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Evaluation of a New Trap for Tabanids and Stomoxyines

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Abstract

The role of tsetse flies in the transmission of trypanosomes has for long overshadowed that of mechanical vectors. Tabanids and stomoxyines have direct effects (cutaneous lesions, blood loss, disturbance, etc.) and indirect effects (transmission of pathogenic agents) on livestock which can have significant veterinary and economic impact. In West Africa, trapping of mechanical vectors has usually been carried out using tsetse fly traps. Only the Nzi trap, developed in Kenya by Mihok, is considered more effective in trapping tabanids. For stomoxyines the Vavoua trap (monoconic) is considered most effective. The authors compared trapping performances of a new trap (the Tetra), conceived and developed by Desquesnes at CIRDES, with the Nzi trap. During one year, both traps were deployed every two days and regularly rotated to collect insects in Lahirasso, Burkina Faso. Out of 17,991 tabanids trapped, 62.7% were caught by the Tetra trap and 37.3% by the Nzi trap, and out of 2,149 stomoxyines trapped, 53.9% were caught by the Tetra trap and 46.1% by the Nzi trap. Results showed that the Tetra trap is an effective tool to be recommended for the capture of mechanical vectors especially tabanids. A collection of tabanids caught on this occasion is available at CIRDES, as well as a booklet of information and identification of the most common West African Tabanids.

Keywords : Tetra trap, Nzi trap, Mechanical vectors, Tabanids, Stomoxyines, Burkina Faso.

Introduction

Control of tsetse flies, the cyclical vectors of trypanosomes has long been based on the massive use of insecticides but in recent years less polluting techniques have been promoted. The development of traps for tsetse has contributed greatly to the control of animal trypanosomosis (CHALLIER & LAVEISSIÈRE, 1973; CUISANCE, 1989). By its simplicity and low cost, trapping constitutes one of the most accepted ways for rural communities to participate in environmentally acceptable control.

Tabanids are dipter flies belonging to the sub-order Brachycera and the family Tabanidae, while stomoxes are dipters belonging to the family Muscidae and the sub-family Stomoxyinae. They cause direct damage to livestock (cutaneous lesions, blood loss, disturbance of grazing, etc.) and indirect damage by the transmission of pathogens, amongst which are trypanosomes such as *T. vivax* and *T. evansi* in cattle and/or camels and horses (KRINSKY, 1996). Many attempts have been made in different countries to evaluate and improve the trapping techniques of these insects. In the USA, various techniques were applied to tabanid trapping, including the Canopy trap, which allowed extensive entomological studies (THOMPSON, 1969; CUISANCE *et al.*, 1994; KRINSKY, 1996; FOIL, 1999). In French Guiana, important work was carried out by RAYMOND, (1987a) with the Malaise trap; he found that carbon dioxide considerably increased the efficacy. In Kenya, MIHOK *et al.*, 1995, tested several traps of various colours. He developed the Nzi trap (MIHOK, 2002), which proved to be effective at catching tsetse-flies, but also tabanids and stomoxyines (MIHOK, 1993) and was considered as an universal trap. Various work completed in West Africa, particularly that of AMSLER & FILLIDIER,(1994a,b), showed that meta-cresol and octenol attractants increased considerably the capture of tabanids.

Traps used in Africa were initially designed to capture tsetse-flies. In order to improve the capture and increase knowledge of tabanids and stomoxyines, and investigate their potential role in livestock trypanosome transmission, studies were carried out to develop a more effective trap. Among the existing traps, the Nzi trap proved to be the most effective for the capture of tabanids (MIHOK, 2002), but according to Foil (personal communication), nearly 70% of the insects approaching the Nzi trap do not penetrate it. An improvement of this trap was undertaken; the general appearance of the front aspect was retained but the number of entrances was increased, thus giving rise to a new trap- the Tetra (DESQUESNES, unpublished); its first evaluation is reported in the present publication. Since in previous studies, the Nzi trap was the most effective trap in the capture of mechanical vectors (MIHOK *et al.*, 1995; MIHOK, 1993), it was selected as a reference trap to evaluate the performances of the Tetra trap, particularly for tabanids.

Fig. 1. Front of the Nzi trap.


Fig. 2. Front of Tetra Trap.


Fig. 3. Inside of the Tetra trap.

2. Material and Methods

2.1. Description of the site

The study was carried out in the Province of Houet, Padéma district, on a site 3 km distant from the village of Lahirasso. The site is located in a flood plain approximately 1.2 km distant from the Mouhoun river with rainfall of 860 and 843 mm, during the last two rainy seasons (1999-2000 and 2000-2001 respectively). The vegetation is soudano-sahelian (ligneous dominated by *Khaya senegalensis*, *Piliostigma thonningii*, *Ziziphus* sp., *Sclerocarya birrea*, etc.). There are many temporary ponds containing water for much of the year. Land use is dedicated to crop cultivation (rice in the eastern part and *Mitragyna africana* in the western part).

2.2. Trap design

The "Tetra" trap was based on the front aspect of the Nzi trap (Fig. 1). The horizontal blue panel was rotated towards the interior of the trap to permit the entrance of insects at a higher level, the number of entries was multiplied by 4 (hence the name "Tetra") (Figs 2, 3, 4). Therefore, this trap has 8 entrances. The Tetra is a square trap 160 cm high and 120 cm wide, with 4 symmetrical districts 80 cm depth and 120 cm wide, and a upper entrance located in the blue cloth and a lower entrance located at intersection of blue and black cloth. It is delimited with the interior by a brace of mosquito net and is covered with a metallic mosquito net cone and a final trapping cage (Fig. 4). (It has 4 non-return horizontal valves located below the blue horizontal panel and 4 in the lower part of the mosquito net cone). Insects with low flight paths enter in the same way as to the Nzi, but insects with high flight paths can enter as a result of the oblique placement of the blue horizontal panel.

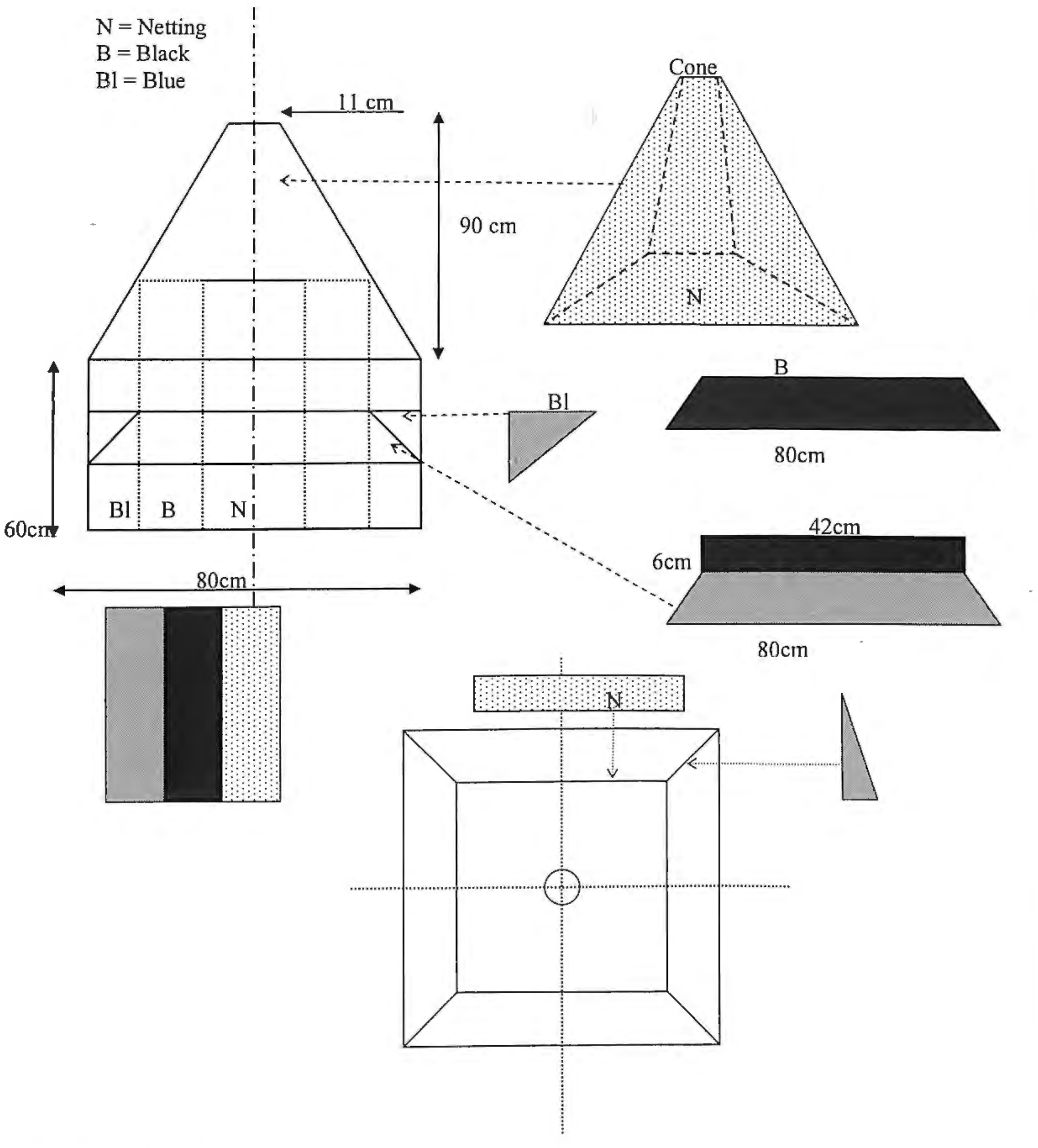

Fig. 4. Configuration of the Tetra trap.

The non-return valves avoid the exit of insects which can only continue more deeply into the trap. Both traps were constructed with identical blue (Santiago) and black cloth, and white mosquito netting (FAO, 1992).

2.3. Data collection

One specimen of each trap was used. The traps were placed on the same line and were covered with Roubaud cages during 24 hours, one day out of two. They were fixed and checked at 6.00pm every two days. When checked, the Roubaud cages were removed from the cones and the insects were collected, killed, identified and counted. Identifications were based on keys of determination (OLDROYD, 1954; ACAPOVI *et al.*,2000).

The Nzi and Tetra traps were used from 17th January to 31st December 2001. Between August and September the Nzi and Tetra traps were rotated for 4 days each month following a Latin Square design : with one type of trap being removed and replaced by the other in a given site. For the entire period of trap deployment total monthly capture of all traps was recorded, to calculate the apparent density of tabanids and stomoxyines per month. Additionally the apparent daily density for each trap was calculated from the number of flies collected and the number of days deployed.

2.4. Data analysis

The response was the number of insects caught by trap and by day. Two variables were analysed : the number of tabanids caught by trap and by day, and the number of stomoxyines caught by trap and by day. A preliminary analysis showed that a high variability occurred with this count data, and that no insect was caught in several occasions (0 count). The raw response $y_{i,j,k}$ was transformed into $y^*_{i,j,k} = \log(y_{i,j,k} + 1)$, with *i, j, k* the indices for the insect category (tabanid or stomoxyine), the time and the kind of trap (Nzi or Tetra), respectively.

A graphical analysis was carried out to assess the time trend and to visualise the trap effect (and possibly the time * trap interaction) for each insect family. A loess smoother (i.e. a kind of moving average (CLEVELAND, 1993), was used for this purpose.

Because time trends in insects counts were likely to be complex (as the result of different population dynamics according to insect-species biology and ecology), time was coded in months and considered as a qualitative variables in statistical analyses. A linear model was used to analyse $y^*_{i,j,k}$. Time (12 months), trap type (2 Nzi or Tetra) and insect category (tabanid or stomoxyine) were the explanatory variables. They were used as main effects and all possible interactions were considered in different models. The two responses (number of tabanids and number of stomoxyines) were measured on the same trap and on the same day. Therefore, they were possibly correlated and the analysis had to account for this (DONNER, 1985). Generalized-least-square models were used, in which the correlation between dependent variables recorded on the same trap and on the same day was estimated from the data. These models had the same correlation structure but different fixed effects. They were fitted with a maximum-likelihood algorithm (PINHEIRO & BATES, 2000). A widespread statistic used for comparing a set of (possibly non-nested) models is the Akaike information criterion (BURNHAM & ANDERSON, 1998). The basic version of this criterion is the deviance (i.e. -2 * log-likelihood of the model) penalised by twice the number of parameters (*k*) in the model: AIC = deviance + 2 * *k*. When the number of parameters in the model is large compared to the number of observations: $n / k < 40$, a small-sample adjustment is required (Hurvich & Tsai, 1995) : $AICc = AIC + \frac{2k(k+1)}{n-k-1}$. The list of investigated models was chosen after the graphical exploration step. Because the most complex model (all the main effects plus two- and three-way interaction terms) had 50 parameters and the sample size was only $n = 738$, this adjusted criterion was used in the subsequent steps.

Models were ranked according to *AICc* and the *AICc* difference was computed as $\Delta_i = AICc_i - \min(AICc)$, where $AICc_i$ was the corrected AIC for model *i*, and min(*AICc*) was the minimum value of *AICc* in the set of examined models. When $\Delta_i < 2$, models were close in terms of plausibility (given the data); when $2 < \Delta_i \leq 7$, the best model was much more plausible than the other but the latter might not be discarded; when $\Delta_i > 7$, the "worst" model was highly implausible (BURNHAM & ANDERSON, 1998).

Because the selected-best model was likely to have many parameters and different interaction terms, the assessment of trap effect relying on tables of model parameters would have been difficult. Instead, predicted values (from the selected-best model) were computed for each month, insect category and trap type. For each insect category, the differences between predictions for Tetra and Nzi traps were calculated for each month, as well as the yearly average of these differences.

Confidence intervals were obtained for all these statistics with a bootstrap method (EFRON & TIBSHIRANI, 1993) : the list of all *D* capture days was set up and a sample of size *D* was drawn from this list, with replacement. Data corresponding to these sampled days were used to build a new table. The selected-best model was fitted to these data and the above-described statistics were computed from this model and stored. The process was iterated 2,000 times, and the empirical 2.5% and 97.5% quantiles of the distribution of each statistic were used to form a 95% confidence interval. Theses statistics were then exponentiated (to express the results as the ratio of apparent density by trap: Trap / Nzi) and plotted.

3. Results

3.1. Global capture

Taking the two traps together, during 174 days of trapping, (17th January 2001 to 31st December 2001) a total of 17,991 tabanids and 2,149 stomoxyines were caught. A distinct peak in the density of tabanids was observed in November with a smaller peak in February. For stomoxyines there are two peaks in density one in January-February and the second in November-December.

The tabanids caught included representatives of 2 sub-families (*Tabaninae*, *Chrysopinae*), 4 genus (*Atylotus*, *Tabanus*, *Chrysops*, *Ancala*) and 12 species de (*Chrysops longicornis*, *C. distinctipennis*, *Atylotus agrestis*, *A. fuscipes*, *A. albipalpus*, *Tabanus taeniola*, *T. sufis*, *T. gratus*, *T. par*, *T. biguttatus*, *Ancala fasciata*, *An. necopina)*. *Atylotus agrestis* (62,7%) dominated the counts followed by *Atylotus fuscipes* (21,8%), *Tabanus taeniola* (7,1%), *Tabanus sufis* (3,6%), *Chrysops distinctipennis* (3,5%). *A. agrestis* and *T. teaniola* had a peak in density in November and a secondary lower peak in February, for *A. fuscipes* this was in August and November respectively.

The stomoxyines belong to the genus *Stomoxys*. Two species were caught : *Stomoxys nigra* (99,95%) and *S. calcitrans* (0,05%).

Compared between the traps, the results showed that the Tetra trap caught more species than the Nzi trap (Tables 1, 2).

Table 1. Comparison of numbers of tabanid species caught.

Species	Nzi	Tetra	Total
Chrysops longicornis	1	10	11 (0,06%)
Chrysops distinctipennis	192	434	626 (3,48%)
Atylotus agrestis	4331	6944	11275 (62,67%)
Atylotus fuscipes	1388	2534	3922 (21,8%)
Atylotus albipalpus	54	81	135 (0,75%)
Tabanus taeniola	454	828	1282 (7,13%)
Tabanus sufis	249	390	639 (3,55%)
Tabanus gratus	27	41	68 (0,38%)
Tabanus par	8	3	11 (0,06%)
Tabanus biguttatus	6	9	11 (0,06%)
Ancala fasciata	1	4	5 (0,03%)
Anacala necopina	1	5	6 (0,03%)
Total	6713 (37,3%)	11278 (62,7%)	17991 (100%)

Table 2. Comparison of numbers of stomoxynes species caught.

Species	Nzi	Tetra	Total
Stomoxys calcitrans	1	0	1 (0,05%)
Stomxys nigra	987	1161	2148 (99,95%)
Total	988 (46%)	1161 (56%)	2149 (100%)

3.2. Performance of the Tetra trap

Among the 17 991 tabanids collected, 62.7% were caught with the Tetra and 37.3% by the Nzi. During the period of high density of tabanids and stomoxyines, for 4 days (from the 4th to the 7th of November) an average of 575 tabanids per day were caught with the Tetra with a range of 459 and 760 tabanids per day. With the Nzi, for the same period, the average and range are respectively 309, 227 and 339 tabanids. In all species of tabanids for which more than 5 specimens were captured, more than 60% of the total were caught with the Tetra.

For the stomoxyines, out of a total of 2,149, 53.9% were caught with the Tetra and 46.1% with the Nzi. Only one *S. calcitrans* was caught with the Nzi trap.

3.3. Data analysis

The graphical exploration showed a complex time trend with major differences between tabanids and stomoxyines. For tabanids, the apparent density by trap was least in May (end of the dry season) with a single peak in October

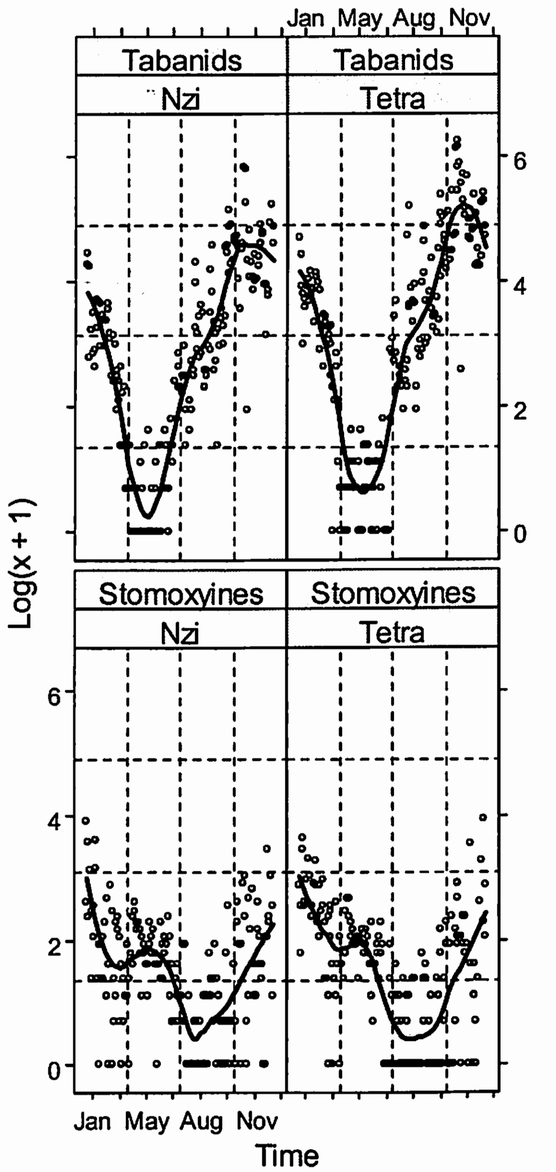

Fig. 5. Apparent density by trap of tabanids and stomoxyines captured with Nzi and Tetra traps during the survey period. Data were transformed on the log scale. Points show the transformed data. The curve is a loess smoother of these data against time.

(end of the rainy season). For stomoxyines, the main abundance peak was observed in January (cool, dry season) and a secondary peak appeared in May (i.e. when tabanids apparent density was minimum). Stomoxyines apparent density reached its lowest in August (middle of the rainy season) and a second decline was observed in April (hot, dry season) (Fig. 5).

On the basis of this graphical exploration, the following main effects were retained: month of capture (large seasonal variation), insect category (large differences in the abundance of tabanids and stomoxyines) and trap type (Tetra looked more efficient than Nzi, mostly for tabanids). Moreover, the very different monthly patterns between Tetra and Nzi highlighted an obvious need for an insect * month interaction. An insect * trap interaction was also probably needed to account for the difference of abundance between Nzi and Tetra traps for tabanids (and very little difference for the stomoxyines). The apparent-density patterns looked similar for both traps (given the insect category). To assess the importance of these interactions, five models were compared:

1) month + insect + trap + month*insect + month*trap + insect*trap + month*insect*trap

2) month + insect + trap + month*insect + month*trap + insect*trap

3) month + insect + trap + month*insect

4) month + insect + trap + month*insect + month*trap

5) month + insect + trap + month*insect + trap*insect

The selected-best model (according to *AICc*) was model 2, i.e. the model with all the main effects and two-way interaction terms (Table 3). The second best model was model 4, with Δ_i = 6.7, i.e. close to 7. Therefore, we considered that model 2 was the only plausible model, given the available data and we ignored the other models in the rest of this paper.

The bootstrap results were computed with this model. For tabanids, the average apparent-density ratios of the two traps was 1.3 [1.2; 1.5]

Table 3. Comparison of 5 generalised-least-square models of log(apparent density by trap + 1) according to *AICc*. Models were ranked in increasing-*AICc* order. Model numbers (1st column in the table) refer to their presentation in the text.

N°	**Explanatory variables in the model**	Δ_i
2	month + insect + trap + month*insect + month*trap + insect*trap	0.0
4	month + insect + trap + month*insect + month:trap	6.7
5	month + insect + trap + month*insect + trap:insect	7.8
1	month + insect + trap + month*insect + month*trap + insect*trap + month*insect*trap	8.7
3	month + insect + trap + month*insect	14.1

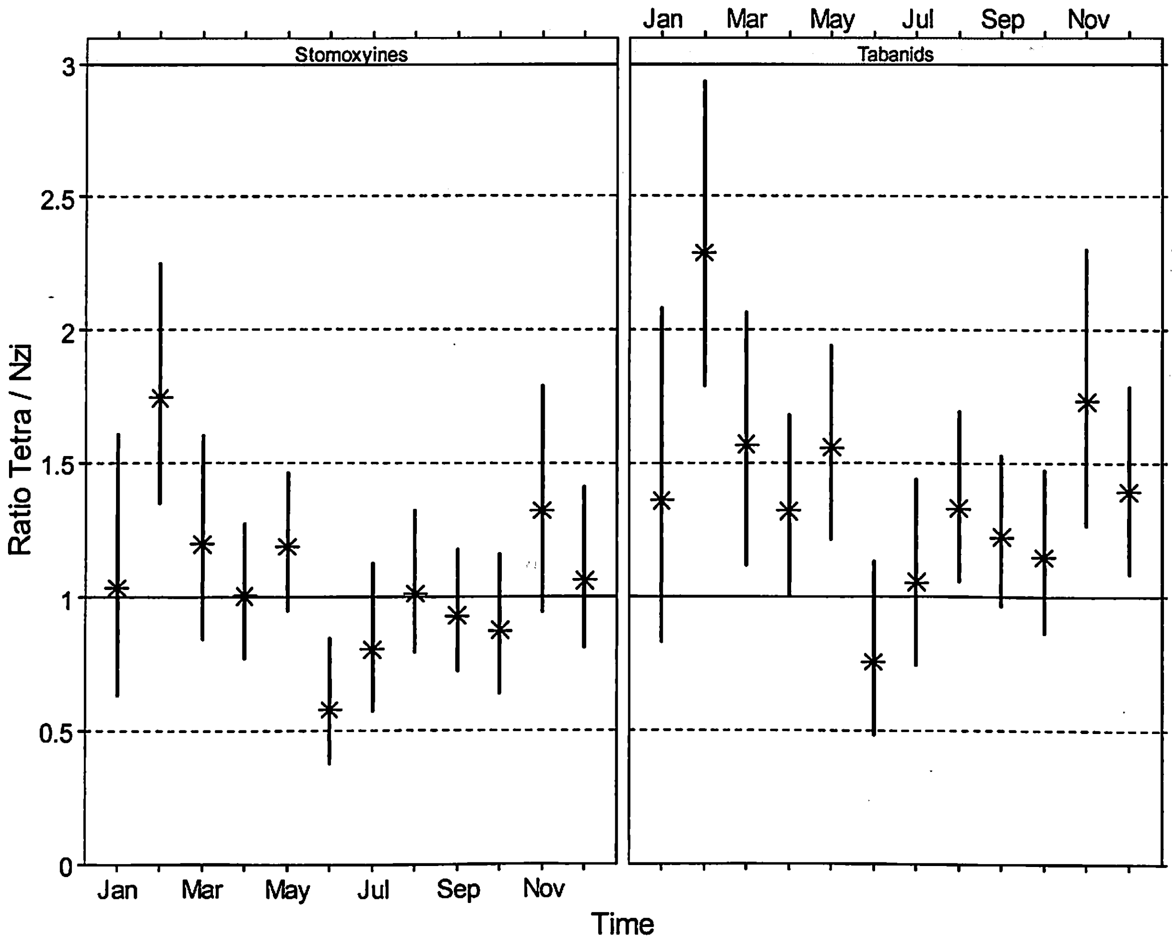

Fig. 6. Ratios of apparent density by trap and 95% confidence intervals (Trap / Nzi) as predicted by the selected-best model.

(95% confidence interval in brackets). Therefore, the apparent density was, on average, 30% higher with the Tetra trap than with the Nzi trap, and this difference was statistically significant ($P < 0.05$). For stomoxyines, the ratio was close to one : 1.0 [0.9; 1.2]: Tetra and Nzi traps were as attractive as each other for these insects.

Monthly results are shown in Fig. 6. For tabanids, they were highly variable, with a remarkable peak in February in favour of the Tetra trap. The Nzi trap was more efficient in June, but the difference was not significant ($P > 0.05$). Results were more homogeneous with stomoxyines. However, two ratios were significantly ≠ 1: Tetra was better than Nzi in February and Nzi was better than Tetra in June.

4. Discussion

Tabanids provoke painful bites and defence movements by animals, leading to an important waste of energy (RAYMOND, 1982; 1987b), disturbance of food seeking behaviour (BOY & DUNCAN, 1979) and a blood loss of 15 to 700 mg of blood per bite, which can reach 200 ml /day according to HOLLANDER & WRIGHT, (1980) resulting in immunodepression and reduced production. Moreover, tabanids may transmit various viruses (infectious anaemia, lumpy skin disease), bacteria (anthrax) and trypanosomes, particularly *Trypanosoma evansi* and *T. vivax*. The economical and medical effects of their impact on cattle may justify the development of tools to reduce their density in some highly infested areas.

Control methods are scarce. The use of insecticides has given good results (RAYMOND & FAVRE, 1991) and has been recommended in some area of high tabanid density in French Guyana (DESQUESNES, 1997). In some countries, like in Mauritania (personal observation), or in French Guyana (DESQUESNES, 1997), farmers light fires during the day producing thick smoke which they believed repel biting insects. However this technique must be evaluated in the various situations since, in some instances, it could attract some tabanid species like *Chrysops spp* (RODHAIN & PEREZ, 1985).

Most of the trapping techniques for tabanids (THOMPSON, 1969; LEPRINCE *et al.*,1994; FOIL, 1999) were developed for entomological studies rather than for control (CUISANCE *et al.*, 1994). The performance of the Manitoba trap (THOMPSON, 1969) or Malaise trap improved considerably when baited with carbon dioxide, increasing the number of tabanids caught fivefold (RAYMOND, 1987a), but the cost of carbon dioxide attractant is high. Some studies on the bipyramidal trap with a functioning device of collection out of bottle as non-return system gave results but the efficacy of this device in dry environment was questioned (DIA *et al.*, 1998).

For the stomoxyines, in Kenya, the Vavoua trap was compared with the biconical and pyramidal traps using different colours. It was most effective with one type of blue cloth (MIHOK, 1993; MIHOK *et al.*, 1995). Adding octenol to this trap increased the number of species captured (MIHOK *et al.*, 1995). In Mauritius, the trapping of stomoxyines was effective with the "exit traps" (which consist of cubes of 30 × 30 × 30 cm with metal reinforcement and a conical entrance) applied on the windows of cowsheds (CUISANCE *et al.*, 1994).

Among these traps, the Vavoua was the most effective for stomoxyines (MIHOK, 1993; MIHOK *et al.*, 1995; DIA & DESQUESNES, unpubl.), but the Nzi trap proved to be most effective for catching tabanids, and also attracted substantial numbers of stomoxyines and other insects. However, according to Foil's observations (personal communication), it was speculated that only a third of the insects approaching the trap were caught and that improvement could be obtained by increasing the entrances. The Tetra trap was conceived on this basis, in order to increase numbers caught and to catch species with high and low flight patterns.

It is generally considered that the performances of a trap are proportional to its size. The front aspect of the Tetra has the same size as that of the Nzi. However, due to its cubic shape, it is bigger than the triangular Nzi. For some authors, the shape of the trap is of less importance for capturing tabanids than its colour (RAYAISSE, 1995). In the case of the Tetra, it is probable that its attractiveness is the same as that of Nzi, since its frontage is similar, but insects may enter from all sides (360°) compared to an effective trapping angle of about 120° for Nzi ; also the greater number of entries and their placement at different levels may increase its performances relative to the Nzi.

In general, the best results of captures of the stomoxyines were obtained with the Vavoua trap. The Tetra trap is designed not only to increase performance but also to catch tabanids flying close to the ground.

Irrespective of the trap used our results showed that tabanids caught decrease from May / June before starting to increase from July onwards. There are several possible reasons for this. From March/April onward temperatures are high and temporary ponds of water disappear. Animals are taken considerable distances for grazing and watering. These conditions are not favorable to adult tabanids and even less for nymphs. The first rains usually start in June, and with conditions becoming more and more suitable the tabanid numbers increase again. Large numbers of tabanid larvae can be collected in the mud rich in organic matter found around the roots of plants along the small water courses and pans which retain water (GOODWIN, 1982).

There are however considerable differences between species. This may be explained by species specific biology and life cycles. For example while the longevity of female tabanids is in general around 2 months for certain species of *Tabanus* the longevity does not exceed 16 days (ITARD, 2000).

As for stomoxyines the 2 peaks are clear, and are due almost entirely to a single species *S. nigra*. A longer period of observation is needed to assess if this is a recurrent pattern.

The Tetra appears to be clearly more effective than the Nzi. Even in the hot season when their activity is reduced the Tetra captures tabanids. This is shown in figure 4 where it can be seen that whether for tabinids or stomoxyines the Tetra trap is more effective.

The traps were built using identical blue and black cloth and a white mosquito net. The amount of cloth needed for the Tetra trap was slightly more than for the Nzi trap. Consequently, the cost, sticks included, is about 12 500 FCFA for the Nzi trap and 15 000 FCFA (656 FCFA = 1 Euro) for the Tetra trap. In the future, the design of the Tetra trap will take the aspect of price into account by decreasing the number of poles from 5 to 1 and decreasing considerably the size of the trap. As the performances of the Tetra trap in catching tabanids and stomoxyines was higher than those of the Nzi trap, it is likely to be a better choice than the Nzi as a universal trap for mechanical vectors.

5. Conclusion

Since the 1970s, trapping of tsetse flies as a non polluting control method was promoted due to its simplicity and low cost.

A trap called Tetra was developed on the basis of the Nzi trap, with modifications permitting the capture of insects within a 360° angle, at high and low flights. Results of the evaluation showed that the Tetra trap collected 1,6 more tabanids than the Nzi trap, considered as the best trap for catching these insects. For stomoxyines, performances of Tetra proved to be always better than that of the Nzi trap. As the best results for captures of stomoxyines were obtained with the Vavoua trap (DIA & DESQUESNES, unpublished data), the Vavoua trap can be recommended for stomoxyines trapping, while the Tetra trap can be recommended for mixed studies (tabanids and stomoxyines) or tabanids studies.

If these results are confirmed in other sites, the Tetra trap could be used to monitor mechanical vectors (inventory of the species, establishment of distribution maps, estimation of the apparent densities, etc.) and could be evaluated as a control method for tabanids in very high density areas.

However, further improvements of the Tetra trap are required, especially in order to reduce the cost and fashion complexity. For example, the number of sticks needed (5) could be reduced to 1 by using a rigid internal structure, as in the biconical trap. Finally a new design could emerge from further assays.

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