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Estimation of the efficiency of the biconical trap for *Glossina fuscipes fuscipes* along the lake Victoria shore, Kenya

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Abstract

Prior to estimating the efficiency of the unbaited biconical trap for *Glossina fuscipes fuscipes* Newstead (Diptera:Glossinidae) the flying height of the insects was estimated using 1 m^2 electrified nets placed at 0 and 4 m above the ground level. The degree of avoidance of these nets by the flies was determined by comparing catches in traps surrounded and those not surrounded by incomplete rings of nets. On the basis of the catches in traps surrounded by nets, the expected catches on both sides of the nets were computed and compared with the observed catches, to further estimate this degree of avoidance. About 48% of males and 35% of females were captured above one metre. An average of 61% of males and 40% of females appeared to avoid the nets. Between 18% and 40% fewer tsetse were caught in traps surrounded by an incomplete ring of nets of respectively 1 m and 2 m radius than in traps not surrounded. After corrections for net avoidance and flying height, it appeared important to determine the optimum radius for the incomplete ring of nets for a reliable efficiency estimate.

Introduction

The efficiency of a tsetse trap is defined as the percentage of flies approaching the trap that are actually caught (Hargrove, 1980). Vale & Hargrove (1979) developed a technique for estimating the efficiency of tsetse traps. This technique involves placing an incomplete ring of electrified nets (Vale, 1974) around a test trap, thereby enabling the estimation of the total number of flies which approach and the proportion actually caught by the trap. The technique has been used to estimate the efficiency of different traps for various tsetse species (Hargrove, 1980; Kyorku et al., 1990).

The biconical trap (Challier et al., 1977) is the most widely used for the *Glossina palpalis* Robineau-Desvoidy group of tsetse, but the electrified nets have never been used critically for sampling *Glossina fuscipes fuscipes*. In order to use the nets to estimate the efficiency of the biconical trap for *G. f. fuscipes*, it was essential to evaluate first the response of the flies to the nets. It was also necessary to determine whether the flies naturally fly above the 1 m height of the nets that were available to us. We present results of preliminary experiments aimed at estimating the efficiency of the unbaited biconical trap for *G. f. fuscipes* along the shores of Lake Victoria, Kenya.

General methods

Study site
The investigations were carried out during the dry periods, 1–15 July 1993 and 3–20 February 1994, in forest patches near the Mbita Point Field Station of ICIPE (0°25′ S, 34°15′ E). The forest patches harboured *G. f. fuscipes* at a density between 20–100/trap/day.

Electrified nets
Two sizes of nets were used: large (1 m × 1 m), and small (0.5 m × 1 m) (Bonar Industries, Zimbabwe). Each net consisted of two electrifiable copper wire grids (large: 0.9 m × 0.9 m; small: 0.45 m × 0.9 m) separated by black mosquito netting (Vale, 1974). Flies electrocuted on either face of the net were retained in shallow dark brown trays placed under the net and containing soapy water.

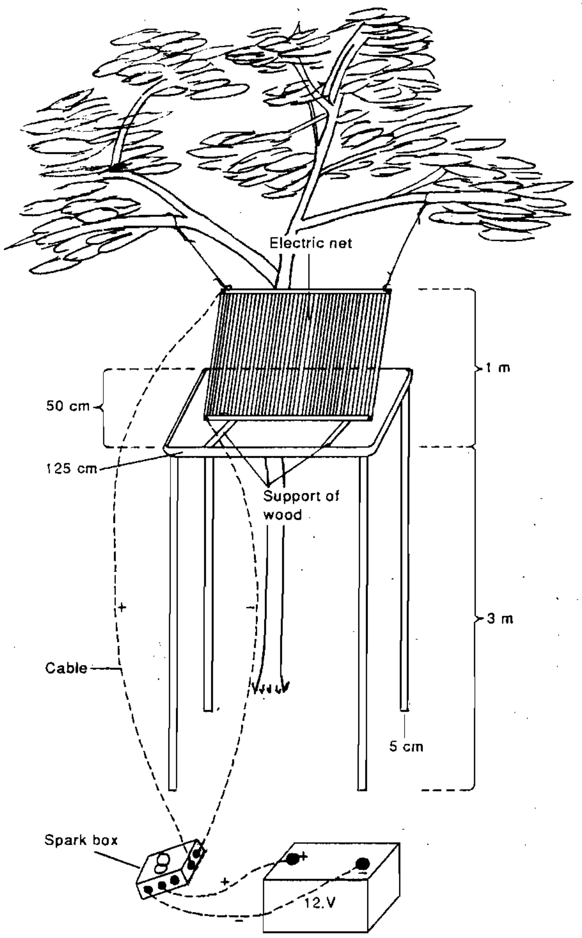

Figure 1. A diagram of the tower system used for the flight height study.

Experiments

Flight height. To capture flies travelling at different heights, four large nets were placed on trays containing soapy water and mounted on towers made of dark brown water pipes at 0–1 m, 1–2 m, 2–3 m and 3–4 m heights as illustrated in Figure 1. The design was a 4 × 4 Latin square involving four fixed positions for four days and repeated three times over 12 days. Each daily run was from 11:00 to 16:00 h. This time interval spans the peak activity periods of both sexes (M. M. Mohamed-Ahmed et al., 1994; unpublished). This experiment assumes that the nets, retrieval trays and towers (Figure 1) do not interfere with the natural flight paths of ranging tsetse by attracting or repelling them. If they do, it is assumed that the interference is the same at all heights.

Response to electrified nets. In the first set of experiments, two biconical traps were set at two fixed sites about 400 m apart. One trap was surrounded with an incomplete ring of three small nets and the other trap was left without nets as a control. The nets were placed on their shorter sides and the ring had a radius of 0.5 m. The ring of nets was alternated between the traps in a set of 2 × 2 Latin squares replicated 4 times. The experiments were set up at 11:00 h and catches recorded hourly between 12:00–16:00 h.

For the second set of experiments, three biconical traps were placed at three fixed sites about 400 m apart. Each of two traps was surrounded with an incomplete ring of three large nets and the third trap was used as a control. Two wider radii of 1 m and 2 m were employed for the rings. The experiment was laid out in a 3 × 3 Latin squares replicated twice. Catches were made daily between 11:00–16:00 h.

Data analysis

Data from all experiments were transformed to $\log_{10}(X + 1)$ before analysis.

The number of flies caught at different heights were compared using analysis of variance (ANOVA). Percentages of flies caught flying at each height were computed and compared.

Theory

Let x and y respectively represent the number of flies caught inside and outside the nets, z represent the number of flies caught by the trap surrounded by nets, and w represent the number of flies caught by the control trap. Furthermore, let the fraction of the perimeter covered by the incomplete ring of nets around a trap be p.

If the flies approach the trap in random directions and the nets do not interfere with the response of flies to the trap, then, $z/(1 - p)$ will be equal to w. Hence, the hypothesis to be tested is

H_0: $z/(1-p) = w$, i.e. flies do not 'see' the electric net,

H_1: $z/(1 - p) > w$, i.e. flies 'see' the electric net and are attracted to it,

$z/(1 - p) < w$, i.e. flies 'see' the electric net and avoid it.

Fly catches obtained from traps surrounded by nets were appropriately weighted (divided by $1 - p$) and compared to the unweighted catches of the control traps using analysis of variance (ANOVA).

To confirm whether the flies 'see' and avoid the nets, the number of flies expected to be caught on the outside net was estimated as

$$y' = (x + pz)/(1 - p),$$

while the number of expected to be caught on the inside net was obtained as

$$x' = (1 - p)y - pz.$$

If $y > y'$ then the flies were attracted to the nets, otherwise, they avoided the nets. If $x > x'$ then the flies were either attracted to the nets or were colliding with the inside nets while maneuvering round the enclosed trap.

The trap efficiency is estimated as

$$E = z/(z + x/p) \quad (1a)$$

or

$$E = pz/[y(1 - p)] \quad (2a)$$

or

$$E = w/(y/p). \quad (3a)$$

(Vale & Hargrove, 1979; Hargrove, 1980; Kyorku et al., 1990). If the flies avoid and also naturally fly over the nets, the number of flies caught on the outside or inside of the nets are underestimates of the number actually approaching or departing from the trap, respectively. Hence, the preceding formulae will yield over-estimates of the trap's efficiency.

If a proportion, r, of the flies 'see' and avoid the nets, equations (1a), (2a) and (3a) should be modified to become

$$E = z/[z + (1 + r)x/p] \quad (1b)$$

or

$$E = pz/[y(1 - p + r)] \quad (2b)$$

or

$$E = w/[y(1 + r)/p] \quad (2c)$$

which yield lower efficiency values.

Given that a proportion, h, of the flies naturally fly above the 1 m nets, equations (1a), (2a) and (3a) should be rewritten as

$$E = z/[z + (1 + h)x/p]. \quad (1c)$$

Table 1. Proportions of flies caught by electric nets at different heights above the ground level

Height (m)	No. of reps.	Male ($N = 72$)	Female ($N = 79$)	Total ($N = 151$)
0–1	12	51.4a	64.6a	58.3a
1–2	12	37.5a	27.8b	32.5a
2–3	12	6.9b 48.6	6.3c 35.4	6.6b 41.7
3–4	12	4.2b	1.3c	2.6b

Proportions in the same column having the same letter are not significantly different at 5% level.

or

$$E = pz/[y(1 - p + h)] \quad (2c)$$

or

$$E = w/[y(1 + h)/p]. \quad (3c)$$

Equations (1b) and (1c), (2b) and (2c), and (3b) and (3c) can be combined to give

$$E = z/[z + (1 + r + h)x/p], \quad (1d)$$

or

$$E = pz/[y(1 - p + r + h)] \quad (2d)$$

or

$$E = w/[y(1 + r + h)/p] \quad (3d)$$

which could yield a more reliable estimate of the efficiency of the trap. We assume that the probability of capture by, avoidance of, or flying over, the nets is the same on the way in as on the way out of the ring of nets. Equations 1d, 2d and 3d assume that there is no overlapping of the set of avoiding and over-flying tsetse. This assumption may not be entirely true as the tsetse may fly over the net in an attempt to avoid it. Hence, these last set of equations may yield underestimates of the trap efficiency.

Results and discussion

Flight height

Table 1 shows the proportions of flies caught by electric nets at different heights. Generally, the number of flies caught decreased as the height increased. However, the number of males flying below 1 m and between 1–2 m were not significantly different, indicating that male *G. f. fuscipes* naturally fly within 2 m above ground level. In contrast, females flying between 1–2 m were significantly fewer than (less than half of) those flying below 1 m. There were no significant differences between the proportions of either males or females flying between 2–3 m and 3–4 m. Overall, significantly higher ($P < 0.05$) proportion of males (48.6%) were flying over the 1 m net than the females (35.4%).

Whereas a fly can avoid a net hoisted above the ground level by flying under it, this is not true when the net is on the ground. Hence, the chances of a fly avoiding the net is probably higher when it is hoisted above the ground level. Thus, the percentage of flies travelling above the 1 m level may therefore be regarded as an underestimate.

Response of flies to electric nets

The trap surrounded by the 0.5 m radius incomplete ring of nets caught fewer flies than the control trap, with significant reductions in females and the total catches (Table 2). However, the follow-up experiment using the 1 m and 2 m radii showed that the average catches of traps within these two rings were not significantly different from those of the control trap (Table 3). These results indicate that flies were probably colliding with the inside net and getting killed while manoeuvering around the trap within the 0.5 m radius ring, thereby reducing the number of flies that would have been caught by the trap. Conversely, the similarity of catches by the traps within the 1 m and 2 m radii rings suggests that there was sufficient space for the flies to mill about near the traps without colliding with the inside nets. Nonetheless, catches in the control trap were higher than those of traps surrounded by nets (Table 3), thus suggesting that the flies were still colliding with the inside nets or being repelled by the nets. Hargrove (1980) suggested that the nets could have been repelling some flies because the presence of nets around a trap resulted in fewer catches than expected by the trap.

To confirm the above results, the expected catches on the two sides of the nets were computed for only the total (males + females) because of the low catches. Table 4 shows the result of the comparison of the expected and observed catches on both the outside and inside nets for all the three radii. The observed outside catches were significantly lower than expected thus confirming that the flies probably 'saw' and avoided the net. This result, combined with the fact that catches in the control trap were always higher than those of traps

Table 2. Mean catch/trap/hour in biconical traps enclosed by 0.5 m radius incomplete rings of electric nets (trap + net) and trap alone

Treatment	No. of reps.	Male	Female	Total
Trap alone	20	4.7 ± 1.3	11.2 ± 2.7	15.9 ± 3.3
Trap + net	20	2.9 ± 0.7	6.7 ± 1.9	9.6 ± 2.4
Prob > F		0.1872	0.0176	0.0086

(Trap catches in the trap + net system have been weighted as explained in the text.)

surrounded by nets (Table 3), suggests that the flies were repelled by the nets and do not enter into the ring when repelled. Conversely, the observed inside net catches were significantly higher than expected. This most likely confirms that some flies were still colliding with the inside nets while maneuvering around the trap, rather than suggests that the nets attracted the flies.

By subtracting the observed outside net catches from the expected and expressing the difference as a percentage of the expected catch, about 42–55% (46.7 ± 4.1%) of the total flies approaching the trap seemed to have avoided the nets, with the percentage ranging between 45–78 (61.4 ± 9.6%) for males and 27–51 (40.0 ± 7.1%) for females (Table 4). It has been shown by video-recordings that 15–20% of tsetse 'see' the nets and avoid contacting it altogether (Packer & Brady, 1990). Moreover, Griffiths & Brady (1994), provided some evidence, also from video-recordings, that up to 40% of *G. pallidipes* and *G. m. morsitans* behaviourally 'avoid' the nets. The latter authors further showed that this percentage may in fact be an underestimate of the real number of tsetse which avoid the electric nets. Our result of 42–55% for *G. f. fuscipes* supports these findings.

Since 42–55% of the flies were shown above to 'see' and avoid the nets (Table 4), the figures of the overflyers (Table 1) may well be taken to apply to the 45–58% which did not 'see' the nets. Provided that the flies did not fly over a net in an attempt to avoid it, it can be shown that 72–93% of all approaching flies will escape being caught by the 1 m net as against the mean of ca 42% obtained (Table 1) when assuming that the flies do not 'see' the nets. The proportions of flies which naturally fly over the ring of nets together with those which 'see' and avoid the nets must therefore be accounted for when estimating trap efficiency.

Table 3. Mean catch/trap/day in biconical traps enclosed by incomplete rings of electric nets (trap + net) and trap alone

Treatment	No. of reps.	Male	Female	Total
Trap alone	6	14.5 ± 3.5	23.3 ± 4.9	37.8 ± 6.0
Trap + net (1 m radius)	6	14.6 ± 4.5	16.4 ± 3.3	31.0 ± 7.1
Trap + net (2 m radius)	6	14.0 ± 2.6	16.9 ± 4.5	30.8 ± 6.4
Prob. > F		0.8737	0.2438	0.5608

Trap catches in the trap + net system have been weighted as explained in the text.

Table 4. Observed and expected mean of total (males + females) catches by electric nets

Net surface	Radius of ring m	Observed mean catch	Expected mean catch	Prob. > Chi^2
Outside	0.5	3.9 ± 0.7	6.7 ± 1.3	0.0193
	1	15.2 ± 2.5	26.9 ± 5.2	0.0492
	2	4.8 ± 0.5	10.6 ± 2.2	0.0293
Inside	0.5	3.3 ± 0.7	1.5 ± 0.4	0.0288
	1	10.5 ± 1.8	3.4 ± 1.3	0.0456
	2	3.5 ± 0.8	0.4 ± 0.2	0.0268

*Means are per hour for the 0.5 m radius and per day (consisting of 5 hours) for the other radii.

Table 5. Efficiency estimates of the biconical trap using two radii of electric nets ring and different equations*

		Radius	
		1 m	2 m
Male	eq. 1(a)	52.8 ± 14.4	87.9 ± 5.4
	eq. 1(b)	45.9 ± 14.7	83.0 ± 7.6
	eq. 1(c)	47.1 ± 14.7	83.9 ± 7.2
	eq. 1(d)	42.3 ± 14.7	79.9 ± 9.0
Female	eq. 1(a)	35.8 ± 4.5	55.5 ± 9.7
	eq. 1(b)	28.7 ± 3.9	48.9 ± 10.8
	eq. 1(c)	29.4 ± 4.0	49.5 ± 10.7
	eq. 1(d)	24.5 ± 3.5	44.7 ± 11.5
Total	eq. 1(a)	38.3 ± 2.9	63.7 ± 8.1
	eq. 1(b)	29.9 ± 2.6	56.0 ± 9.5
	eq. 1(c)	30.6 ± 2.6	56.7 ± 9.3
	eq. 1(d)	25.0 ± 2.3	51.0 ± 10.3

^{ast} h and r for equations 1b-d are obtained from Tables 1 and 4, respectively. If the expected outside net catch is y' and observed is y, then $r = (y' - y)/y'$.

Trap efficiency

All the equations (1a–3d) for estimating trap efficiency assume that a fly approaches and departs from the trap in random directions. While our data approximately supported random departure, the assumption with respect to random approach was grossly violated. This probably explains why most of the estimates obtained using all forms of equations 2 and 3, which assume random approach, fell within unrealistic ranges (i.e. >100%). Hence, only the estimates obtained using all forms of equation (1) are presented.

The efficiency estimates (Table 5) show substantial differences between equations within the same sex or the total catch. However, all equations gave higher estimates for males than females and higher values for the 2 m radius than the 1 m radius ring. This suggests that the 2 m radius ring had provided more room than the 1 m radius for tsetse to mill about without colliding with the inside of the nets. Higher efficiency estimates would probably be obtained if larger radii of the ring of nets were used. This reveals the danger of determining the efficiency of a tsetse trap based only on one radius. However, while too narrow radius may result in underestimates, too wide radius may result in overestimates of the efficiency as a result of too few flies getting caught in the inside nets. There is therefore a need to determine the optimum radius of the incomplete ring of nets in such experiments. Experiments are being planned to determine the optimum radius of incomplete ring of electric nets in order to estimate the trap efficiency for *G. f. fuscipes* along the Lake Victoria shore, Kenya.

Although the numbers of tsetse caught during these experiments were few, the present study nonetheless confirmed the need to account for flies which 'see' and avoid the nets and those which naturally fly above the nets in the estimation of the efficiency of tsetse traps using the electrified nets method.

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