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: density, longevity of teneral flies, 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 excessive effort and cost.

The application of trapping by rural communities, while representing a useful approach, also has limitations. Posting 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 teneral flies. Consequently, we take as the first element for calculation the apparent density of teneral flies (T) caught by p traps during t days.

In the forest zone, GOUTEX & 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:

\[ N = k (ADT)^a \]

where \( k = 632 \) and \( a = 1.23 \)

For the teneral flies we have the relation:

\[ T = k \left( \frac{t+1}{p} \right)^a \]

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 (DoD). 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 tsetse 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 \( C \) the number of human blood meals found in the catch, the number of days \( (P) \) multiplied by the number of blood meals \( (C) \) gives:

\[ P = k \left( \frac{C}{P} \right)^a \]

with \( a = 1.23 \)

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.

\[ P = k \left( \frac{C}{P} \right)^a \]

1994; 88, 645-648}
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 (Dr)² of tsetse flies surviving after 20 d; (iv) the average duration of life remaining, \( \log(Dsr) \); and (v) the proportion P of blood meals taken on humans by the residual population.

Thus \( r = k' \times T \times P \times (Dr)^2 \times \frac{-1}{\log(Dsr)} \), where k' is a constant.

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

\[
 r = \left( \frac{t+1}{p} \right)^{1/2} \times \left( \frac{C_D^2}{p'^2} \right) \times (Dr)^2 \times \frac{1}{\log(Dsr)} \times \left( \frac{C_D}{p'} \right)
\]

therefore \( r = \left( \frac{t+1}{p} \right)^{1/2} \times \left( \frac{C_D^2}{p'^2} \right) \times \frac{(Dr)^2}{\log(Dsr)} \)

or \( r = \left( \frac{t+1}{p} \right)^{1/2} \times \left( \frac{C_D^2}{p'^2} \right) \times \frac{(Dr)^2}{\log(Dsr)} \)

In order to obtain workable figures, the index (r) is multiplied by 10⁴.

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 minimum 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.

**Teneral.** Only individuals which had never taken a blood meal were counted (identified by the residual sac from the larval stage in the midgut: LAVEISSIBRE, 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 interlerval 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 meal.** 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 Veterinärmedizin, 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) Zoukougbeg 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

<table>
<thead>
<tr>
<th></th>
<th>Zoukougbeu</th>
<th>Vavoua</th>
<th>Daniela</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teneral density (T)</td>
<td>0.366</td>
<td>0.455</td>
<td>0.255</td>
</tr>
<tr>
<td>Human blood meals</td>
<td>52</td>
<td>16</td>
<td>6</td>
</tr>
<tr>
<td>Risk (r)</td>
<td>176</td>
<td>577</td>
<td>43</td>
</tr>
<tr>
<td>HAT prevalence</td>
<td>1%</td>
<td>6%</td>
<td>6%</td>
</tr>
</tbody>
</table>

HAT not recorded.

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

<table>
<thead>
<tr>
<th></th>
<th>Before treatment</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survival rate (Dr)</td>
<td>0.977</td>
<td>0.977</td>
<td>0.977</td>
<td>0.977</td>
<td>0.977</td>
<td>0.980</td>
<td></td>
</tr>
<tr>
<td>Teneral density (T)</td>
<td>0.545</td>
<td>0.119</td>
<td>0.022</td>
<td>0.005</td>
<td>0.003</td>
<td>0.004</td>
<td></td>
</tr>
<tr>
<td>Human blood meals</td>
<td>52</td>
<td>16</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Risk (r)</td>
<td>577</td>
<td>0.1</td>
<td>0.017</td>
<td>0.007</td>
<td>0.003</td>
<td>0.002</td>
<td></td>
</tr>
<tr>
<td>HAT prevalence</td>
<td>43</td>
<td>1.015</td>
<td>0.127</td>
<td>0.048</td>
<td>0.051</td>
<td>0.089</td>
<td></td>
</tr>
</tbody>
</table>

Very low risk.

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).
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, when 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 teneral 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).

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

<table>
<thead>
<tr>
<th>Season</th>
<th>Survival rate (Dsr)</th>
<th>Traps×days (C)</th>
<th>Teneral density (T)</th>
<th>Human blood meals (n)</th>
<th>Risk (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sep.</td>
<td>0.977</td>
<td>0.977</td>
<td>0.977</td>
<td>0.977</td>
<td>0.977</td>
</tr>
<tr>
<td>Nov.</td>
<td>0.972</td>
<td>0.972</td>
<td>0.973</td>
<td>0.972</td>
<td>0.985</td>
</tr>
<tr>
<td>Jan.</td>
<td>0.973</td>
<td>0.969</td>
<td>0.972</td>
<td>0.985</td>
<td>0.977</td>
</tr>
<tr>
<td>Mar.</td>
<td>0.973</td>
<td>0.969</td>
<td>0.972</td>
<td>0.985</td>
<td>0.977</td>
</tr>
<tr>
<td>May</td>
<td>0.983</td>
<td>0.972</td>
<td>0.972</td>
<td>0.985</td>
<td>0.977</td>
</tr>
<tr>
<td>Jun.</td>
<td>0.983</td>
<td>0.972</td>
<td>0.972</td>
<td>0.985</td>
<td>0.977</td>
</tr>
<tr>
<td>Jul.</td>
<td>0.983</td>
<td>0.972</td>
<td>0.972</td>
<td>0.985</td>
<td>0.977</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Season</th>
<th>Survival rate (Dsr)</th>
<th>Traps×days (C)</th>
<th>Teneral density (T)</th>
<th>Human blood meals (n)</th>
<th>Risk (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nov.</td>
<td>0.977</td>
<td>0.977</td>
<td>0.977</td>
<td>0.977</td>
<td>0.977</td>
</tr>
<tr>
<td>Feb.</td>
<td>0.972</td>
<td>0.972</td>
<td>0.972</td>
<td>0.972</td>
<td>0.972</td>
</tr>
<tr>
<td>May</td>
<td>0.983</td>
<td>0.972</td>
<td>0.972</td>
<td>0.985</td>
<td>0.977</td>
</tr>
<tr>
<td>Jul.</td>
<td>0.977</td>
<td>0.977</td>
<td>0.977</td>
<td>0.985</td>
<td>0.977</td>
</tr>
<tr>
<td>Sep.</td>
<td>0.972</td>
<td>0.972</td>
<td>0.972</td>
<td>0.972</td>
<td>0.972</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Ethnic</th>
<th>Survival rate (Dsr)</th>
<th>Traps×days (C)</th>
<th>Teneral density (T)</th>
<th>Human blood meals (n)</th>
<th>Risk (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mossi</td>
<td>0.972</td>
<td>0.977</td>
<td>0.977</td>
<td>0.977</td>
<td>0.977</td>
</tr>
<tr>
<td>Baoulé</td>
<td>0.977</td>
<td>0.972</td>
<td>0.972</td>
<td>0.972</td>
<td>0.972</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Ethnic</th>
<th>Social environment</th>
<th>Whole focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baoulé</td>
<td>Excl.</td>
<td>92</td>
</tr>
<tr>
<td>Mossi</td>
<td>Open</td>
<td>338</td>
</tr>
</tbody>
</table>

*See text for explanation.

### 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 anti-vector 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.

### Acknowledgements

This programme received financial support from the
UNDP/World Bank/WHO Special Programme for Research and Training in Tropical Diseases. We are indebted to Dr C. H. Green (Tsetse Research Laboratory, Bristol) for his critical reading of the manuscript, his suggestions for analysis, and the translation of the text. We also warmly thank Dr D. G. Godfrey, Dr P. Truc and Mme Soufflet for translation of the text; Dr C. Staak for the identification of tsetse blood meals; and the anonymous referees whose pertinent criticisms greatly helped us to clarify the paper.

References


Received 16 March 1993; revised 8 February 1994; accepted for publication 15 March 1994

Announcements

The Year of Louis Pasteur: International Symposium on Actiology and Pathogenesis of Infectious Diseases
Dakar, Sénégal: 10–13 April 1995
Organised by the Institut Pasteur, Paris, the University of Dakar, the Institut Pasteur de Dakar and UNESCO

Plenary sessions will include Tuberculosis, Viral hepatitis, Parasitic diseases, Infections of the CNS, Enteric diseases, and AIDS.
Further information from Dr J.-P. Digoutte, Institut Pasteur de Dakar, 36 Avenue Pasteur, B.P. 220, Dakar, Sénégal; telephone +221 23 98 83, fax +221 23 87 72.

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Fellows of the Society have always been actively involved in many tropical countries in establishing and developing medical schools and other training institutions. But some of these schools, particularly in poorer African countries, face severe hardships. Students have no books, there is no foreign exchange for journals, equipment lacks spares, research cannot be supported and external aid is directed towards primary health care.

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The Tropical Health and Education Trust aims to extend support like this to more countries, hospitals, medical schools and students and needs funds to do it: Fellows of the Society who would like to take this opportunity to help our colleagues overcome some of their obstacles can do so through a single gift, a four-year or a deposited covenant, or even through a legacy.
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