Stable fly (*Stomoxys calcitrans*: Diptera, Muscidae) trap response to changes in effective trap height caused by growing vegetation

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ABSTRACT: Stable flies (*Stomoxys calcitrans* L.) are bloodfeeding pests of cattle, whose populations are often monitored using sticky traps. Trap responses at different heights were compared with: 1) a choice and no-choice test, with sticky cards set at 30 and 121 cm heights (above ground), and 2) tall (120 cm) traps placed in short (3 cm) and tall (40 cm) grass to assess how vegetation height affects trap catches. In the first experiment, the percentage of upper to lower trap catches were similar at choice (16%) and no-choice traps (15%). In the vegetation study, stable fly catch height data were fitted to gamma distributions to determine the most productive trap heights; 20 cm above short grass and 24 cm above tall grass (from lower edge of trap). The results indicate that traps used to monitor stable fly populations should be maintained at a constant distance above surrounding vegetation rather than ground surface, otherwise trap data can be misleading. ***Journal of Vector Ecology* 33 (1): 40-45. 2008.**

Keyword Index: Stable flies, sticky traps, trap height, Coroplast, Muscidae.

INTRODUCTION

In every method of trapping insects there are inherent biases that result in sampling error (Muirhead-Thomson 1991). Some of these are well understood. For example, traps that rely upon bait sample only a subset of any population, and conclusions based on these methods can be interpreted accordingly. How other factors may affect trap catch is not always as well understood, including factors as simple as the height at which traps are set. Not knowing how trap set-up affects catch population profiles can produce data that is difficult to interpret, to compare to other research, and may be misleading.

One such example involves the stable fly, a noxious cattle pest and a potential vector of food-borne pathogens (Mramba et al. 2007). Stable fly populations are commonly sampled using panels or cylinders made of Alsynite (Williams 1973, Broce 1988) or Coroplast®[1] (Beresford and Sutcliffe 2006) which are coated with a sticky material. The height of sticky traps used to sample stable fly populations is not standardized. In the original work with Alsynite (Williams 1973), interconnected panels were placed with the bottom edge 90 cm above ground level. Since then, sticky trap placement has been lower, with the average trap placement being 48 cm above the ground surface (Table 1).

Earlier work has provided some general insights into how trap height can affect fly catches. Broce et al. (1991) found that the cylindrical Alsynite traps set at 40 cm caught the most stable flies between 40 and 47.5 cm. Gersabeck and Merritt (1983), using an Alsynite panel 3 m tall, caught 71% of stable flies below 60 cm, and less than 5% above 120 cm. Black and Krafsur (1985) using sticky note cards (10 x 15 cm) at 36, 76, and 116 cm above ground, caught 76.1%, 18.5%, and 5.4% of stable flies, respectively.

The problem of trap placement is generally addressed by maintaining traps at a consistent height above ground over the research period. However, this does not allow for changes in the surrounding vegetation, nor is it clear how growing vegetation surrounding a trap affects trap catches. Without understanding the relationship between trap height and catching stable flies, there is no way to correct for height differences when comparing the results of different studies.

In this paper, we first tested whether stable flies respond to trap height differently if presented with a choice of landing heights or not. Secondly, we examined how stable fly catch height varied with height above both ground surface and surrounding vegetation. We reasoned that over the course of a field season, the changes in vegetation height surrounding sticky traps might alter the effective trap-height and affect stable fly trap response.

METHODS AND MATERIALS

Choice vs no-choice test

A choice vs no-choice experiment comparing stable fly catches at different heights was conducted on a dairy farm 10 km east of Peterborough, Ontario, from August 15 to September 21, 2006. Treatments were 'choice' and 'no choice' sticky traps made of Coroplast[R] panels 20 cm wide by 30 cm

[1]Coroplast® is a registered trade name of a twinwall polypropylene plastic sheeting, manufactured by Coroplast, a division of Great Pacific Enterprises Inc. 700 Vadnais, Granby, Quebec J2J1A7, and 4501 Spring Valley Rd., Dallas, TX 75244.

tall and coated with Tangle-Trap®[2] (Beresford and Sutcliffe 2006). Traps were either low or high, with the bottom edges set at 30 or 121 cm above the ground and screwed to 2 x 2 wooded stakes. Vegetation was maintained 25 cm high so that traps were either 5 cm or 96 cm above the top of the grass.

The choice set-up was both a low and high sticky panel on the same wooded stake, whereas no choice set-up was either a single low or high sticky trap. Traps were spaced 2.5 m apart along a row 12 m south of an open cattle barn across a graveled area, and bounded by a gravel driveway along the east side and fenced pasture on the west side. Traps were coated with Tangle-Trap® on the north side of each panel. Two of each treatment, no-choice down, no-choice up, and choice set-ups (upper and lower traps) were used for each trapping session for a total of six set-ups using eight traps per trial. A Latin squares experimental design was used, with six placements within each row for six trapping sessions (Table 2). Traps were kept in place for at least two days and changed at midday.

Vegetation and trap catch

Coroplast® panels, 25 cm wide by 125 cm high and coated on one side with Tangle-Trap®, were installed on wooden stakes and set with the bottom edge against the ground surface. One was placed in 3 cm high grass from July 27 to August 3 and a second from August 6 to August 9. This set-up was followed at the same site from October 4 to October 10, with traps deployed in 40 cm high grass. The trapping site was within a 4 m wide drainage ditch area that separated pasture and a gravel barnyard. Traps were placed in the center of this region, and protected from the cattle by an electric fence. Catches were analyzed as to number, sex, and capture height above ground.

Trap catch height

In order to calculate the maximum density (or mode) of stable fly catch height, the height distribution of number of stable flies was fitted to a gamma distribution, a flexible distribution that is useful for skewed data (Hilborn and Mangel 1997). Goodness of fit was tested using the Kolmogorov-Smirnov test (Sokal and Rohlf 1997). The probability density function of the gamma distribution is:

$$p(h) = (h/\beta)^{\alpha-1}[exp(-h/\beta)]/\beta\Gamma(\alpha) \qquad (3)$$

where h is capture height, Γ is the gamma function, α is the shape parameter, and β is the scale parameter (Matis et al. 1992). The mean and variance (of capture height in this instance) can be determined by the scale and shape parameters such that:

$$\text{mean} = \alpha\beta \qquad (4)$$
$$\text{variance} = \alpha\beta^2 \qquad (5)$$

[2]Tangle-Trap® is a registered trade name of the Tanglefoot Company, 314 Straight Ave. SW, Rm 209 Grand Rapids, MI, U.S.A.

The expected maximum density (Milton and Arnold 1995) is calculated as:

$$\text{height} = (\alpha - 1)/\theta \qquad (6)$$

and was used to determine the mode for each of the trapping sessions, where $\theta = 1/\beta$ (note that θ is the scale parameter returned by STATISTICA when distribution fitting, whereas the Excel functions use β for modelling the gamma distribution).

A Mann-Whitney *U*-test was used to determine if there was a difference in capture height based on sex for traps set in 3 cm and 40 cm grass. All statistical analysis was performed using either an Excel spreadsheet or STATISTICA 4.5 (Statsoft[R] Inc.).

RESULTS

There was no significant difference in the percentage of stable flies caught on upper traps (100 x upper/lower) between the choice and no-choice tests (total flies: $F_{(1, 10)} = 0.04$, $p = 0.85$; males: $F_{(1, 10)} = 0.73$, $p = 0.41$; females: $F_{(1, 10)} = 0.91$, $p = 0.36$)(Table 3).

The vertical catch profiles on tall traps from both grass heights were described by the gamma distribution (Figure 1; e.g., Kolmogorov-Smirnov test for goodness of fit for combined trap data, 3 cm grass height $d = 0.013$, $p = > 0.05$; 40 cm grass height $d = 0.037$, $p > 0.05$). Using equation 6, the greatest expected fly catch was 19.5 cm above the 3 cm grass and 24.4 cm above the 40 cm grass (Table 4).

More males than females were caught on both the 3 cm trap, (64%), and the 40 cm trap, (55%) (Table 5). There was no significant difference in the catch heights of male and

Table 1. Height at which sticky traps were deployed by different researchers. Height measured from ground to bottom edge of trap.

Height cm	Author(s)
45	Ruff (1979)
50	Berry et al. (1981)
25	Pickens and Hayes (1984)
15 – 20	Hogsette and Ruff (1985)
90	Berry et al. (1986)
55	Mullens and Meyer (1987)
30.5	Thomas et al. (1989)
40	Broce et al. (1991)
70	Lysyk (1993)
30.5	Berkebile et al. (1994)
45	Guo et al. (1998)
60	Cilek (1999, 2003)
69.5	Taylor and Berkebile (2006)

Table 2. Sampling plan of choice vs no-choice sticky traps.

Week collected	Trap placement along row					
Aug 15-17	down	choice	up	choice	up	down
Aug 27	choice	down	choice	up	down	up
Sept 7	up	choice	up	down	choice	down
Sept 9	choice	down	down	up	up	choice
Sept 15	up	up	down	choice	down	choice
Sept 21	down	up	choice	down	choice	up

female stable flies on either the 3 cm trap (*U*-test, number caught/cm, males vs females, $Z = -0.87$, $p = 0.38$) or the 40 cm trap ($Z = -1.2$, $p = 0.23$).

DISCUSSION

Choice vs no-choice

The similarity between the choice and no-choice test results indicates that stable flies did not alter their flight height and become caught by upper traps when no low traps were available. This is evidence that trap height is an important factor in sampling populations. Had the choice vs no-choice trap response been different, this would indicate that variations in trap height were of little consequence, however this was not the case. For any long-term sampling program, trap height needs to be monitored with respect to the surrounding vegetation, as indicated by the catches on tall traps set in 3 and 40 cm grass.

Not keeping trap height constant with respect to the top of the surrounding grass or weeds can be misleading. For example, consider a sampling session from when stable flies first appear on a farm in spring and continue to mid-summer, i.e., from May 1 to June 21, with traps placed 100 cm high. With the growth of surrounding hay over 50 days, the effective trap height would drop to about 15-20 cm. We examined this, modelling a population of 1,000 "flies" using Excel (GAMMAINV(n, α, β) function, $\alpha = 2.17$ and $\beta = 19.23$, and n being a random number between 0 and 1, 1,000 flies binned into a frequency distribution according to flight height). By gradually dropping the effective trap height, the modelled population appeared to be growing exponentially over time, even though the population was constant at 1,000 flies.

Our results indicate that sticky traps should be set with their bottom edges about 20 cm above surrounding grass in order to sample the 20-50 cm region, where most stable flies were caught, i.e., between the mode and mean (based on calculations using the fitted gamma distribution parameters). Is this born out by other studies? Fitting a gamma distribution to the results of Gersabeck and Merritt (1983, data reported in 30 cm height categories), produced an expected maximum density of 19.15 cm (gamma parameters $\theta = 0.0276$, $\beta = 36.25$, and $\alpha = 1.53$). This is comparable to our catch results (Table 4).

The peak catches we observed for stable flies of both sexes were within the 27 cm flight boundary layer (a layer of air close to the ground within which insect flight speed exceeds wind speed) for larger Diptera identified by Taylor (1974). This, coupled with the increased catches at lower heights in windy conditions reported by Broce et al. (1991) suggests that stable flies are disinclined to fly above the height where they might be dislocated by wind. Stable

Table 3. Catches of stable flies on lower and upper traps for choice vs no-choice tests. The % up was calculated as 100 times up/down.

Trial	Choice			No choice		
	down	up	% up	down	up	% up
1	31	4	12.9	35	6	17.1
2	100	8	8	77	7	9.1
3	25	8	32	45	5	11.1
4	43	2	4.7	21	6	28.6
5	24	6	25	25	5	20
6	30	4	13.3	30	1	3.3
mean	42.17	5.3	15.98	38.83	5	14.87
SD	29.13	2.4	10.45	20.48	2.10	8.94

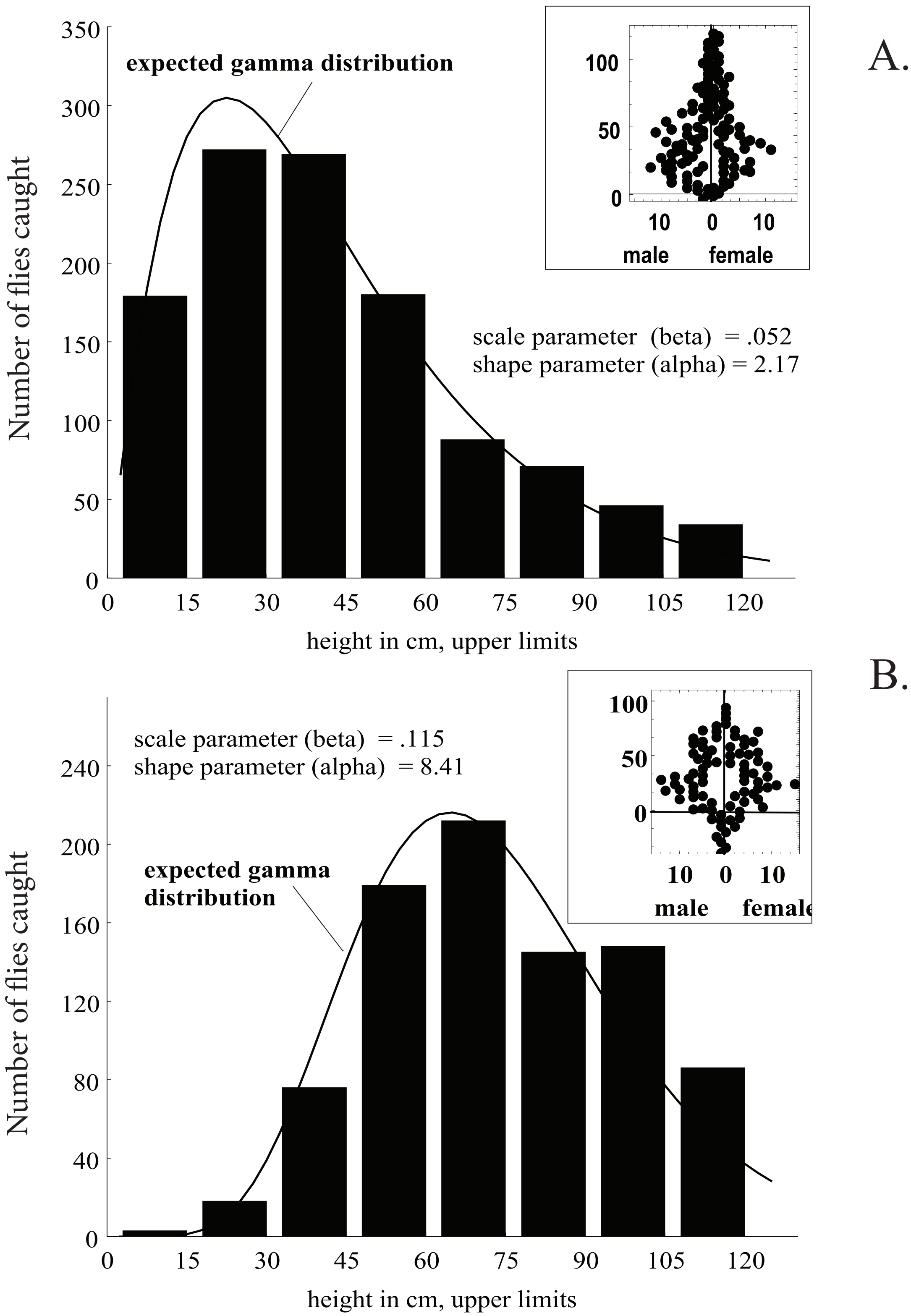

Figure 1. Frequency distributions and the fitted gamma distributions of the number of stable flies caught on elongated Coroplast® sticky traps (120 cm tall) deployed over (A) 3 cm tall grass and (B) 40 cm tall grass (combined data from two traps set in each grass height). Inset is number stable flies caught in each cm section of the trap, with grass height set at zero.

Table 4. Gamma distribution parameters obtained by fitting stable fly trap catch heights for traps set in 3 and 40 cm grass, and expected mean and mode (maximum density) height of stable fly trap catches above the ground surface and top of grass. Catch data combined for "both".

Grass height (cm)	Gamma parameters			Expected mean		Expected max. density	
	θ	β	α	ground	grass	ground	grass
3	0.042	23.94	1.73	41.5	38.5	17.6	14.6
3	0.065	15.34	2.85	42.5	39.5	27.1	24.1
3 both	0.052	19.23	2.17	41.7	38.7	22.5	19.5
40	0.141	7.11	10.44	74.3	34.3	67.1	27.1
40	0.098	10.23	6.92	70.7	30.7	60.5	20.5
40 both	0.115	8.70	8.4	73.0	33.0	64.3	24.3

Table 5. Summary statistics of stable fly catch height on Coroplast® traps set in 3 cm and 40 cm grass. Male vs female catch heights compared using Mann-Whitney U-test.

Grass height (cm)	Sex	Number	Heights (cm)				
			above ground			above grass	
			mean	(SD)	median	mean	median
3	male	379	41.5	(24.9)	37	38.5	34
3	female	228	44.1	(24.7)	39	41.1	36
40	male	484	72	(23.2)	70	32	30
40	female	396	73.9	(21.6)	71	33.9	31

fly flight height responses are more likely determined by aerodynamic/atmospheric conditions than by trap material, which would enable studies that used different trap materials to be compared.

There is evidence that females of different physiological stages are found at different distances from cattle and/or oviposition sites at farms (Guo et al. 1998). It would be interesting to examine the trap height response with respect to different physiological stages of females, dispersing and non-dispersing flies, and how large the area around a trap needs to be to affect stable fly trap height response.

Trap placement for sampling stable flies on working farms is often a compromise between research requirements that require traps be visible and near where stable flies aggregate, and such practical considerations as the need to avoid damage to traps from cattle and machinery. As in this study, suitable areas can be beside manure mounds, ponds, barnyards, and drainage ditches where cattle and machinery are excluded and weeds and grass remain uncut. Our research indicates that traps deployed in such areas should be kept at a constant height above surrounding vegetation rather than above the ground surface.

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REFERENCES CITED

Beresford, D.V. and J.F. Sutcliffe. 2006. Studies on the effectiveness of Coroplast sticky traps for sampling stable flies (Diptera: Muscidae), including a comparison to Alsynite. J. Econ. Entomol. 99: 1025-1035.

Berkebile, D.R., G.D. Thomas, and J.B. Campbell. 1994. Overwintering of the stable fly (Diptera: Muscidae) in Southeastern Nebraska. J. Econ. Entomol. 87: 1555-1563.

Berry, I.L., P.J. Scholl, and J.I. Shugart. 1981. A mark and recapture procedure for estimating population sizes of adult stable flies. Environ. Entomol. 10: 88-93.

Berry, I.L., A.K. Nelson, and A.B. Broce. 1986. Effects of weather on capture of stable flies (Diptera: Muscidae) by Alsynite fiber glass traps. Environ. Entomol. 15: 706-709.

Black, W.C. and E.S. Krafsur. 1985. Use of sticky traps to investigate seasonal trends in the spatial distribution of house flies and stable flies (Diptera: Muscidae). J. Med. Entomol. 22: 550-557.

Broce, A.B. 1988. An improved Alsynite cylinder trap for stable flies, (Diptera: Muscidae). J. Med. Entomol. 25: 406-409.

Broce, A.B., J.R. Schwenke, and K.E. Hampton. 1991. Landing pattern of stable flies (Diptera: Muscidae) on the Alsynite cylinder trap: effect of wind speed and direction. J. Med. Entomol. 28: 730-733.

Cilek, J.E. 1999. Evaluation of various substances to increase adult *Stomoxys calcitrans* (Diptera: Muscidae) collections on Alsynite cylinder traps in North Florida. J. Med. Entomol. 36: 605-609.

Cilek, J.E. 2003. Attraction of colored plasticized corrugated boards to adult stable flies, *Stomoxys calcitrans* (Diptera: Muscidae). Fla. Entomol. 86: 420-423.

Gersabeck, E.F. and R.W. Merritt. 1983. Vertical and temporal aspects of Alsynite Panel sampling for adult *Stomoxys calcitrans* (L.) (Diptera: Muscidae). Fla. Entomol. 66: 222-227.

Guo Y., G.L. Greene, and M.D. Butine. 1998. Population profile of stable flies (Diptera: Muscidae) caught on Alsynite traps in various feedlot habitats. J. Econ. Entomol. 91: 159-164.

Hilborn, R. and M. Mangel. 1997. *The Ecological Detective: Confronting Models With Data.* Princeton University Press, Princeton, N. J.

Hogsette, J.A. and R.P. Ruff. 1985. Stable fly (Diptera: Muscidae) migration in northwest Florida. Environ. Entomol. 14: 170-175.

Lysyk, T.J. 1993. Seasonal abundance of stable flies and house flies (Diptera: Muscidae) in dairies in Alberta, Canada. J. Med. Entomol. 30: 888-895.

Matis, J.H., W.L Rubink, and M. Makela. 1992. Use of the gamma distribution for predicting arrival times of invading insect populations. Environ. Entomol. 21: 436-440.

Milton, J.S., and J.C. Arnold. 1995. *Introduction to Probability and Statistics*, 3rd edition. McGraw-Hill, New York.

Mramba, F., A.B. Broce, and L. Zurek. 2007. Vector competence of stable flies, *Stomoxys calcitrans* L. (Diptera: Muscidae), for *Enterobacter sakazakii*. J. Vector Ecol. 32: 134-139.

Mullens, B.A. and J.A. Meyer. 1987. Seasonal abundance of stable flies (Diptera: Muscidae) on California dairies. J. Econ. Entomol. 80: 1039-1043.

Muirhead-Thomson, R.C. 1991. *Trap Responses of Flying Insects The Influence of Trap Design on Capture Efficiency*. Academic Press, New York.

Pickens, L.G. and D.K. Hayes. 1984. Evaluation of a new trap which segregates the catches of face flies and stable flies. Environ. Entomol. 13: 1256-1260.

Ruff, J.P. 1979. Trapping effectiveness of several combinations of colors and textures of sticky traps for stable flies, *Stomoxys calcitrans*. Mosq. News 39: 290-292.

Sokal R.R. and F.J. Rohlf. 1997. *Biometry*, 3rd edition. W. H. Freeman and Company, New York.

Taylor, L.R. 1974. Insect migration, flight periodicity, and the boundary layer. J. Anim. Ecol. 43: 225-238.

Taylor, D.B. and D. Berkebile. 2006. Comparative efficiency of six stable fly (Diptera: Muscidae) traps. J. Econ. Entomol. 94: 1415-1419.

Thomas, G.D., I.L. Berry, D.R. Berkebile, and R.S. Skoda. 1989. Comparison of three sampling methods for estimating adult stable fly (Diptera: Muscidae) populations. Environ. Entomol. 18: 513-520.

Williams, D.F. 1973. Sticky traps for sampling populations of *Stomoxys calcitrans.* J. Econ. Entomol. 66: 1279-1280.