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Measurement of risk in endemic areas of human African trypanosomiasis in Côte d'Ivoire

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Abstract

An index of epidemiological risk was developed for the foci of human African trypanosomiasis (HAT) in the forest zone of Côte d'Ivoire, based on the following characteristics of *Glossina palpalis palpalis* populations: daily survival rate, apparent density of teneral males and females, and frequency of human–fly contact. The index agreed well with HAT prevalence. It varied according to ethnic groups and with seasonal changes in agricultural activities and fell rapidly to zero following the start of an anti-vector control campaign. Further studies in different biogeographical zones are desirable in order to substantiate the validity of the index.

Introduction

The control of tsetse flies (*Glossina* spp.), vectors of human African trypanosomiasis (HAT), is now possible in forest zones: trapping is an effective, rapid and environmentally sound method and is also less expensive than conventional techniques. Nevertheless control by traps or screens remains out of the reach of health services in developing countries with endemic sleeping sickness. Often the control campaigns that are carried out are supported by bilateral or multilateral aid, resulting in delays, deterioration of the situation and consequently excessive effort and cost.

The application of trapping by rural communities, while representing a useful approach, also has limitations. Positioning and maintaining a dozen screens is considered by most farmers to be an obligation at the beginning of the campaign but as 'useless' work as soon as the tsetse nuisance has become imperceptible: often traps or screens are abandoned during the campaign.

In order to remedy this double problem, trapping should be applied more selectively to attack the vectors only at the epidemiologically dangerous points. This would reduce the amount of work for the farmer, resulting in a reduction in cost and an improvement in efficiency. In order to achieve this, it is necessary not only to localize precisely the points of human–fly contact (which has already been carried out in a number of biogeographical zones) but also to determine more precisely the epidemiological risk in each area which this contact represents.

In this paper we propose an index, based on entomological parameters, which quantifies the risk created by a population of tsetse flies in a specific biotope and in a particular sociogeographical situation. We have used this index to explore variations in risk in different HAT foci in Côte d'Ivoire, over an annual cycle of human activities, in different ethnic groups of the high risk population, and before and after an entomological control campaign.

Materials and Methods

The index of epidemiological risk proposed is based on 3 parameters: apparent density of teneral flies; longevity of tsetse populations; human–fly contact.

Teneral flies

A tsetse must be teneral to become infected; thus the risk is increased when the teneral proportion is high. The level of transmission does not depend strictly on the density of tsetse populations; nevertheless, to be self-maintaining the population must be such as to produce a minimum number of tenerals. Consequently, we take as the first element for calculation the apparent density of tenerals (t) caught by p traps during j days.

In the forest zone, GOUTEUX & BUCKLAND (1984) have defined, for populations of *G. palpalis palpalis*, the relationship between the apparent density estimated by trapping (ADT) and the actual density (N). In the coffee and cocoa plantations of Côte d'Ivoire, the relationship is:

$$N=k(ADT)^a, \text{ where } k=632 \text{ and } a=1{\cdot}23$$

For the teneral flies we have the relation:

$$T=k\left(\frac{t+1}{pj}\right)^a$$

where T is the actual density of teneral flies

A biotope where no teneral fly has been trapped should not be considered as a zone without risk because of the probable dispersion of previously infected flies from a breeding site: the risk then depends essentially on other parameters. Therefore we use (t+1) rather than t, to prevent this parameter dropping to zero.

Age of tsetse

The possibility of a previously infected tsetse reaching an age when it can transmit depends on the overall longevity of the population, which must be sufficient for the trypanosome to complete its cycle of approximately 20 d. Moreover, the risk of disseminating the parasite among a significant number of human beings increases with longevity. The epidemiological risk therefore has a two-fold dependence on the longevity factor, evaluated by the daily survival rate (Dsr). It will be proportional (i) to the fraction which survives after 20 d, $(Dsr)^{20}$, and (ii) to the average duration of life remaining, $\frac{-1}{\log(Dsr)}$

Human–fly contact

Human–fly contact (P) must be sufficiently intense and/or regular for the testse to fulfill its role of vector between a carrier of parasites and a healthy person.

At a given time, if P represents the number of flies (in the population N) which have fed on humans, and n the number of human blood meals found in the catch C (the flies caught by pj, the number of traps (p) multiplied by the number of days (j), one finds the relationships:

$\frac{P}{N}=\frac{n}{C}$ and $P=N\frac{n}{C}$, where $N=k(ADT)^a$ (GOUTEUX & BUCKLAND, 1984), and $(ADT)=\frac{C}{pj}$. Thus

$$P=k\left(\frac{C}{pj}\right)^a\frac{n}{C} \text{ or even } P=\frac{knC^{a-1}}{pj^a} \text{ (with } a=1{\cdot}23),$$

$$\text{giving: } P=\frac{knC^{0{\cdot}23}}{pj^{1{\cdot}23}}.$$

Many other factors influence epidemiological risk: external ones such as the presence of human or animal carriers, and those internal to the insect vectors (rickettsia-like organisms, lectins, agglutinins, etc.); unfortunately, knowledge in this area is still too scanty for their influence to be taken into account.

Calculation of index

Thus the calculation of the index (r) takes into account: (i) the size of the teneral population (T); (ii) the proportion P of blood meals taken on humans by this population; (iii) the proportion $(Dsr)^{20}$ of tsetse flies surviving after 20 d; (iv) the average duration of life remaining $\frac{-1}{\log(Dsr)}$; and (v) the proportion P of blood meals taken on humans by the residual population.

Thus $r=k'\times T\times P\times (Dsr)^{20}\times \frac{-1}{\log(Dsr)}\times P$, where k' is a constant.

So we can assume that the risk can be calculated as follows:

$$r = \left(\frac{t+1}{pj} \right)^{1\cdot 23} \times \frac{nC^{0\cdot 23}}{pj^{1\cdot 23}} \times (Dsr)^{20} \times \frac{-1}{\log\ (Dsr)} \times \frac{nC^{0\cdot 23}}{pj^{1\cdot 23}}$$

$$\text{therefore } r= \left(\frac{t+1}{pj} \right)^{1\cdot 23} \times \left(\frac{nC^{0\cdot 23}}{pj^{1\cdot 23}} \right)^{2} \times \frac{-(Dsr)^{20}}{\log\ (Dsr)}$$

$$\text{or } r= \frac{(t+1)^{1\cdot 23}\times n^2 \times C^{0\cdot 46}}{pj^{3\cdot 69}} \times \frac{-(Dsr)^{20}}{\log\ (Dsr)} .$$

In order to obtain workable figures, the index (r) is multiplied by 10^4.

Estimation of parameters

Catches. The tsetse flies (*G. p. palpalis*) were caught with biconical or 'Vavoua' traps. In order to obtain as accurate a picture as possible of the epidemiological situation in each type of biotope, catches were obtained from traps placed in as many sites as possible, presenting given botanical or ethnic characteristics (camps, plantations, water holes, etc.).

The duration of the trapping period must be sufficient to allow accurate estimation of *ADT* and the extent of human-fly contact, especially where this is low. Four days is considered the optimum trapping period.

In all areas, catches were made during the main seasons: dry cold season (November to January), hot dry season (February to April), short rainy season (May to June), short dry season (July), and rainy season (August to October). Each season corresponds to different agricultural activities.

Tenerals. Only individuals which had never taken a blood meal were counted (identified by the residual sac from the larval stage in the midgut: LAVEISSIÈRE, 1975).

Survival rate. Calculation of the daily survival rate (by the method of CHALLIER & TURNER, 1985) requires the dissection of females in order to determine their physiological age according to the method of CHALLIER (1965). It is based on the geometric mean survival per ovarian cycle of an age-graded sample and the duration of the interlarval period (10 d).

The age of males cannot be calculated so precisely; variations in their survival rate were assumed to be consistent with those of the females.

Blood meals. All the intestinal contents were collected in the conventional manner and spread on Whatman no. 1 filter paper, then stored in glass containers with a dessicating agent until analysis by Dr C. Staak (Institut für Veterinärmedicin, Berlin).

Areas of study

Many programmes under way or completed have allowed the collection of numerous entomological, parasitological and epidemiological data in the forest of Côte d'Ivoire. The following were used as sources of data for evaluation of the index. (i) Daniafla region (1981–1983), recently developed for cultivation, and with no HAT; 462 traps. (ii) Vavoua focus, with a very high prevalence of HAT, before and after the control campaign (1984–1985); 235 traps. (iii) Zoukougbeu focus (1991–1992); similar to Vavoua, under cultivation for a long time, but with low HAT prevalence; 590 traps.

In all the foci we made detailed maps and a census of the human population in order to position the traps precisely and to get information about the immediate environment: ethnic group, religion, type of settlement, cultivation habitat, water supply, etc.

Results

Prevalence of HAT

All 3 regions were characterized by the same agricultural activities (coffee and cocoa growing) and were sampled during the same climatic period.

The 2 regions with high HAT prevalence (Zoukougbeu and Vavoua) were distinguished from the low prevalence region (Daniafla) mainly by their high teneral fly density and human–fly contact (the latter due to the scarcity of wild animals and the high density and mobility of the human population). The high index of risk calculated for these 2 areas agreed well with the level of prevalence (Table 1).

Table 1. Calculation of the index of risk of human African trypanosomiasis (HAT) during November in 3 forest areas of Côte d'Ivoire

	Zoukougbeu	Vavoua Treated	Vavoua Control[a]	Daniafla
Survival rate (Dsr)	0·972	0·977	0·979	0·977
Traps×days (pj)	2048	536	430	1692
Catches (C)	5866	2203	1129	1942
Teneral density (T)	0·366	0·545	0·202	0·035
Human blood meals (n)	52	16	6	11
Risk (r)	176	577	43	0·97
HAT prevalence[b]	1%	6·1%		0·2%

[a]HAT not recorded.
[b]Data for the Mossi ethnic group in Burkina Faso.

The effects of an anti-vector campaign

For 6 months in 1984–1985, we conducted a pilot control campaign in the Vavoua focus using traps and ground spraying on the edge of villages and along tracks. This campaign resulted in a rapid and drastic reduction of the densities of *G. p. palpalis*, not only in the treated area but also in the neighbouring control area.

The effects of the campaign are illustrated (Table 2) by a reduction of the tsetse population and teneral fly density, and also of the epidemiological risk. The risk remained much higher in the control zone, although it varied according to season and as a result of the effects of the neighbouring treated area.

Table 2. Calculation of risk of HAT before and during an anti-vector campaign in the Vavoua focus, Côte d'Ivoire

	Before treatment	Months after intervention 1	2	3	4	5	6
Survival rate (Drs)	0·977	0·966	0·969	0·979	0·974	0·977	0·980
Traps×days (pj)	536	547	549	544	542	547	538
Catches (C)	2203	285	179	56	42	43	178
Teneral density (T)	0·545	0·119	0·022	0·005	0·003	0·004	0·041
Human blood meals (n)	16	0	1	0	0	0	2
Risk (r)	577	ϵ[a]	0·017	ϵ[a]	ϵ[a]	ϵ[a]	0·259
Control risk[b]	43	8·159	1·200	0·127	0·048	0·051	6·889

[a]Very low risk.
[b]Risk in control area.

Seasonal variation

In Daniafla, the risk of transmission varied significantly according to the season, independently of the apparent tsetse density (Table 3). This was linked to the relationship between the human and *G. p. palpalis* populations: the index of risk increased when the farmers work (sometimes permanently residing) in their plantations, either for the harvest (November to January) or when clearing the plantation (July).

Table 3. Seasonal variation in epidemiological risk of HAT in the Daniafla area, Côte d'Ivoire

	Sep.	Nov.	Jan.	Mar.	May	Jul.
Survival rate (*Dsr*)	0·979	0·977	0·973	0·972	0·985	0·977
Traps×days (*pj*)	1699	1692	1692	1698	1697	1756
Catches (*C*)	2236	1942	1460	434	273	875
Teneral density (*T*)	0·035	0·035	0·36	0·007	0·005	0·014
Human blood meals (*n*)	3	11	23	10	10	25
Risk (*r*)	0·089	0·970	3·011	0·059	0·085	1·320

Table 4. Calculation of the risk of HAT in the Zoukougbeu focus, Côte d'Ivoire

	Nov.	Feb.	May	Jul.	Sep.	Dec.
Survival rate (*Dsr*)	0·972	0·968	0·980	0·973	0·977	0·975
Traps×days (*pj*)	1949	2139	2252	2261	2251	2253
Catches (*C*)	5589	3359	4259	10525	9623	10170
Teneral density (*T*)	0·389	0·193	0·103	0·527	0·353	0·257
Human blood meals (*n*)	51	31	27	34	18	43
Risk (*r*)	199	18	15	118	27	103

A similar effect was seen in the Zoukougbeu focus (Table 4). The index of risk was 10 times greater during coffee harvesting (November) than in the period of inactivity (February) or in May, which was mostly devoted to the cultivation of food crops. In July, the farmers returned to their plantations to clear the ground: human–fly contact was not as high in November (mainly due to the reduction of visibility because of plant growth, leading to an increase in the time between consecutive blood meals), but the percentage of tenerals and the daily survival rate of flies were high: consequently, the risk was rather high. In the following December, because of a slump in the coffee and cocoa trade, the farmers reduced their activities and many immigrants had returned to Burkina Faso): the epidemiological risk was still high, but only half of that in the previous hot dry season (November 1991).

According to ethnic groups

Preliminary analysis of the observations made in the Zoukougbeu focus (Table 5) confirmed the results of parasitological investigations. In all the endemic foci, the Baoulé group (from Côte d'Ivoire) was very little affected by HAT: in contrast, the Mossi people (from Burkina Faso) were generally the principal victims of the disease. For example, in the Vavoua focus, the prevalences in the 2 groups were 0·6% and 6·1% respectively. This was due principally to the higher frequency with which tsetse fed on people of the Mossi group, a consequence of the distinctive pattern of their agricultural activity and way of life.

Table 5. Epidemiological risk of HAT in the Mossi and Baoulé ethnic groups Zoukougbeu focus, Côte d'Ivoire, in November

	Mossi	Baoulé
Survival rate (*Dsr*)	0·972	0·965
Traps×days (*pj*)	970	363
Catches (*C*)	2738	531
Teneral density (*T*)	0·404	0·223
Human blood meals (*n*)	31	5
Risk (*r*)	305	16

Within a focus it was possible to distinguish between 2 types of social environment: the 'socially exclusive' environment, inhabited almost exclusively by the Baoulé and with little communication with other groups; and the 'socially open' situation, inhabited by many different tribes with a high level of interpenetration and where the Baoulé were not numerous. In the first type of environment, the risk for Baoulé and others was effectively nil (Table 6); and cases of HAT have never been found there. But in the second situation, the risk was very high for both the Mossi and the Baoulé: all the reported cases of HAT were found there, and all the infected persons were Baoulé.

Table 6. Epidemiological risk of HAT in two types of social environment in the Zoukougbeu focus, Côte d'Ivoire, in November

Ethnic group	Social environment[a] Exclusive	Open	Whole focus
Baoulé	ϵ^b	92	16
Mossi	ϵ^b	338	305

[a]See text for explanation.
[b]Very low risk.

It is evident that the social characteristics of the 2 environments influenced the fly population structure and behaviour, which affected the potential for transmission of HAT.

Discussion

The index of risk which we propose seems to be a sensitive and accurate tool, which correlates well with epidemiological field observations. The only limits for its use are the techniques required (physiological age determination of flies, and blood meal identification).

The prevalence of HAT is a parasitological measure of the extent of transmission in a focus, but it is a relatively crude measure. More precise estimation requires the use of entomological data, and calculation of the index of risk as outlined in this paper.

The risk is never equal to zero, at least in the forest area; nevertheless low values correspond with very low prevalences (or complete absence of infection, as with the Baoulé). It should therefore be possible, by further analysis, to establish a hierarchy of biotopes within a focus to be controlled, so as to identify those to be treated with priority. This would in turn lead to a more efficient antivector campaign, with speedier intervention, fewer traps, and a decrease in the work-load for the farmers. Finally, the calculation of risk would allow epidemiological patterns to be compared between different regions of the forest zone in Côte d'Ivoire, without the necessity of large scale research programmes. This would lead to the rapid identification of other areas in which the campaign protocol developed in Vavoua could be applied.

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