The responses of *Glossina pallidipes* and *G. longipennis* (Diptera: Glossinidae) to odour-baited traps and targets at Galana Ranch, south-eastern Kenya

M. Baylis[1] and C.O. Nambiro

Kenya Trypanosomiasis Research Institute (KETRI)

Abstract

Four designs of trap, all made from identical material, were compared at Galana Ranch, south-eastern Kenya, as sampling devices for *Glossina pallidipes* Austen and *G. longipennis* Corti. The NG2G and Epsilon traps caught more than twice as many female *G. pallidipes* as the biconical trap, and the F3 was intermediate. A similar pattern was observed for males, although the differences were smaller, and not significant. The NG2G, Epsilon and F3 traps all caught approximately twice as many male and female *G. longipennis* as the biconical trap. Acetone (500 mg/h) significantly increased trap catches of *G. pallidipes*, and there was a synergism between acetone and 4-methylphenol (0.8 mg/h). There was little or no effect with 1-octen-3-ol (0.8 mg/h). Acetone, 1-octen-3-ol, and 4-methylphenol all increased trap catches of *G. longipennis*, and there were no synergisms among them. Cow urine (850 mg/h) increased the catches of both species in traps baited with acetone and 1-octen-3-ol, although not significantly for *G. longipennis*. There was no effect with 3-methylphenol (0.8 mg/h). The addition of 3-propylphenol to traps baited with acetone, 1-octen-3-ol and 4-methylphenol had no effect on the catches of either species. For *G. pallidipes*, a combination of acetone, 1-octen-3-ol, 4-methylphenol and 3-propylphenol was calculated to have a catch index of 6-8 over unbaited traps, a value lower than that reported for Zimbabwe and Nguruman, Kenya, and greater than that reported for Somalia. The catches of *G. longipennis* were approximately three times higher on electrified targets than in F3 traps, although there was no difference in the catch of *G. pallidipes*.

Introduction

Studies in several African countries have demonstrated that certain odours derived from host animals are potent olfactory attractants of the tsetse fly, *Glossina pallidipes* Austen (Vale, 1974a; Takken, 1984; Vale & Hall 1985a, 1985b; Dransfield *et al.*, 1986; Vale *et al.*, 1988; Torr *et al.*, 1989). However, where results are directly comparable, it appears that the response of *G. pallidipes* to such odours is not always consistent. For example, in Zimbabwe a combination of acetone, 1-octen-3-ol, 4-methylphenol and 3-propylphenol increased the trap catches of *G. pallidipes*, compared to traps without odour, by approximately 20 times (Vale & Hall, 1985a; Vale *et al.*, 1988); in Somalia the same odours, at similar release rates, increased trap catches by only 3-4 times (Torr *et al.*, 1989).

In contrast to the situation with *G. pallidipes*, little is known about the responses of *G. longipennis* Corti to odour baits probably because, as a member of the *fusca* group, it has previously not been considered an important vector of trypanosomiasis. Recently, however, there has been growing interest in this species (Kyorku *et al.*, 1990; Brightwell *et al.*, 1991) because it is known to carry infections of *Trypanosoma congolense* and *T. vivax* (Owaga, 1981), and to feed on and be able to spread infection to cattle (J.N. Makumi, unpublished data).

Correspondence: Dr M. Baylis, Tsetse Research Laboratory, University of Bristol, Langford, Bristol BS18 7DU, UK.
[1]on secondment from the Tsetse Research Laboratory, University of Bristol, UK.

Odour attractants may be used with traps for tsetse fly control and population monitoring. In recent years in Kenya, odour-baited traps have been used for such purposes against both *G. pallidipes* and *G. longipennis* (Dransfield *et al.*, 1990; Opiyo *et al.*, 1990). Some work has been carried out on the relative performances of several trap designs against the two species (Brightwell *et al.*, 1987, 1991; Torr *et al.*, 1989; Kyorku *et al.*, 1990). However, these comparisons included F3 traps made in Zimbabwe, and other traps manufactured elsewhere, with the complication that the traps were made from different materials. This is important because, when comparing different trap designs, the variables being examined are shape, size and colour.

These observations prompted studies at Galana Ranch, south-eastern Kenya, of the responses of *G. pallidipes* and *G. longipennis* to various types of odour bait and the performance of four trap designs made from identical materials.

Materials and methods

Study sites

Galana Ranch is a 6000 km² cattle ranch in south-eastern Kenya (39-40°E, 3-4°S), bordered to the west by Tsavo East National Park, and to the south by the Sabaki River. Four species of tsetse fly occur on the ranch (Opiyo *et al.*, 1990) although only two are found in large numbers. *G. longipennis* inhabits the dryer western and central regions. Experiments on this species were performed at sites near the edge of the Sabaki river, where it is most abundant. Experiments on *G. pallidipes* were performed at sites in the wetter, eastern part of the ranch.

Traps and targets

For the comparison of different trap designs, three each of four trap types were manufactured from single batches of blue and black cotton cloth. The four types were the biconical (Challier *et al.*, 1977), NG2G (Brightwell *et al.*, 1991), Epsilon (G.A. Vale, unpublished data) and F3 (a blue/black version of the F2 (Green & Flint, 1986)). Biconical and F3 traps were supported internally on metal frames, and NG2G and Epsilon traps were supported externally, with metal poles. All traps had cones of white nylon netting into which a 2 cm metal ring was sewn. This was the entrance hole to the collecting cage, a 20 x 10 x 7 cm metal frame covered with a polythene bag. The netting cone and collecting cage were held up by a metal frame on a centre pole, of the type usually used for biconical traps.

Imported F3 traps (Bonar Industries, Harare, Zimbabwe) were used in most experiments to compare odour baits. In two experiments, F3 traps were compared with 1 x 1 m electrified black targets (Vale, 1974b), without flanking nets. Tsetse flies attracted to the black target were killed or stunned by the electrocuting wires, and fell into a tray containing sticky polybutene. The traps and electric targets were operated from 16.00 to 18.00 h daily for *G. pallidipes*, and from 18.00 to 19.15 h for *G. longipennis*. This coincided with the peak activity time of the two species at Galana Ranch.

Odour baits

Acetone was dispensed from bottles with a 1.5 cm diameter aperture (release rate 500 mg/h). 1-octen-3-ol (hereafter octenol) was dispensed from 10 ml bottles with the lid replaced by a rubber septum (0.8 mg/h), or from 5 x 5 cm sachets manufactured from 150 µm polythene tubing (1.5 mg/h). Mixtures of 4 ml of 3-methylphenol, 4-methylphenol, 3-propylphenol and octenol were also dispensed from 5 x 5 cm sachets (0.8 mg/h). Cow urine, collected from local Zebu cattle, was stored at ambient temperature in 5 l plastic jerry cans until use in experiments. It was dispensed from beakers with a 10 cm diameter aperture (850 mg/h).

All release rates were estimated by measuring the weight loss of odour samples, kept outdoors in Galana Ranch, for seven days.

Experimental design and analysis

All experiments used thrice-replicated 4 x 4, twice-replicated 6 x 6, or unreplicated 8 x 8 Latin square designs. Sites were at least 200 m apart, and treatments were changed after 24 h. Males and females were analysed separately. Daily catches were subjected to a log (n+1) transformation prior to analysis of variance. Where the effect of treatment was significant, differences among means were examined by the T method (Sokal & Rohlf, 1981). In some cases, the experimental design allowed treatments to be considered to be permutations of three factors. In these instances, a second ANOVA was used to detect effects of individual factors and interactions among them.

For presentation, detransformed mean catches of treatments were divided by that of the control to give a 'catch index'.

Results

Comparison of trap types

The performances of the biconical, NG2G, Epsilon and F3 traps were compared for *G. pallidipes* and *G. longipennis*, in separate experiments. All traps were baited with acetone and a sachet of an 8:4:1 mixture of 4-methylphenol, octenol and 3-propylphenol. The NG2G and Epsilon traps caught significantly more female *G. pallidipes* than the biconical trap. The performance of the F3 trap was intermediate. The same pattern was observed for male *G. pallidipes*, although the treatments were not significantly different (table 1).

There were no differences in the catches of *G. longipennis* in NG2G, Epsilon and F3 traps although all caught significantly more males and females than the biconical trap (table 2).

Comparison of odours

Eight treatments were made from all possible permutations of acetone, a bottle of octenol and a sachet containing 4-methylphenol. These treatments were compared for *G. pallidipes* and *G. longipennis* in separate experiments, using F3 traps.

For both male and female *G. pallidipes*, the treatments of octenol and 4-methylphenol, alone and both together,

Table 1. The detransformed mean catches of *Glossina pallidipes* in baited traps of four types. The catch index is relative to that of the biconical trap.

Trap	Males			Females		
	detrans mean	catch index	F-value (d.f.)	detrans mean	catch index	F-value (d.f.)
Biconical	16.5		1.09^{ns} (3,24)	19.6^{a}		7.21** (3,24)
NG2G	23.2	1.4		43.3^{b}	2.2	
Epsilon	21.8	1.3		44.8^{b}	2.3	
F3	18.2	1.1		28.3^{ab}	1.4	

Means not followed by the same letter are significantly different (P <0.05). ** P <0.01; ^{ns}not significant.

Table 2. The detransformed mean catches of *Glossina longipennis* in baited traps of four types. The catch index is relative to that of the biconical trap.

Trap	Males			Females		
	detrans mean	catch index	F-value (d.f.)	detrans mean	catch index	F-value (d.f.)
Biconical	12.1^{a}		8.9*** (3,24)	6.3^{a}		15.9*** (3,24)
NG2G	25.3^{b}	2.1		15.0^{b}	2.4	
Epsilon	22.6^{b}	1.9		14.3^{b}	2.3	
F3	21.5^{b}	1.8		17.6^{b}	2.8	

Means not followed by the same letter are significantly different (P <0.05). *** P <0.001.

did not perform significantly better than the control with no odour. However, all treatments which included acetone caught significantly more flies than the control (table 3).

There was very little effect of octenol, either on its own, or in combination with acetone and 4-methylphenol. Considering the addition of octenol (O) to a treatment (for example to acetone (A), to make A,O), in seven out of eight instances such addition increased the catch, although not significantly. This suggests that there is a small, but positive effect of octenol on the catches of *G. pallidipes*.

For both male and female *G. pallidipes*, the highest catches were obtained with the combination of acetone, octenol and 4-methylphenol. These catches were significantly greater than those with acetone alone.

The situation was different with *G. longipennis*. For males, acetone and octenol caught significantly more flies than the control with no odour, and 4-methylphenol was intermediate (table 4). All combinations of two odours caught significantly more males than the treatments of acetone, octenol and 4-methylphenol alone. The highest catch was with acetone, octenol and 4-methylphenol together, although this was not significantly greater than catches with combinations of two odours. The same pattern was evident with female *G. longipennis*, although this was less apparent statistically.

To elucidate more clearly the effects of the individual odours and possible non-multiplicativity (non-additivity

Table 3. The detransformed mean catches of *Glossina pallidipes* in traps baited with all combinations of acetone (A), octenol (O) and 4-methylphenol (4MP).

Odour	Males			Females		
	detrans mean	catch index	F-value (d.f.)	detrans mean	catch index	F-value (d.f.)
No odour	8.4^{a}		14.5*** (7,42)	16.3^{a}		22.6*** (7,42)
A	22.3^{bc}	2.7		39.3^{bc}	2.4	
O	12.1^{ab}	1.4		15.8^{a}	1.0	
4MP	10.4^{ab}	1.2		21.4^{ab}	1.3	
A,O	28.5^{cd}	3.4		56.2^{cd}	3.5	
A,4MP	42.6^{cd}	5.1		92.8^{d}	5.7	
O,4MP	12.0^{ab}	1.4		22.4^{ab}	1.4	
A,O,4MP	48.8^{d}	5.8		99.1^{d}	6.1	

Means not followed by the same letter are significantly different (P <0.05). *** P <0.001.

Table 4. The detransformed mean catches of *Glossina longipennis* in traps baited with all combinations of acetone (A), octenol (O) and 4-methylphenol (4MP).

Odour	Males			Females		
	detrans mean	catch index	F-value (d.f.)	detrans mean	catch index	F-value (d.f.)
No odour	5.2^{a}		20.0*** (7,42)	6.2^{a}		14.3*** (7,42)
A	12.5^{b}	2.4		12.0^{ab}	1.9	
O	12.3^{b}	2.4		12.7^{ab}	2.1	
4MP	8.4^{ab}	1.6		9.0^{a}	1.5	
A,O	27.8^{c}	5.4		23.4^{b}	3.8	
A,4MP	29.8^{c}	5.7		26.0^{bc}	4.2	
O,4MP	34.4^{c}	6.6		23.9^{bc}	3.9	
A,O,4MP	52.3^{c}	10.1		50.4^{c}	8.1	

Means not followed by the same letter are significantly different (P <0.05). *** P <0.001.

with log-transformed data) among them, the log-transformed data from the two experiments were reanalysed by ANOVA, with the single 'treatment' effect replaced by the three factors 'acetone', 'octenol' and '4-methylphenol'. This allowed the statistical detection of main effects (an effect of a factor which occurs in any combination of other factors) as significant factor terms in the ANOVA, and the statistical detection of non-additive effects (either synergisms or interferences) as significant interaction terms in the ANOVA. For *G. pallidipes*, there were strong main effects of acetone and 4-methylphenol (table 5). There was no main effect of octenol, although it approached significance in males. For males, there was an apparent synergism between acetone and 4-methylphenol when presented together. The catch indices were 2.7 for acetone alone, and 1.2 for 4-methylphenol alone, suggesting a combined catch index of 3.2 if there was no synergism. The observed combined catch index was 5.1 (table 3). A similar pattern was observed for females, although the synergism was not quite significant.

For *G. longipennis*, there were strong main effects of acetone, octenol and 4-methylphenol, but no synergism or interferences (table 5).

Table 5. The effects of acetone (A), octenol (O) and 4-methylphenol (4MP) on catches of *Glossina pallidipes* and *G. longipennis* presented with F3 traps. Numbers are F-values (all with d.f. = 1,42) from the ANOVA.

Effect	*G. pallidipes*		*G. longipennis*	
	males	females	males	females
Main effects				
A	86.1***	130.8***	45.1***	36.8***
O	3.1[a]	1.0	52.4***	35.4***
4MP	7.9**	21.2***	36.3***	25.6***
Interactions				
A x O	0	0.8	2.8	0.4
A x 4MP	4.1*	3.5[a]	0	1.4
O x 4MP	0.4	0.2	0.6	0.4
A x O x 4MP	0.1	0.7	2.7	0.3

[a]P <0.1; *P <0.05; **P <0.01; ***P <0.001.

Table 6. The detransformed mean catches of *Glossina pallidipes* and *G. longipennis* with an F3 trap and an electrified black target, when presented with different combinations of acetone (A) and 4-methylphenol (4MP).

A. *G. pallidipes*

Odour	Males		Females	
	F3 trap	Target	F3 trap	Target
No odour	9.9	9.0	7.4	11.7
A	23.4	22.3	22.8	26.2
4MP	13.5	17.4	12.1	15.3
A + 4MP	51.6	57.0	56.1	57.0
Effect of trap-target	$F_{1,42}$ = 1.7[ns]		$F_{1,42}$ = 1.5[ns]	

B. *G. longipennis*

Odour	Males		Females	
	F3 trap	Target	F3 trap	Target
No odour	2.7	10.0	2.2	8.4
A	10.5	17.4	4.3	11.9
4MP	4.8	14.1	3.2	11.3
A + 4MP	13.3	28.3	7.2	24.3
Effect of trap-target	$F_{1,42}$ = 30.7***		$F_{1,42}$ = 62.9***	

***P <0.001; [ns]not significant.

Further experiments investigated whether the attraction of *G. pallidipes* and *G. longipennis* to acetone and 4-methylphenol differed when the odours were presented with F3 traps or targets. The four permutations of acetone and a sachet of 4-methylphenol were presented with either F3 traps or electrified black targets to give eight treatments. The results were analysed by ANOVA with the factors acetone, 4-methylphenol and trap-target. As expected from the previous experiments, there were significant effects of acetone and 4-methylphenol on the catch of male and female *G. pallidipes* and *G. longipennis*. For *G. pallidipes*, there was no effect of trap-target on catch (table 6). However, targets caught approximately 2.6 times as many male *G. longipennis*, and 3.4 times as many females, as the F3 traps. There were no significant interactions between trap-target and odour.

Table 7. Detransformed mean catches of *Glossina pallidipes* in F3 traps baited with synthetic phenols and cow urine. 4MP = 4-methylphyenol; 3MP = 3-methylphenol; PP = 3-propylphenol. All treatments include acetone and octenol.

Odour	Males			Females		
	detrans mean	catch index	F-value (d.f.)	detrans mean	catch index	F-value (d.f.)
Control	34.7[a]		6.4*** (3,45)	45.2[a]		8.2*** (3,45)
3-month-old urine	59.5[b]	1.7		99.3[b]	2.2	
1-week-old urine	50.8[ab]	1.5		94.8[b]	2.1	
4MP	57.5[b]	1.7		91.9[b]	2.0	
3MP	35.8[a]	1.0		46.6[a]	1.0	
4MP:PP (8:1)	58.5[b]	1.7		102.1[b]	2.3	

Means not followed by the same letter are significantly different (P <0.05). *** P <0.001.

Table 8. Detransformed mean catches of *Glossina longipennis* in F3 traps baited with synthetic phenols and cow urine. 4MP = 4-methylphenol; 3MP = 3-methylphenol; PP = 3-propylphenol. All treatments include acetone and octenol.

Odour	Males			Females		
	detrans mean	catch index	F-value (d.f.)	detrans mean	catch index	F-value (d.f.)
Control	12.1[ab]		10.5*** (3,45)	8.3[ab]		10.2*** (3,45)
3-month-old urine	15.8[bc]	1.3		11.0[bc]	1.3	
1-week-old urine	18.5[bc]	1.5		12.0[bc]	1.4	
4MP	24.3[c]	2.0		21.9[c]	2.6	
3MP	7.7[a]	0.6		4.8[a]	0.6	
4MP:PP (8:1)	21.9[c]	1.8		19.9[c]	2.4	

Means not followed by the same letter are significantly different (P <0.05). *** P <0.001.

The responses of *G. pallidipes* and *G. longipennis* to cow urine and phenols were examined in separate experiments. One-week-old and three-month-old cow urine, and sachets of 4-methylphenol alone, 3-methylphenol alone, and an 8:1 mixture of 4-methylphenol and 3-propylphenol were presented with F3 traps. All treatments, including a control, were baited in addition with acetone and an octenol sachet. The catches of male and female *G. pallidipes* were not increased when traps were baited with sachets of 3-methylphenol (table 7). One-week-old and three-month-old cow urine, 4-methylphenol and the mixture of 4-methylphenol and 3-propylphenol increased the catches of males by 1.5-1.7 times, although not significantly for one-week-old urine. The catches of females were significantly increased by all four treatments and were at least doubled in all cases. There were no differences among the four treatments.

The catches of *G. longipennis* in traps baited with 3-methylphenol were only 60% that of the control, although this reduction was not significant (table 8). Three-week-old and three-month-old cow urine increased the catches of *G. longipennis*, although again this was not significant. Significantly increased catches were obtained with sachets of 4-methylphenol and a mixture of 4-methylphenol and 3-propylphenol, which approximately doubled the catches of males, and increased the catches of females by about 2.5 times.

Discussion

In general, there were only small differences in the performances of the four trap designs for both *G. pallidipes* and *G. longipennis*. The greatest catch indices (compared to biconical traps) were 2.3 for *G. pallidipes*, and 2.8 for *G. longipennis*. This is similar to the findings in Somalia for *G. pallidipes* (Torr *et al.*, 1989), and many of those reported in Nguruman, Kenya (Brightwell *et al.*, 1987, 1991), and contrasts with a catch index of ten for the F2 (a less effective version of the F3: Green & Flint, 1986) relative to the biconical trap in Zimbabwe (Flint, 1985).

It has been reported in Zimbabwe that F3 traps catch 200-300% more female *G. pallidipes* than NG2B traps (an earlier version of the NG2G design) while in Kenya the catches of F3 and NG2B traps did not differ (Brightwell *et al.*, 1991). Both experiments used F3 traps and NG2B traps made from different materials with netting cones of different colours. At Galana Ranch, with traps made from identical materials and colours, the NG2G trap caught 50-60% more female *G. pallidipes* than the F3 design. Since the NG2G trap is reported to catch 60% more females than the NG2B (Brightwell *et al.*, 1991), this result provides strong support for the findings in Kenya described above. The different findings in Kenya and Zimbabwe probably reflect differences in fly behaviour or climate between the two countries. However, they may also reflect differences in experimental design. In the experiments in Kenya, traps were run for 24 h periods while those in Zimbabwe were run for afternoons only (R.D. Dransfield, pers. comm.). Since the relative performance of traps may change during the day in relation to changes in temperature (Brightwell *et al.*, 1987) it is possible that some of the differences between results may be attributable to the exclusion of the morning catch in Zimbabwe. However, such an effect must at the most be small because in Rekomitjie, Zimbabwe, the catch of *G. pallidipes* between 07.00 and 09.00 h is only approximately 10% of the catch between 15.00 and 18.00 h, while at Galana Ranch it is approximately 75% (personal observation).

The odour responses of *G. pallidipes* at Galana Ranch differed in some ways from those observed in Zimbabwe (Vale & Hall, 1985a, 1985b; Vale *et al.*, 1988), Nguruman in Kenya (Dransfield *et al.*, 1986), and Jilaal Moogi in Somalia (Torr *et al.*, 1989). In Zimbabwe, acetone released at 500 mg/h increased trap catches by 2-3 times, in Nguruman by 1.5 times, and at Galana Ranch by about 2.5 times. However, in Somalia the catch was not significantly increased. In Zimbabwe, octenol released at 0.5 mg/h increased the catch significantly by 1.5 times, and in Nguruman by 1.5 times. In Somalia the catch was not significantly increased, and at Galana Ranch a slightly higher release rate of octenol had little or no effect on the catch. It thus appears that with respect to attraction to acetone, *G. pallidipes* at Galana Ranch are similar to those at Nguruman in Kenya and in Zimbabwe; but with respect to attraction to octenol they are similar to those at Jilaal Moogi in Somalia.

The addition of 3-methylphenol to F3 traps baited with acetone and octenol, significantly increased the catch of *G. pallidipes* in Zimbabwe by 1.6 times (Hall *et al.*, 1990), while at Galana Ranch there was no effect on catch. The reason for this difference is not clear. The addition of 3-methylphenol reduced the catch of *G. longipennis*, suggesting that it may be a repellent of this species, although the reduction was not significant.

Vale *et al.* (1988) reported that in Zimbabwe 4-methylphenol did not significantly increase the catch of *G. pallidipes* in traps baited with acetone and octenol, but that it reacted synergistically with 3-propylphenol such that together the catch was increased by 3.5 times. At Galana Ranch, 4-methylphenol increased the catch of traps baited with acetone and octenol by about 1.7 times. However, the addition of 3-propylphenol to 4-methylphenol did not appear to increase the catch further. This is of importance in light of the high cost of 3-propylphenol. From the prices given by Vale *et al.* (1988), this chemical contributes 90% of the cost of the odours in an 8:1 sachet of 4-methylphenol and 3-propylphenol.

Based on the catch indices of the individual components, in Zimbabwe an odour combination of the two phenols, acetone and octenol (PAO mixture) is expected to increase the catch of *G. pallidipes* by about 20 times (Vale & Hall, 1985a; Vale *et al.*, 1988; Torr *et al.*, 1989). At Nguruman, NG2B traps baited with the PAO mixture caught 1.5 times more *G. pallidipes* than traps baited with acetone and cow urine (Brightwell *et al.*, 1991). Using catch indices of 3.6 and 3.1 for acetone and cow urine, respectively (Dransfield *et al.*, 1986), this gives an estimated catch index of about 17 for the PAO mixture over unbaited traps. However, at Jilaal Moogi in Somalia, the PAO mixture gave a catch index of only 3-4 (Torr *et al.*, 1989). At Galana Ranch, the phenols increased the catch of *G. pallidipes* in traps baited with acetone and octenol by a factor of 2. Since acetone and octenol combined, increased the catch by a factor of 3-4, this suggests a catch index of 6-8 for the PAO mixture. This is interesting in the light of the location of Galana Ranch between Nguruman and Somalia (fig. 1).

Studies in Zimbabwe have suggested the existence of certain synergisms between odours in their effects on the catch of *G. pallidipes*. Vale & Hall (1985b) reported a synergism between octenol and an unidentified component of ox breath, and Vale *et al.* (1988) reported a synergism between 4-methylphenol and 3-propylphenol. These synergisms are suggested by a comparison of catch indices, but have not been demonstrated statistically. Using a factorial experimental design, we here demonstrated a statistically significant synergism between acetone and 4-methylphenol for male *G. pallidipes*, and a synergism that approached significance for females of the species. No synergisms among these odours were detected for *G. longipennis*, although a synergism between acetone and cow urine has been reported at Nguruman (Kyorku *et al.*, 1990).

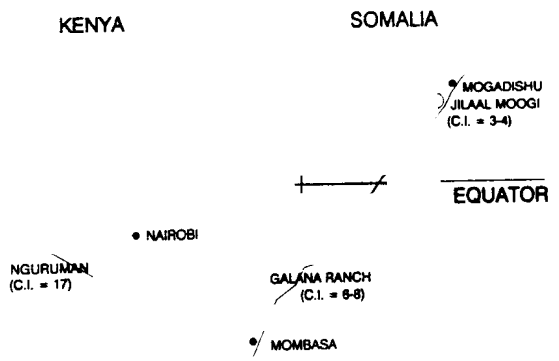

Fig. 1. The location of Galana Ranch relative to that of Nguruman, Kenya, and Jilaal Moogi, Somalia. At each locality, C.I. is the catch index of *Glossina pallidipes* for traps baited with acetone, octenol, 4-methylphenol and 3-propylphenol, compared to unbaited traps.

The responses of *G. longipennis* to odours differed in some ways to those of *G. pallidipes*. Notably, octenol was very attractive to *G. longipennis*, while, at the same concentration, it had little or no effect on the catches of *G. pallidipes*. It is also interesting that at Galana Ranch acetone alone increased the catch of *G. longipennis* by approximately 2 times, while there was no significant effect of acetone alone on the catch of *G. longipennis* at Nguruman (Kyorku *et al.*, 1990). As with *G. pallidipes*, estimates of the catch index of the PAO mixture for *G. longipennis* are lower at Galana Ranch than in Nguruman. At Galana Ranch, phenols increased the catch of *G. longipennis* in traps baited with acetone and octenol by about 2.1 times. Since acetone and octenol combined gave a catch index of 3.5-5.5, this suggests a catch index of 7-12 for the PAO mixture. Using the reasoning given earlier for *G. pallidipes*, a catch index of about 20 can be estimated for the PAO mixture for *G. longipennis* at Nguruman.

There was no significant difference between the catches of *G. pallidipes* with F3 traps and unflanked electrified targets when unbaited or baited with acetone and 4-methylphenol. However, electrified targets caught approximately 3 times as many *G. longipennis* as the F3 traps. NG2B traps are known to have a low efficiency (Vale & Hargrove, 1979) at capturing *G. longipennis* (Kyorku *et al.*, 1990), and the significantly greater catches with targets therefore suggest that target control operations may be more effective against *G. longipennis* than those with traps. A trap control operation at Nguruman, Kenya, reduced the numbers of *G. longipennis* by 80-90% in the dry season, but during the rainy season numbers returned to the level found outside the control area (Dransfield *et al.*, 1990). Interestingly, a target control operation at Galana Ranch also failed to control *G. longipennis* as effectively as *G. pallidipes*, although it was eradicated in one out of three blocks (Opiyo *et al.*, 1990).

In conclusion, the results presented here suggest that at Galana Ranch the control of *G. pallidipes* should be attempted with targets or traps (either NG2G or Epsilon design), baited with acetone and 4-methylphenol, or acetone and cow urine. The control of *G. longipennis* should be attempted with targets, baited with acetone, octenol and 4-methylphenol, or acetone, octenol and cow urine. The control or both species should be attempted with targets baited as described for *G. longipennis*.

Acknowledgements

We are grateful to the management of ADC Galana Ranch for use of facilities and the Director, KETRI, for permission to publish. We are also grateful to R.D. Dransfield and R. Brightwell for much advice and a demonstration of how to compare traps. We thank them, and C.H. Green, A.D. Irvin, and A.M. Jordan for comments on the manuscript. Special thanks are offered to the KETRI Entomology team at Galana Ranch for assistance with the experiments; and H. Alushula, A. Masinde, E.A. Opiyo and P. Stevenson for more general assistance. This work was funded by KETRI and the Overseas Development Administration of the UK government, through their ODA/KETRI Animal Trypanosomiasis Research Project.

References

Brightwell, R., Dransfield, R.D., Kyorku, C., Golder, T.K., Tarimo, S.A. & Mungai, D. (1987) A new trap for *Glossina pallidipes*. *Tropical Pest Management* **33**, 151–159.

Brightwell, R., Dransfield, R.D. & Kyorku, C. (1991) Development of low-cost tsetse trap and odour baits for *Glossina pallidipes* and *G. longipennis* in Kenya. *Medical and Veterinary Entomology* **5**, 153–164.

Challier, A., Eyraud, M., Lafaye, A. & Laveissière, C. (1977) Amélioration du rendement du piege biconique pour glossines (Diptera, Glossinidae) par l'emploi d'un cone inferieur bleu. *Cahiers ORSTOM, Serie Entomologie Medicale et Parasitologie* **15**, 283–286.

Dransfield, R.D., Brightwell, R., Chaudhury, M.F., Golder, T.K. & Tarimo, S.A.R. (1986) The use of odour attractants for sampling *Glossina pallidipes* Austen (Diptera: Glossinidae) at Nguruman, Kenya. *Bulletin of Entomological Research* **76**, 607–619.

Dransfield, R.D., Brightwell, R., Kyorku, C. & Williams, B. (1990) Control of tsetse fly (Diptera: Glossinidae) populations using traps at Nguruman, south-west Kenya. *Bulletin of Entomological Research* **80**, 265–276.

Flint, S. (1985) A comparison of various traps for *Glossina* spp (Glossinidae) and other Diptera. *Bulletin of Entomological Research* **75**, 529–534.

Green, C.H. & Flint, S. (1986) An analysis of colour effects in the performance of the F2 trap against *Glossina pallidipes* Austen and *G. morsitans morsitans* Westwood (Diptera: Glossinidae). *Bulletin of Entomological Research* **76**, 409–418.

Hall, D.R., Gough, A.J.E., Adams, P.H., Beevor, P.S., Cork, A., Green, C.H., Smith, J.L., Taylor, J.H.L. & Warnes, M.L. (1990). *Identification of host odour attractants for tsetse flies*. Final Report 1986-1990, Natural Resources Institute, Chatham, Kent.

Kyorku, C., Brightwell, R. and Dransfield, R.D. (1990) Traps and odour baits for the tsetse fly *Glossina longipennis* (Diptera: Glossinidae). *Bulletin of Entomological Research* **80**, 405–415.

Opiyo, E.A., Njogu, A.R. & Omuse, J.K. (1990) Use of impregnated targets for control of *Glossina pallidipes* in Kenya. *Insect Science and its Application* **11**, 417–425.

Owaga, M.L.A. (1981) Ecological studies and laboratory rearing of the tsetse species *Glossina longipennis* Corti in Kenya. *Insect Science and its Application* **2**, 197–200.

Sokal, R.R. & Rohlf, F.J. (1981) *Biometry*. 2nd edn. pp. 245-247. New York, W.H. Freeman and Company.

Takken, W. (1984) Studies on the biconical trap as a sampling device for tsetse (Diptera: Glossinidae) in Mozambique. *Insect Science and its Application* **5**, 357–361.

Torr, S.J., Parker, A.G. & Leigh-Browne, G. (1989) The responses of *Glossina pallidipes* Austen (Diptera: Glossinidae) to odour-baited traps and targets in Somalia. *Bulletin of Entomological Research* **79**, 99–108.

Vale, G.A. (1974a) The responses of tsetse flies (Diptera, Glossinidae) to mobile and stationary baits. *Bulletin of Entomological Research* **64**, 545–588.

Vale, G.A. (1974b) New field methods for studying the responses of tsetse flies (Diptera, Glossinidae) to hosts. *Bulletin of Entomological Research* **64**, 199–208.

Vale, G.A. & Hall, D.R. (1985a) The use of 1-octen-3-ol, acetone and carbon dioxide to improve baits for tsetse flies, *Glossina* spp. (Diptera: Glossinidae). *Bulletin of Entomological Research* **75**, 219–231.

Vale, G.A. & Hall, D.R. (1985b) The role of 1-octen-3-ol, acetone and carbon dioxide in the attraction of tsetse flies, *Glossina* spp. (Diptera: Glossinidae), to ox odour. *Bulletin of Entomological Research* **75**, 209–217.

Vale, G.A. & Hargrove, J.W. (1979) A method of studying the efficiency of traps for tsetse flies (Diptera: Glossinidae) and other insects. *Bulletin of Entomological Research* **69**, 183–193.

Vale, G.A., Hall, D.R. & Gough, A.J.E. (1988) The olfactory responses of tsetse flies, *Glossina* spp. (Diptera: Glossinidae), to phenols and urine in the field. *Bulletin of Entomological Research* **78**, 293–300.

(Accepted 10 August 1992)