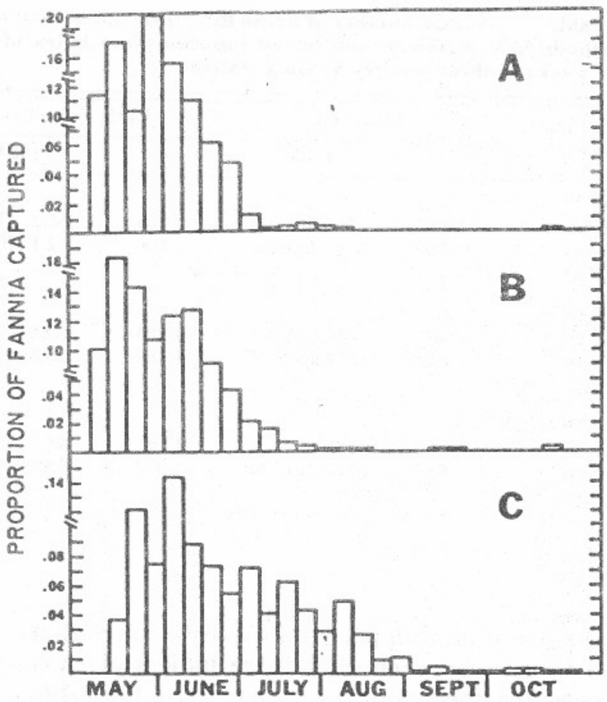

Fig. 3. Relative frequency of little house fly capture with sticky ribbons from May to October in three poultry systems: (A) narrow caged-layer houses, (B) high-rise houses, (C) broiler-breeder layer houses.

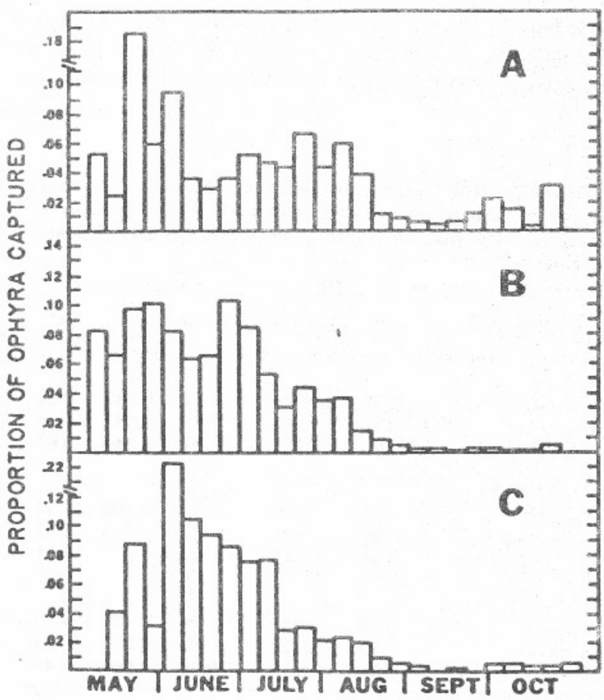

Fig. 4. Relative frequency of *Ophyra* spp. capture with sticky ribbons from May to October in three poultry systems: (A) narrow caged-layer houses, (B) high-rise houses, (C) broiler-breeder layer houses.

Table 3. Simple regressions between indices of fly abundance obtained with spot cards compared with sticky ribbons and baited jug-traps in three poultry housing systems[a]

Housing system	House fly[b]				Little house fly[b]				*Ophyra* spp.[b]			
	n	Intercept	Slope	r^2	n	Intercept	Slope	r^2	n	Intercept	Slope	r^2
Sticky ribbon												
Narrow	468	0.915	0.366	0.20	468	1.649	0.071	0.02	468		NS[c]	—
High-rise	238	0.643	0.348	0.23	196	0.958	0.241	0.25	196	0.956	0.244	0.19
Broiler-breeder	205	0.332	0.551	0.54	205	0.692	0.340	0.19	205	0.833	0.694	0.27
Baited jug-trap												
Narrow	150	0.692	0.471	0.61	150	1.545	0.309	0.06	150		NS	—
High-rise	188	0.100	0.530	0.29	146	1.182	0.143	0.04	146	0.956	0.276	0.26
Broiler-breeder	196	−0.151	0.596	0.50	196	0.684	0.367	0.19	196	0.930	0.702	0.15

[a] Model is $Y = a + bX$ where $Y = \log_{10}$(mean no. spots per card per week + 1), $X = \log_{10}$(mean no. flies caught per week + 1), b = slope, a = intercept.
[b] Slopes (b) significantly different from 0 at $P < 0.01$ (PROC REG, SAS Institute [1982]).
[c] NS, not significant.

restricted due to the system's greater size and more closed nature, thus concentrating black garbage flies inside the house where they would be more likely to respond to the traps.

Legner et al. (1973) found that a relationship existed between ribbon counts and emergence of five fly species, including house flies, little house flies, and black garbage flies (*O. leucostoma*) in poultry houses. Apparently, the sticky ribbon is more suitable than the baited jug-trap for monitoring little house flies and black garbage flies.

The relative distribution of each fly species over the season was determined in each system. Trap and ribbon captures of house flies were analyzed separately, but only the ribbon captures were used for little house flies and black garbage flies since trap captures of these species were low in the narrow and broiler-breeder systems. Observations were pooled over years and houses within each system and were grouped according to week of collection. Since the number of samples taken each week was not consistent, the mean number of flies caught per sample during each week was used in calculating the proportion of flies caught during each week of the fly-breeding season. The frequency of captures of house flies with ribbons during the fly season is shown in Fig. 1 A–C and with traps in Fig. 2 A–C. House flies were present throughout the entire fly season in all poultry systems, and were most abundant in June and July, with a tendancy to decline through August. This decline was most pronounced in the broiler-breeder houses (Fig. 1C and 2C).

Little house flies were most abundant from May to July in all poultry systems (Fig. 3 A–C) and were relatively scarce from August to October. This is consistent with the observations of Anderson and Poorbaugh (1964) based on data collected in California. The relative frequency of black garbage flies was also concentrated from May to August

Table 4. Relationship between index of fly abundance obtained with spot cards and the number of flies captured with two sampling methods (sticky ribbons and baited jug-traps) in three poultry systems determined by stepwise multiple regression

System	Parameter estimates[a]					Model[b] r^2	r^2 (HF)[c]	r^2 (LHF)[d]	r^2 (BGF)[e]
	n	a	b_1 (HF)	b_2 (LHF)	b_3 (BGF)				
Sticky ribbons									
Narrow	468	0.351	0.355	0.244	NS	0.36	0.20	0.02	0
High-rise	196	0.100	0.438	0.317	NS	0.63	0.23	0.25	0
Broiler-breeder	206	0.332	0.551	NS	NS	0.54	0.54	0	0
Baited jug-trap									
Narrow	150	0.651	0.466	0.269	NS	0.66	0.61	0.06	0
High-rise	146	−0.033	0.480	NS	0.219	0.45	0.29	0	0.26
Broiler-breeder	196	−0.151	0.596	NS	NS	0.50	0.50	0	0

[a] General form of regression is $Y = a + b_1X_1 + b_2X_2 + b_3X_3$ where $Y = \log_{10}(\bar{x}$ spots per card per week + 1), $X_1 = \log_{10}(\bar{x}$ no. house flies per week + 1), $X_2 = \log_{10}(\bar{x}$ no. little house flies per week + 1), $X_3 = \log_{10}(\bar{x}$ no. *Ophyra* spp. per week + 1). All parameter estimates significant ($P < 0.01$; PROC REG, SAS Institute [1982]).
[b] Model r^2 = total proportion variation in Y accounted for by X's.
[c] r^2 (HF) = total proportion variation in Y accounted for by house fly alone.
[d] r^2 (LHF) = total proportion variation in Y accounted for by little house fly alone.
[e] r^2 (BGF) = total proportion variation in Y accounted for by *Ophyra* spp. alone.

(Fig. 4 A–C) in each system, but black garbage flies were present in low numbers throughout the remainder of the fly season.

Relationship Between Fly Abundance Indices and Spot Card Indices. The average number of house flies, little house flies, and black garbage flies caught per ribbon and trap per week in each poultry house was calculated and used as abundance indices for each species. The number of spots per card per week was also calculated for each house on a weekly basis and used as an index of fly activity (Axtell 1970). All indices were transformed to $\log_{10}(\bar{x} + 1)$ before analysis where $\bar{x}$ = mean number of flies captured per week. Simple linear regression and stepwise multiple regression (SAS Institute 1982) were used to determine which species abundance indices were most closely related with the index of fly activity measured with the spot cards.

The simple regressions between fly activity indices and indices of fly abundances obtained with ribbons and traps are shown in Table 3. The regressions involving house fly abundance indices obtained with ribbons and traps had higher r^2 values (0.20–0.61) than did regressions involving little house fly abundance indices (r^2 = 0.02–0.25) or black garbage fly (r^2 = 0–0.27).

The results of the stepwise multiple regressions of fly activity indices against abundance indices of the three fly species obtained with ribbons show that the house fly was the species contributing most to the variation in spot card indices in all systems, accounting for 20–54% of the variation (Table 4). Inclusion of little house fly abundance indices obtained with ribbons in the models for both the narrow and high-rise houses increased the amount of variation in spot card indices accounted for to 36 and 63%, respectively. House fly indices obtained with ribbons were the only important source of variation influencing spot card indices in broiler-breeder houses, and accounted for 54% of the variation in the spot card indices.

Table 4 shows the results of the stepwise regression analysis when indices of fly abundance obtained with baited jug-traps were used as the independent variables. House fly indices alone accounted for 29, 61, and 50% of the variation in spot card indices in the narrow, high-rise, and broiler systems, respectively. Addition of little house fly indices to the model for narrow houses increased the variation accounted for to 66%, and addition of black garbage fly indices to the model for high-rise houses increased the variation accounted for to 45%. The house fly was the only significant source of variation influencing spot card indices in the broiler houses and accounted for 50% of the variation.

Generally, house fly abundance as measured with sticky ribbons or baited jug-traps had the highest correlation with the spot card indices. When other species of flies were abundant, such as little house flies in narrow or high-rise houses, the spot card indices appeared to be influenced. Consequently, the spot card index should be used as an index of fly *activity* as originally suggested by Axtell (1970). This does not detract from the usefulness of spot cards as a monitoring technique in pest management programs, as the adults of little house flies and black garbage flies are generally considered pests and are controlled by the same methods used against house flies. If these species influence the fly activity indices, any control decision made on the basis of spot card indices will affect those species as well as house flies present.

For studies of house flies, the baited jug-trap is reasonably selective and indices obtained with this method have been shown to be related to actual density of house flies (Lysyk and Axtell 1985). When it is important to know species composition, sticky ribbons should be used. Spot cards can be used as a convenient means to determine total fly activity.

Sample Size and Precision. The precision of an estimate is important in decision-making and is related to the variation inherent to a method as well as the number of samples taken. Karandinos (1976) provided formulae for calculating the lowest number of samples required to obtain estimates with a fixed level of precision, and defined this as the optimum sample size. He used the coefficient of variability as a measure of precision, and defined it as:

$$CV = \frac{SE}{\bar{x}} = \frac{S/\sqrt{n}}{\bar{x}} \qquad (2)$$

where $\bar{x}$ = sample mean, SE = standard error of the mean, S = sample standard deviation, and n = sample size. This statistic expresses the variation about a mean as a proportion of that mean (i.e., the higher the CV, the higher the variation and lower the precision). Karandinos (1976) showed that equation 2 can be rearranged to find the optimum number of samples for a fixed level of precision for a given mean and variance. This expression is (Karandinos 1976, eq. 3):

$$n = \frac{S^2}{\bar{x}^2\,(CV)^2} \qquad (3)$$

and is useful for a given mean and variance; however, the variance often increases with the mean (Taylor 1961, Taylor et al. 1978). The relationship between a mean and variance can be used to estimate the optimum sample size for fixed levels of precision over a range of mean densities (Régnière and Sanders 1983, Lampert et al. 1984, Safrit and Axtell 1984).

The relationship between the mean and variance of the number of house flies caught per sticky ribbon and baited jug-trap, and the number of spots per card per week per poultry house was determined separately for each poultry production system. Since the house fly was the most abundant species found, optimum sample size calculations were directed towards estimating its abundance.

Table 5. Results of regressions of the variance against the mean for three methods of sampling house fly abundance[a]

Sampling method	System	n	a	b	r^2
Sticky ribbons	Narrow	468	0.221	1.512	0.79
	High-rise	238	0.188	1.692	0.88
	Broiler-breeder	205	−0.065	1.532	0.86
Baited jug-trap	Narrow	150	−0.011	1.722	0.90
	High-rise	188	0.402	1.574	0.75
	Broiler-breeder	196	−0.415	1.751	0.82
Spot card	Narrow	468	0.170	1.523	0.78
	High-rise	294	0.241	1.512	0.84
	Broiler-breeder	205	0.085	1.499	0.77

[a] Model is $Y = a + bX$ where $Y = \log_{10}(s^2 + 1)$ and $X = \log_{10}(\bar{x} + 1)$. All nonintercept parameters significantly greater than 0 ($P < 0.01$; PROC REG [SAS Institute 1982]).

The data were fit by least-squares regression to the model

$$Y = a + bX \quad (4)$$

where $Y = \log_{10}(s^2 + 1)$, $X = \log_{10}(\bar{x} + 1)$, a = y intercept, and b = slope. The results of these regressions are presented in Table 5. There was a strong relationship between the variance and the mean for all sampling methods in all systems as evidenced by the high r^2 values (0.75–0.90). The variance can, thus, be expressed as a function of the mean by rearranging equation 4, so that for any $\bar{x}$

$$s^2 = 10^a(\bar{x} + 1)^b - 1 \quad (5)$$

where a and b are coefficients for a particular sampling method in a given production system and are obtained from Table 5. By substituting equation 5 into equation 3, the optimum number of samples for a particular method is determined from

$$\hat{n} = \frac{10^a\,(\bar{x} + 1)^b - 1}{\bar{x}^2\,(CV)^2}. \quad (6)$$

This expression was solved for each sampling method and production system over a range of densities to determine the optimum sample size required to obtain estimates with CV's of 0.10, 0.15, and 0.20. These are presented in Table 6.

Use of Table 6 in a routine monitoring program requires knowledge of what level of abundance is acceptable. Treatment thresholds will vary depending on the proximity of the producer to local

Table 6. Number of samples required at different house fly densities for three levels of precision (CV = 0.10, 0.15, 0.20) in three poultry housing systems

House fly density	Narrow			High-rise			Broiler-breeder		
	0.10	0.15	0.20	0.10	0.15	0.20	0.10	0.15	0.20
Ribbons (flies per ribbon per wk)									
25	37	16	9	61	27	15	20	9	5
50	25	11	6	48	21	12	14	6	4
75	21	9	5	42	19	10	12	5	3
100	18	8	4	38	17	9	10	4	3
150	15	6	4	33	15	8	8	4	2
200	13	6	3	30	14	8	7	3	2
250	11	5	3	28	13	7	7	3	2
300	10	5	3	27	12	7	6	3	2
Baited jug-trap (flies per trap per wk)									
25	42	19	11	68	30	17	18	8	5
50	34	15	8	49	22	12	15	7	4
75	30	13	8	41	18	10	13	6	3
100	28	12	7	36	16	9	72	6	3
200	23	10	6	27	12	7	10	5	2
300	20	9	5	22	10	6	9	4	2
400	19	8	5	20	9	5	9	4	2
500	17	8	4	18	8	4	8	4	2
Spot cards (spots per cards per wk)									
10	56	25	14	64	29	16	43	19	11
20	38	17	9	43	19	11	29	13	7
30	31	14	8	35	15	9	23	10	6
40	26	12	7	30	13	7	20	9	5
50	24	10	6	27	12	7	18	8	4
60	21	10	5	24	11	6	16	7	4
80	19	8	5	21	9	5	14	6	3
100	17	7	4	19	8	4	12	5	3

businesses and communities (Axtell 1985) (i.e., the closer the producer, the lower the threshold). Common treatment thresholds are 300 flies per ribbon per week, 350 flies per jug-trap per week, or 50 spots per card per week (Rutz 1981) and can be used as initial levels to determine the number of samples that need to be taken. These levels and the corresponding number of samples for fixed precision levels can be adjusted for a particular circumstance as information is gained on what levels of abundance in the poultry system are associated with neighbors' complaints.

Southwood (1978) suggested that a SE/$\bar{x}$ ratio of 0.25 is enough to detect doubling or halving of a population. Using a CV of 0.15 will allow a workable number of samples per house using any given method and will provide abundance estimates with a reasonable degree of precision. High-rise houses generally require more samples than narrow or broiler-breeder houses, possibly due to their much larger size.

In summary, the house fly was the predominant pest species in three types of poultry production systems in North Carolina. Little house flies and black garbage flies (*Ophyra* spp.) were present in lower numbers and primarily during the earlier parts of the fly season. Indices of house fly abundance obtained with sticky ribbons, baited jug-traps, and spot cards were correlated. The house fly was the major contributor to spot card indices, but little house flies and black garbage flies influenced the number of spots per card under certain conditions. The spot card index, should, therefore, be taken as an index of fly activity, particularly early in the season when little house flies and black garbage flies may be abundant. Since the three sampling methods are correlated, any of the methods can be used to estimate relative density of house flies. The optimum sample sizes for each method over a range of densities for routine monitoring have been determined.

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