A newly developed odour-baited "H trap" for the live collection of *Glossina brevipalpis* and *Glossina austeni* (Diptera: Glossinidae) in South Africa

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ABSTRACT

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A new trap, named the "H trap", was developed at Hellsgate Tsetse Research Station in South Africa for the simultaneous collection of live *Glossina brevipalpis* Newstead and *Glossina austeni* Newstead. Its design followed an evaluation of the responses of the two species towards traps that are used elsewhere in Africa for the collection of other tsetse fly species. These traps were found at Hellsgate to be unsuitable for capturing both *G. brevipalpis* and *G. austeni.* Some new trap designs and many modifications of these were tested, most of which were unsuccessful. The odour-baited blue and black H trap represents a different approach for trapping tsetse flies as it is fitted with lateral cones of white netting which induce the flies to take a more horizontal flight path once they have entered the trap, instead of the vertical flight paths they assume in existing tsetse fly traps. A number of modifications of the prototype H trap were devised (H1–H5), before the final design was established. Catches of up to 76 *G. brevipalpis* and 37 *G. austeni* were obtained per trap on a single day with the H3 modification. Further modifications improved on the trap's efficiency to capture *G. brevipalpis* and *G. austeni.* The final modification caught a record number of 180 *G. brevipalpis* and 57 *G. austeni* on a single day.

Keywords: *Glossina austeni*, *Glossina brevipalpis*, H trap, KwaZulu-Natal, South Africa, trap, tsetse flies

INTRODUCTION

In 1990 a serious outbreak of nagana (Kappmeier, Nevill & Bagnall 1998) in N.E. KwaZulu-Natal Province, South Africa, precipitated a need to develop a long-term control strategy for the two vector species *Glossina austeni* and *Glossina brevipalpis,* which inhabit dense evergreen forests and riverine bush in the low-lying areas north of the Umfolozi River. Studies on colour targets (Kappmeier & Nevill 1999a) and odours (Kappmeier & Nevill 1999b) have resulted in the development of a suitably coloured and odour-baited target (Kappmeier & Nevill 1999c) that, if treated with a suitable pyrethroid, can be used for the control of the two species in South Africa. To site the targets successfully in optimal locations and densities in the field and to monitor their efficacy, it is, however, necessary to use a suitable trap to obtain baseline data on the behaviour, movement, population structure and ecology of the two species.

Hargrove (1998) has defined a tsetse fly "trap" as a device designed to induce tsetse to enter a space from which they cannot escape. Harris (1931) developed the first trap used for tsetse flies and used it to capture large numbers of *Glossina pallidipes* Austen in South Africa. Since then, many traps for tsetse flies have been designed for other species of tsetse in

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other parts of Africa (Morris & Morris 1949; Challier & Laveissière 1973, cited in Hargrove 1998; Moloo 1973; Hargrove 1977; Laveissière & Couret 1980; Vale 1982a; Flint 1985; Gouteux & Lancien 1986; Brightwell, Dransfield, Kyorku, Golder, Tarimo & Mungai 1987; Laveissière & Grébaut 1990; Brightwell, Dransfield & Kyorku 1991; Gouteux 1991; FAO 1992; Kyorku, Machika, Otieno & Mwandandu 1993; Mhindurwa 1994; Vreysen, Khamis & Van der Vloedt 1996). Traps are, however, preferably used as monitoring tools rather than for control purposes.

The only traps so far found to be effective for capturing *G. austeni* in KwaZulu-Natal have been sticky panels (Vreysen *et al.* 1996) of various shapes and colours (Kappmeier, unpublished 1996). When baited with synthetic ox-odour (Vale, Hall & Gough 1988), they are also effective for the capturing of *G. brevipalpis* (Kappmeier, Nevill & Venter 1995). The sticky traps are, therefore, useful tools for monitoring the relative distribution of both species in KwaZulu-Natal (Nevill, Kappmeier & Venter 1995; Nevill 1997), but, do not provide live flies suitable for mark-release-recapture or age-grading studies. For this it is necessary to use a trap that catches live specimens in large enough numbers. For *G. austeni* no such trap exists as its behaviour is elusive and only low numbers are caught in existing tsetse fly traps elsewhere in Africa (Takken 1984, Hall 1986, Madubunyi 1990). The only trap available for this purpose for *G. brevipalpis* was the Siamese trap but it is only partially effective for this species in Kenya (Kyorku *et al.* 1993).

Preliminary studies in KwaZulu-Natal, South Africa, have indicated that, with the exception of sticky traps, most existing tsetse fly traps, which are effective for other species elsewhere in Africa, were not effective for the capture of *G. brevipalpis* and particularly not for *G. austeni* (Kappmeier, in press). Traps that have been tested in South Africa for capturing live *G. austeni* and *G. brevipalpis* include the Epsilon, Pyramidal, Biconical, Vavoua, Ngu (Ng2f) and Siamese (B) (Gouteux & Lancien 1986; Brightwell *et al.* 1987; Laveissière & Grébaut 1990; FAO 1992; Kyorku *et al.* 1993).

The best of these, namely the Ngu (Ng2f) and Siamese (B), caught mean daily numbers of 8,2 and 5,8 *G. brevipalpis* respectively (35 replicates) and 0,4 *G. austeni* (35 replicates) (Kappmeier, in press). In addition, the efficiencies of the Ngu and Siamese traps, as determined by comparing the results obtained with those when electrified nets were placed immediately adjacent to the traps, as suggested by Vale (1982a), were also found to be very low (Kappmeier, in press). The reason for the ineffectiveness of the traps for *G. brevipalpis* and *G. austeni* in KwaZulu-Natal was determined during further trap-orientated behavioural studies, as described by Vale (1982b), when, by the use of electrified nets, it was shown that the upward flight responses of the flies were very low. Only 21–45 % of the *G. brevipalpis* that entered a Ngu and Siamese (B) trap flew upwards towards the cone (Kappmeier, in press). The same basic trend also held true for *G. austeni*.

The poor vertical movement of these tsetse fly species led to the development of a prototype of a new trap using lateral or side-cones instead of vertical or top-cones so that the flies, once they had entered the trap, flew horizontally rather than upwards. In order to improve on the design, several modifications of this prototype trap were assessed for trap-orientated responses of the flies as well as for efficiency.

Months of studies on numerous modifications of existing traps and on new designs preceded the development of the H trap. Because they were unsuccessful these efforts will only be referred to briefly and the main body of the paper will concentrate on the evolution of the H trap.

MATERIALS AND METHODS

Study area

The studies were conducted during 1996–1998 at the Hellsgate Tsetse Research Station (28°02'40"S, 32°25'50"E) situated on Lake St Lucia in N.E. KwaZulu-Natal Province, South Africa, where both *G. brevipalpis* and *G. austeni* occur. The study area has been described in detail in Kappmeier (1997) and its situation indicated in Kappmeier *et al.* (1998).

Experimental designs and techniques

Preceding trap tests and designs

Before the prototype of the H trap was designed, many modifications of existing traps were made and some other traps were originated at Hellsgate. The designs of all these traps took into account the flies' reluctance to fly upwards towards the cones. Some of these designs were also described in Kappmeier (in press).

The first designs consisted of modifications of the Ngu and Siamese traps where both were fitted with lowered or sunken cones so that the path towards the collecting devices was lower. Some of the latest tsetse traps were included in these tests, namely the M3 (Mhindurwa 1994) and the Nzi traps (S. Mihok, personal communication 1999). The Nzi was also modified into what was referred to as the Nzi3 which consisted of three Nzi traps united back to back thus with three separate entrances. The Nzi was also further modified so that the rear netting part was incorporated into a horizontal and diagonally sloping cone plus collecting device, therefore doing away with the top/vertical cone. The Canopy trap used for Tabanidae (Catts 1970) was also tested and then

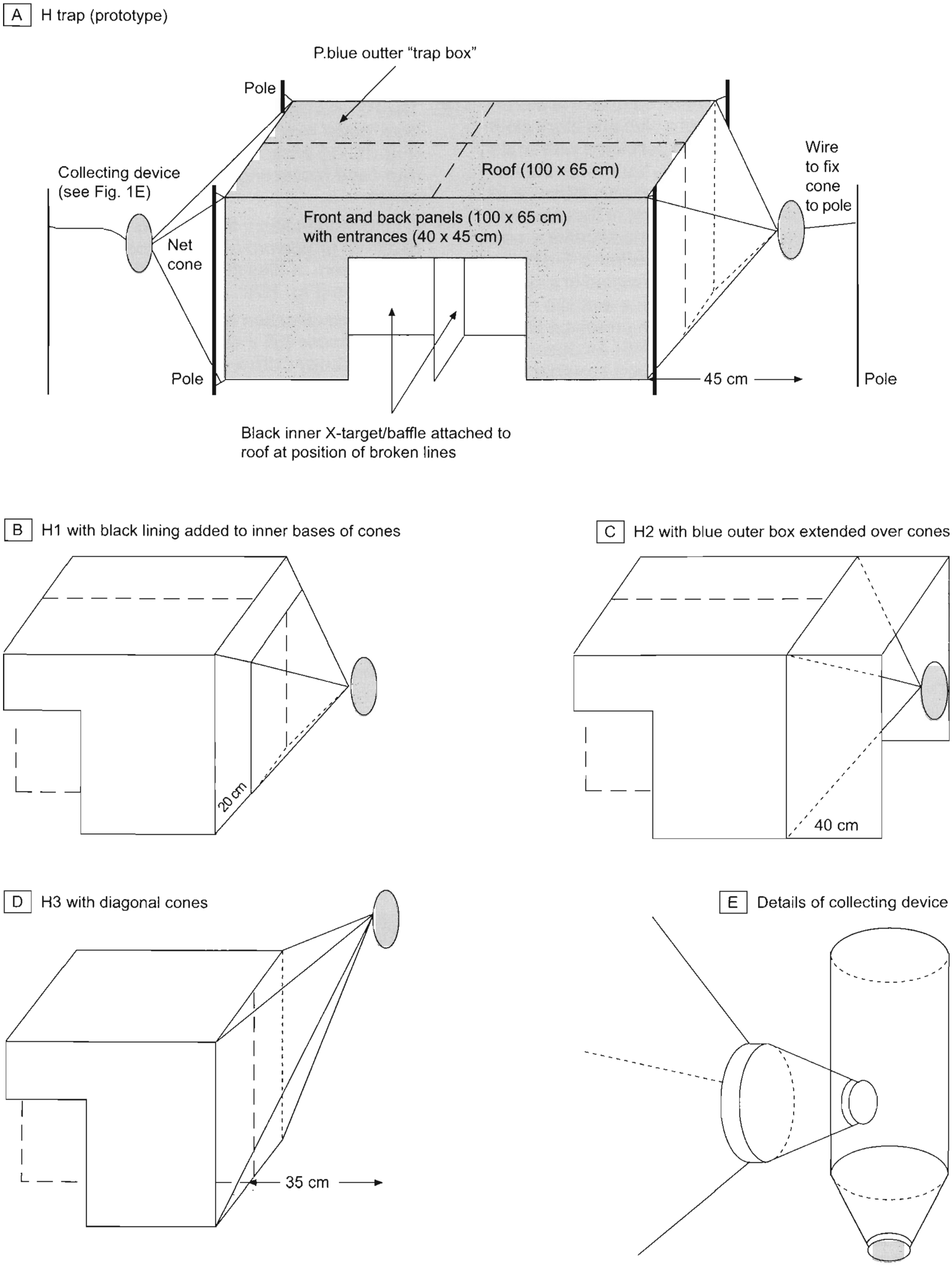


FIG. 1 Diagrammatic representations of the prototype H trap (A) with its H1, H2 and H3 modifications (B–D) and details of the collecting device (E)

modified, firstly by adding a pthalogen blue panel to the base (to enhance attraction), and later by providing openings in the blue pyramidal base, and simultaneously lowering the top cone part. Some new trap designs included what was referred to as the Monoscreen trap, which consisted of a blue and black cloth target with two thirds of the top part fixed with white mosquito netting which formed a "tent" over the target. A few modifications to the net part followed to encourage the horizontal movement of flies towards a collecting device. One of these modifications was further modified into what was called a 3-dimensional-screen trap (3DS), which consisted of a cross-shaped cloth target, also fixed with a tent-like cover of netting and collecting cages. The prototype H trap (with different modifications [H1-H5] as described below) was designed and developed together with a B trap (P.W. Trollip, personal communication 1997) and its modifications B1–B5. The latter were similar to the H trap, but had only one horizontal cone.

Of all the above designs and modifications, other than the H trap modifications, only a few looked promising, namely the Nzi, Nzi3 and B1–B5 traps. Further experiments included the comparison of these traps with an electric blue/black XT sticky trap (Kappmeier, unpublished 1996). These results will briefly be summarized below.

The prototype H trap

The prototype design (Fig. 1A) of the H trap consisted of a pthalogen blue cloth outer "box" (100 x 65 x 65 cm) with two opposite side entrances (40 x 45 cm), an inner black cloth X-target (which also acted as a baffle, attached to the centre of the roof), and then two "horizontal" cones of white mosquito netting extending laterally from the ends of the trap in opposite directions, therefore initially named the "Horizontal trap". Although the "cone"-device used here, was a hollow four-sided pyramid-shaped structure with a square base and straight (not curved) sides, it will here and henceforth be referred to as a "cone", which is an accepted term to use with tsetse fly traps (FAO 1992). The four corners of the trap body were fastened, with strings attached to the trap, to four poles penned into the ground at the positions of the trap corners. The cones are held in position by attaching them each to a flexible rod that provided tension to keep them straight/rigid (Fig. 1A). The apex of each cone was fitted with the top third of a 750 mℓ polythene bottle on which a second bottle fitted as the collecting device (Fig. 1E).

H trap modifications

Five modifications of the prototype trap (Fig. 1A) were made, and referred to as the H1–H5 traps/modifications. The following is a description of the modifications, also depicted in Fig. 1B–D:

H1: The prototype H trap was modified by adding a black inner lining to the base of the cones to prevent flies from collecting at the corners at the cones' bases (Fig. 1B).

H2: The H2 was made with an extension of the outer blue "body" over the cones of the prototype trap (Fig. 1C) to attract the flies to the light and the trap cage (collecting device) at the apex of the cones.

H3: A third modification, the H3, was designed with diagonal or upward-sloping cones to eliminate the problem of flies collecting at the corners of the bases (Fig. 1D).

H4: The H4 modification was as the H3 but with bigger entrances (65 x 45 cm) and therefore a bigger blue body (125 x 65 x 65 cm).

H5: The H5 modification was as the H4 but with bigger cones.

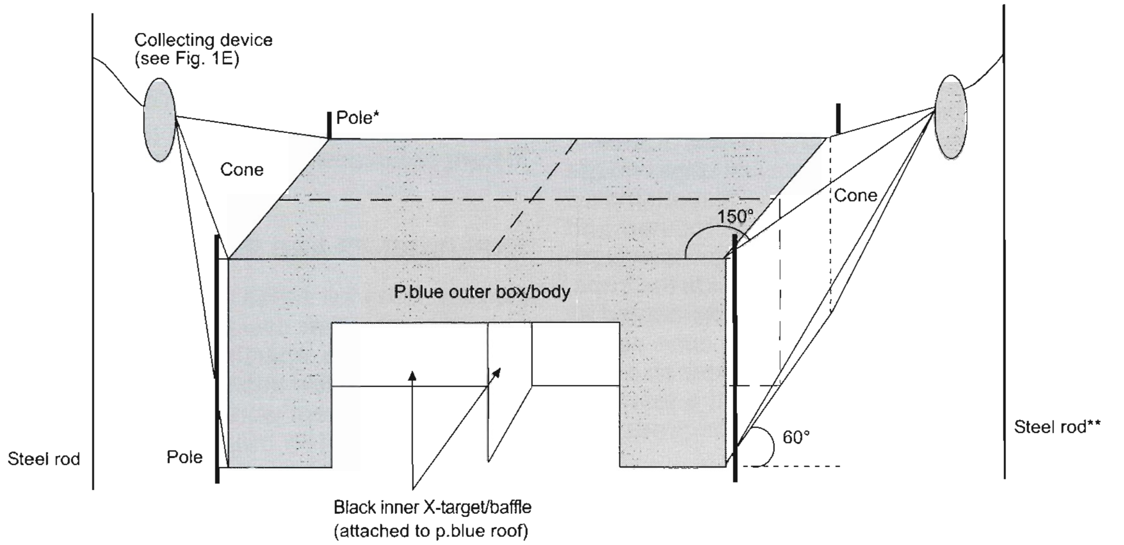
Final "H trap": See Fig. 2 and 3.

Trap efficiencies

The prototype H trap evolved from studying the behavioural responses of *G. brevipalpis* and *G. austeni* in and around the Siamese (B) and Ng2f traps (Kappmeier, in press). These behavioural studies were also conducted on later modifications of the H trap so as to be able to improve on its design. These trap-orientated responses and trap efficiencies of the H trap modification were evaluated by using electric nets (Vale 1974) of various sizes and placements similar to those used by Vale (1982a; 1982b). All flies that were intercepted by the nets were electrocuted and retained on a tray painted sticky with polybutene so that they could be sexed and counted. In order to determine the efficiency of traps, an electric net (1 x 1 m), was placed immediately adjacent to the trap. This net intercepted flies that were attracted to the

FIG. 2 Photograph of the final H trap design for the live capture of *G. brevipalpis* and *G. austeni* (the trap is held upright by fastening the corners to four rigid metal poles (1,2 m long) and the cones are suspended from two flexible steel rods (1,4 m)

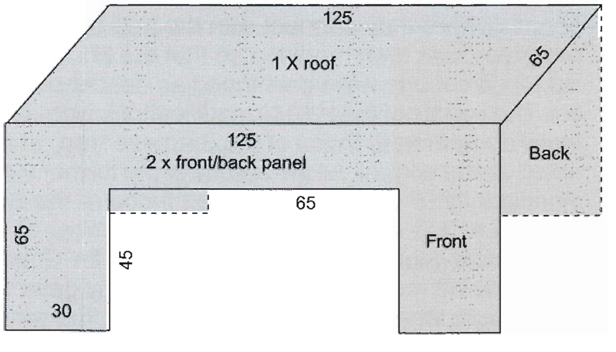
Final H trap



* To erect the trap each corner of the trap is attached with string to a pole driven into the ground
**To keep the cones rigid they are attached with wire at the apex to tops of flexible steel rods

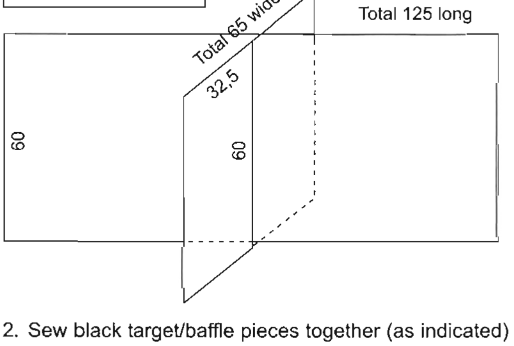
Material requirements (measurements in cm) and steps necessary for making:

P.blue outer box/body



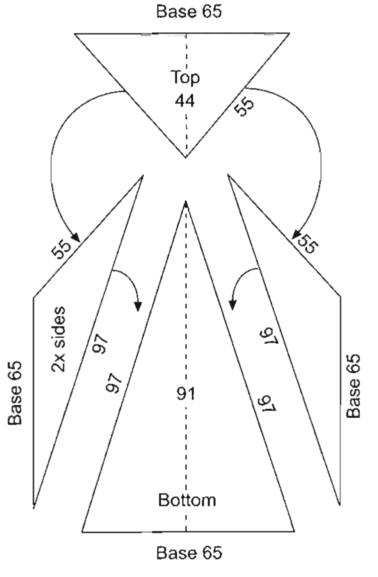
1. Sew the three blue pieces together (along the 125 cm sides) with roof panel between front and back panels

Black inner X-target



2. Sew black target/baffle pieces together (as indicated) and attach target to centre of blue roof (indicated with broken lines in drawing of final H trap)

Net cone (x 2)



3. Sew pieces of netting together (as indicated) and then attach completed cone's top and side bases to sides of blue outer box at the cones' positions
4. Cut apex of cone open to size of circumference of collecting system's base bottle (see Fig. 1E) and attach reinforcing seam to prevent netting from tearing

FIG. 3 Diagrammatic representation of the final H trap design with details of materials and measurements for trap construction trap, but which flew around it, and which might never have been captured.

The number of flies captured by the trap was expressed as a percentage of the total number of flies attracted to the trap, to give an estimate of trap efficiency. To determine the entering responses of flies, the trap's entrances were closed by means of smaller but similar electric nets, which were just large enough to fit into the trap entrances. All flies that attempted to enter the trap were therefore electrocuted and counted. The flies' horizontal flight responses were tested by placing small electric nets inside the traps, at the base of the cone, so that they intercepted all flies that flew horizontally towards the cone part of the trap. [These behavioural studies were also conducted with the Nzi and B3/B4 traps, the results of which are summarized in Kappmeier (in press).]

Experimental design and analyses

The initial H trap modifications were first compared with some existing traps, improved modifications of these, as well as some new trap designs, which consisted of various ideas where a horizontal escape-route could be incorporated, as described above. These comparisons with other traps as well as the efficiency and behavioural response tests with electric nets were tested by means of Latin squares of treatments x days x sites (Perry, Wall & Greenway 1980) with one replicate being one treatment at one site for one day. The comparisons of the traps and modifications were conducted over a 24-h period, after which they were rotated between sites according to the Latin square design. The comparisons of trap efficiencies and trap-orientated behaviour of the flies were determined from data collected from 10:00 until dark, the period of maximum activity of both species (Kappmeier, unpublished 1995).

All data were analyzed, where numbers were adequate, by means of a statistical programme for Latin squares. The general test level of significance was $P = 0,05$. Male and female catches were analyzed separately for *G. brevipalpis*, but numbers were usually too low for *G. austeni* to justify separate analyses according to the sex. Further details are given below in Experiments and Results.

Odour baits

All treatments under comparison were baited either with the odour-blend that was used in Zimbabwe (Vale *et al.* 1988) or the best synthetic odour-blend as described in Kappmeier & Nevill (1999b). This blend (referred to as the SA blend) consisted of 1-octen-3-ol (octenol) and 4-methyl phenol in a 1:2 ratio released from sixteen 69 cm^2 polythene sachets. This resulted in doses of *c.* 9,1 mg/h for octenol and *c.* 15,5 mg/h for 4-methyl phenol under the conditions of the experiments. In addition, acetone was released from a glass bottle at *c.* 350 mg/h via a 6 mm diameter hole in the lid of the bottle. The Zimbabwe blend consisted of 3-*n*-propyl phenol, octenol and 4-methyl phenol (1:4:8 ratio) released from a single 75 cm^2 sachet at 0,1 mg/h, 0,4 mg/h and 0,8 mg/h for the respective components, also with acetone released through a 6 mm diameter opening in the lid of a bottle. The bait was placed about 20 cm in front of the downwind entrance of each trap.

EXPERIMENTS AND RESULTS

Results of the full series of Latin squares and comparisons with other designs and trap modifications are not given here. Apart from the H trap and its modifications, only a few traps and modifications, as described above, were worthwhile which included the Nzi, Nzi3 and B1–5 traps (Kappmeier, in press). Results, given below, are a summary of the work comparing only the H trap modifications and trap orientated behaviour around these modifications, which lead to the final design. Results of the final experiment comparing the H4 and H5 modifications with the Nzi, B4 and B5 traps are given.

Evaluation of initial H trap designs (H1–H3)

It was observed with the prototype H trap that the flies tended to collect at the upper base corners of the cones (where they connect with the trap body). The prototype was then modified so that the H1, H2 and H3 modifications were developed as described earlier. The results of the H1-H3 modifications were originally compared to those of the Siamese trap, which acted as the control. All the results of the former were significantly ($P < 0,01$) better than those of the Siamese (i.e. 3,2–4,2 times for the total number of *G. brevipalpis* caught and at least 6,7 times for *G. austeni*). The H3 modification also consistently gave the best results when compared further with other promising traps, namely the XT, Nzi, Nzi3 and B3 traps (Kappmeier, in press) where it was found that the H3 caught twice as many *G. brevipalpis* as both the B3 and XT, and about three times more than the Nzi. The H3 caught significantly three times more *G. austeni* than the XT, while the remaining traps were ineffective for this species.

The H3 caught mean daily catches of 12,0 *G. brevipalpis* (63 % females; 25 replicates), when baited with the Zimbabwe ox-odour blend, and was even more successful when baited with the best SA blend with mean daily numbers of 45,1 *G. brevipalpis* (64 % females; 12 replicates). The mean daily catches for *G. austeni* were 3,0 (82 % females, 25 replicates) when baited with the Zimbabwe blend and 9,7 (64 % females; 12 replicates) when baited with the best SA blend. For *G. brevipalpis* the record catch by an H3 trap was 76 flies and for *G. austeni* 37 flies in one day.

Trap-orientated responses of tsetse in and around the H3 modification

In order to improve on the H3 design, the behavioural or trap-orientated responses of *G. brevipalpis* and *G. austeni* (Tables 1A and B) were determined by means of electric nets placed in and around the H3 trap, following the methods of Vale (1982a, 1982b). [Simultaneously this was done with the B3, B4 and Nzi traps, the results of which are given in Kappmeier (in press)]. Only 16,8 % of the *G. brevipalpis* (total catches) that were initially attracted to the H3 trap actually attempted to enter them (Table 1A).

The lateral upward-sloping/diagonal cones were quite effective in inducing horizontally-directed flight responses, especially for *G. brevipalpis* for which it was found that all flies that found the entrances of the trap, thereafter flew in a horizontal direction and were captured. For *G. austeni* (Table 1B) only 28,3 % of the flies that found the entrances flew towards the cones. Only four replicates of this experiment were carried out. The statistical *F* and *P* values are given in the tables.

Evaluation of H4 and H5 modifications

The H4 trap was a modification of the H3, and took into account its shortcomings as determined with electric nets. It, therefore, had bigger entrances (65 x 45 cm) and thus a slightly bigger body (125 x 65 x 65 cm) than the H3 to improve on the entrance responses of the flies. The H4 trap was further modified as the H5 by providing it with somewhat larger cones. The lower (bottom) side of each cone was at less of an acute angle (lower slope) to the body of the trap than the previous two modifications. This change was aimed at preventing flies from flying against the lower side and then bouncing off (especially in the case of the bigger *G. brevipalpis*), so that it was easier to progress to the trap collecting device.

The results for *G. brevipalpis* males, females and total catches and for *G. austeni* total catches as obtained with the H4 and H5 traps are compared in Table 2 with the B4 and B5 modifications (from Kappmeier, in press) and the Nzi. The results are given as indices of increase relative to the Nzi (with index = 1). The detransformed means of the catches obtained by the Nzi (28 replicates) are given in brackets. Treatments' indices (for total catches) followed by the same symbols (a, b or c) are not significantly different.

The results showed the Nzi trap to be relatively effective for *G. brevipalpis* and although the H4 and H5 were better than the Nzi, this was not significant. The Nzi was poor for capturing *G. austeni* and the H4 and H5 increased catches significantly by *c.* 3,0–4,1 times respectively compared to the catches obtained with the Nzi. The larger cones of the H5 (compared to the H4) had no effect on the number of flies of either species captured. The mean daily catch for *G. brevipalpis* was 15,7 (69,5 % females) with the H4 trap and 16,9 (70,8 % females) with the H5 trap (28 replicates). For *G. austeni* the mean daily catch was 5,7 (99,0 % females) with the H4 trap and slightly better at 7,6 with the H5 trap (14 replicates).

Trap-orientated responses of tsetse in and around the H4 and H5 modifications

The behavioural or trap-orientated responses of tsetse flies in and around the H4 and H5 traps were tested in a final attempt to confirm whether the modifications of the H3 that were made were worthwhile, and also to make a final decision as to which of the modifications should be employed for future use. The results are given in Tables 1A and B for *G. brevipalpis* and *G. austeni* respectively. The number of replicates performed is indicated in the Tables. The various responses and trap efficiencies are given as a percentage relative to the mean daily number of flies that were attracted to the traps (detransformed means of these are given in brackets). The statistical *F* and *P* values are given in the Table to indicate if differences within an experiment were significant.

For *G. brevipalpis* it was clear that the bigger entrances of the H4 and H5 modifications were an advantage in that more flies (51,6–62,6 %) attempted to enter these traps than the number entering the H3 (16,8 %). On the other hand, all flies that entered the H3 trap flew in a horizontal direction to the cones, while only 42,4–79,9 % of the flies entering the H5 and H4 traps respectively, flew horizontally. It may, therefore, be suggested that because of the bigger entrances, more flies could fly directly out of the trap again, i.e. fewer of them advanced towards the cones. Nevertheless, the overall efficiency of the H4 trap was still better than the H3 (47,9 % versus 38,2 %). The efficiency of the H5 (with larger cones) was lower (31,9 %) than the previous modifications, which might indicate that the flies get disorientated towards the apex of the cones and fewer of them enter the collecting device.

The efficiencies of the H4 and H5 traps were determined respectively at 29,0 % and 37,6 % for *G. austeni*. For this species the bigger entrances of the H4 and H5 traps also prompted more flies to enter the traps (44,4–69,4 %) compared to the number of those entering the H3 (27,2 %). Between 61 % and nearly 100 % of the flies that entered the trap also flew horizontally towards the cones, indicating that, unlike *G. brevipalpis*, they do not often immediately fly out, but, as was observed, tend to "linger" once at the entrance to or inside a trap.

The final design

In accordance with the trap-orientated responses, the final H trap design incorporated entrances of the

TABLE 1 Behavioural responses of (A) *G. brevipalpis* and (B) *G. austeni* in and around the H3, H4 and H5 trap modifications as determined with electric nets. [The results are expressed as a percentage relative to the mean daily number of the flies attracted to the traps (indicated as 100 %). The detransformed mean number of flies attracted are given in brackets]

A *G. brevipalpis*

H3 (4 replicates)	Males		Females		Totals	
Flies attracted	100,0 (26,308)	$F = 30,060$	100,0 (27,112)	$F = 12,390$	100,0 (54,422)	$F = 25,990$
Entrance response	18,4	$P < 0,001$	15,8	$P < 0,010$	16,8	$P < 0,001$
Sideways flight response	22,2		16,2		19,2 (100,00 % of tsetse that entered)	
Eventually caught (efficiency)	34,9		42,4		38,2	
H4 (14 replicates)						
Flies attracted	100,0 (15,827)	$F = 11,080$	100,0 (12,856)	$F = 2,535$	100,0 (29,360)	$F = 6,690$
Entrance response	60,3	$P < 0,001$	61,3	$P > 0,050$	62,6	$P < 0,010$
Sideways flight response	44,7		56,5	NS	50,0 (79,900% of tsetse that entered)	
Eventually caught (efficiency)	37,7		59,7		47,9	
H5 (12 replicates)						
Flies attracted	100,0 (30,299)	$F = 16,090$	100,0 (21,264)	$F = 12,730$	100,0 (51,870)	$F = 16,150$
Entrance response	49,5	$P < 0,001$	54,4	$P < 0,001$	51,6	$P < 0,001$
Sideways flight response	19,7		24,0		21,9 (42,400 % of tsetse that entered)	
Eventually caught (efficiency)	30,5		32,6		31,9	

NS not significantly different

TABLE 1 (continued)

B *G. austeni*

H3 (4 replicates)	Males		Females		Totals	
Flies attracted	100,0 (8,836)	$F = 4,75$	100,0 (16,855)	$F = 15,55$	100,0 (26,964)	$F = 9,129$
Entrance response	36,5	$P = 0,05$	20,3	$P < 0,01$	27,2	$P < 0,050$
Sideways flight response	8,8		5,9		7,7 (28,3 % of tsetse that entered)	
Eventually caught (efficiency)	29,4		45,9		38,4	
H4 (8 replicates)						
Flies attracted	100,0 (6,920)	$F = 1,20$	100,0 (14,983)	$F = 3,61$	100,0 (26,624)	$F = 2,900$
Entrance response	57,8	$P > 0,05$	43,6	$P < 0,05$	44,4	$P > 0,050$
Sideways flight response	58,8	NS	45,3		44,3 (99,8 % of tsetse that entered)	NS
Eventually caught (efficiency)	31,6		26,9		29,0	
H5 (8 replicates)						
Flies attracted	100,0 (4,002)	$F = 1,09$	100,0 (12,173)	F = 6,42	100,0 (16,819)	$F = 7,457$
Entrance response	60,1	$P > 0,05$	66,6	$P < 0,01$	69,4	$P < 0,010$
Sideways flight response	63,2	NS	33,8		42,5 (61,2 % of tsetse that entered)	
Eventually caught (efficiency)	43,1		36,0		37,6	

NS not significantly different

TABLE 2 Final comparisons of the H4 and H5 modifications with B4, B5 and Nzi traps [The results are expressed as the indices of increase relative to the Nzi trap. The de-transformed means of the Nzi are given in brackets]

	G. brevipalpis			*G. austeni*
	Males	Females	Totals	Totals
Nzi	1,0 (4,228)	1,0 (9,610)	1,0 (13,673)[b, c]	1,0 (0,774)[a]
B4	0,7	0,6	0,6[a]	0,8[a]
B5	0,9	0,8	0,8[c]	2,4[b]
H4	1,2	1,1	1,1[bc]	3,0[b]
H5	1,2	1,2	1,2[b]	4,1[b]

a, b and c Treatments' indices followed by the same symbol are not significantly different from each other

same size entrances as those of the H4 and H5 traps but the cone sizes were in-between those of the H4 and H5 traps. Further comparisons between the H4 and H5 and the final design were not conducted. This final H trap design (Fig. 2), caught a record catch of 180 *G. brevipalpis* and 57 *G. austeni* in one day. A schematic representation of the final design is given in Fig. 3 with material measurements and construction procedures. The same method of erection, i.e. with the use of poles, is employed as was described previously and as indicated in the figures.

DISCUSSION

A trap was developed and described for the monitoring and live collection of *G. brevipalpis* and *G. austeni*. It was designed after evaluating the behaviour of *G. brevipalpis* and *G. austeni* at Hellsgate Tsetse Research Station in and around Ngu (Ng2f) and Siamese (B) traps (Brightwell *et al.* 1987; Kyorku *et al.* 1993) in which it was shown that the two species were reluctant to fly upwards towards the cones (Kappmeier, in press). The H trap was, therefore, designed to do away with a top cone system, so that a totally different approach was employed, namely that of a trap fitted with two lateral devices (cones) which induced the flies to fly in a horizontal instead of a vertical flight path as they do in existing tsetse fly traps. The angled cones of the final trap incorporated an element of the ramp trap principle used extensively by mosquito ecologists (Service 1976).

This new H trap design proved to be effective, when baited with synthetic ox-odour, in catching *G. brevipalpis*, since it is known that this species is attracted by colour and odour (Kappmeier & Nevill 1999a, 1999b). It was, however, not as efficient in capturing *G. austeni*, probably because *G. austeni* is not attracted by the odours (Kappmeier & Nevill 1999b) although it responds strongly to colour (Kappmeier 1999a). It may, however, be possible that the odour does influence short-range trap entering behaviour (Vale & Hall 1985) of *G. austeni*. The final version of the "horizontal" or H trap was developed after testing five modifications of the original prototype.

Some of the H trap modifications increased the sizes of the catches when compared to those of the XT sticky trap by up to 1,4 times (not significant) for *G. brevipalpis* and by up to 2,4 times (significantly) for *G. austeni* (Kappmeier, in press). The advantage of the H trap over the XT sticky trap, currently in use in tsetse distribution surveys (Nevill 1997), is that flies are captured alive and can thus be used for studies on population dynamics and for the automatic treatment of wild-caught flies with a variety of agents ranging from entomopathogenic fungi (Kaaya, Kokwaro & Murithi 1991) to insect growth regulators (Hargrove & Langley 1990; Langley 1995, 1999).

Highest catches with the final H trap were 57 *G. austeni* and 180 *G. brevipalpis* in one day. Compared to the previous best live trap catches at Hellsgate with the Ng2f and Siamese traps, this new trap is a definitive advance. Although the Nzi also performs relatively well for capturing *G. brevipalpis*, the H trap is still better and it's significantly better for *G. austeni*. There is no doubt still room for improving the H trap, especially as far as *G. austeni* is concerned. The horizontally situated cones are, however, a major step forward for capturing both *G. brevipalpis* and *G. austeni* alive and make further studies which require the use of live wild-caught *G. austeni* and *G. brevipalpis* possible. The H trap is certainly a major advance in trapping of the two previously "difficult" species of flies.

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