Insect Sci. Application, Vol. 1, pp. 77 to 83 n° 1,
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0191-9040/80/0601-0077$02.00/0

ECOLOGY AND EPIDEMIOLOGICAL IMPORTANCE OF *GLOSSINA PALPALIS* IN THE IVORY COAST FOREST ZONE

ALBERT CHALLIER
International Centre of Insect Physiology and Ecology, P.O. Box 30772, Nairobi, Kenya

and

JEAN PAUL GOUTEUX
Mission O.R.S.T.O.M., auprès de l'O.C.C.G.E., Bobo-Dioulasso, Haute-Volta

Abstract—Ecological surveys were carried out to assess the population characteristics and epidemiological importance of *Glossina palpalis palpalis* (Rob-Desv.), 1830 in the human trypanosomiasis focus of Vavoua in the forest zone of Ivory Coast. *G. p. palpalis* was widespread in all components of the ecosystem: forest, interstitial savannahs, coffee plantations, tracks and villages. Most flies were caught at the forest edge. Sex ratio and age composition of populations varied in relation to trapping sites. Open areas were dispersal places. Plantations provided resting, feeding and breeding sites giving rise to close man–fly contact. Here, teneral flies could become infected and later on transmit trypanosomes to plantation workers and their families. The role of man and domestic pigs together with that of fly behaviour and genetic factors in the transmission of the disease are discussed. Methods of tsetse control are suggested in the light of the findings.

Key Words: Glossina palpalis, tsetse fly, ecology, epidemiology, Ivory Coast

INTRODUCTION

THERE have been many cases of human trypanosomiasis recorded in the Vavoua focus in the Ivory Coast forest zone since 1975. Medical surveys have shown that practically all patients are villagers working in plantations. At the time of our entomological surveys, cases were concentrated in seven villages (most from four of these seven villages), located along a road crossing through the middle of the Vavoua focus area. The fact that tsetse flies were widely dispersed in the area and that patients were all plantation workers aroused our attention.

From October 1977 to March 1978, entomological surveys were carried out to assess the epidemiological importance of tsetse populations and the part they played in trypanosome transmission, in relation to their eco-distribution, density, and physiological composition (in respect of sex ratio and age).

MATERIALS AND METHODS

General description of the Vavoua focus

The Vavoua focus area is located on the western border of the 'Baoulé V'; a southward extension of the Guinea savannah into the rainforest belt. Koetinga and Koudougou-Carrefour are villages considered as the 'epicentre' of the focus (Koudougou-Carrefour: 7°25'N/6°24'30"W). Most cases were found within about 10 km of these villages.

The region lies between altitudes of 200 and 3000 m a.m.s.l. on granitic and schistous soils without exaggerated relief. The Dé, the main river, flows north–south through the area. It is a tributary of the River Lobo which is part of the Sassandra system. Streams have a poorly defined riverbed and most of them dry up during the dry season (December to March).

Climate

According to ELDIN (in: *Le Milieu Naturel de la Côte d'Ivoire*, p. 104), climatic characteristics for zone C in which the Vavoua area is situated are:

rainfall 1200–1800 mm (for the meteorological station of Vavoua, rainfall is 1288 mm);
four seasons, with long dry season from November to March, and short dry season in July;
annual limits of mean minimum and maximum temperatures of 19°–33°C;
annual limits of monthly means of vapour pressure: 25–28 mb (mercury).

Vegetation

According to GUILLAUMET and ADJANOHOUN (in: *Le Milieu Naturel de la Côte d'Ivoire*, p. 189) the Vavoua area lies at the interface of the rain forest and Guinea savannah zones, in a transitional area between two rain forests of semi-deciduous types. Interstitial grasslands (or interstitial savannahs) are natural grassy areas which open through the forest on sandy soils. Some of them are characterised by *Borassus aethiopum* with a bush stratum. They are often crossed by riverine gallery-forests.

Fauna

Main mammals encountered are: cane rat, small species of antelope, monkey and buffalo. In villages and plantation camps, pigs, sheep, goats, chickens and ducks are reared. Moreover, a few cattle graze in the region.

Human population

The human population is concentrated in villages built in the interstitial savannahs or small cleared areas in the forest. These villages are often surrounded by coffee plantations but separated from them by a strip of open scrubland. The inhabitants of Koudougou-PK5, Koudougou-PK8, Koudougou-Carrefour, Koetinga, Gozi and Kuenoufla belong mainly to the Mossi ethnic group, a Voltaic tribe. Workers work in plantations in the day-time and return to their villages in the evening. However, some of them spend continuous periods of the year in plantation camps with their families. Major and minor tracks lead to plantations off main roads. Maize, yam, cassava, banana and other fruit trees grow in small fields, in parts of the plantations or in patches of low ground.

Sampling methods

Various components of the forest ecosystem were sampled (Fig. 1).

Villages: Koetinga is a village surrounded by forest, 10–100 m from the houses; there are ponds which are frequented by pigs. Koudougou-Carrefour, smaller than the previous village, is built in an interstitial savannah partially flooded in the rainy season; its western side is bordered by the gallery-forest of River Dé. Koudougou-PK5 is surrounded by forest; its eastern side is bordered by a track, the forest edge and a small coffee plantation. Traps were set up inside and around villages.

Plantations: Plantations A and B were located 2 km from the Zuenoula road, with their camps in the middle of the plantations. The workers' families lived there all year. Plantations C and D were in Dé forest; C was a mixed plantation (food plants and coffee); and D a plantation of young trees. Plantation E, 5 km from Vavoua, was divided into two parts: one part with coffee trees on flat ground, and the other with cocoa trees on a slope. Traps were set up in small glades between the trees, along paths, in camps and in some coffee drying areas.

Tracks and interstitial savannahs: The Dé forest track crossed an interstitial savannah (2.5 km), penetrated the forest and then again a savannah. It ended in plantations C and D. The Zuenoula track led to plantations A and B, having crossed forest plantations and an interstitial savannah (300 m). The Koetinga–Koudougou—Carrefour tract ran through forest and open areas, for 2.5 km. Traps were positioned at 160 m intervals.

Koudougou-PK5 'bowal': This 'bowal' (a lateritic outcrop) was 1.5 km long with some thickets; it was surrounded by forest.

Low-land field: Cultivated on either side of the Vavoua road, this field extended through a forest (for 200 m). Traps were set on the edge of the field near a small bridge.

Hereafter in this paper, 'zone' means a geographical location where different conditions occur; 'sectors' are sets of trapping sites located in the same component of the ecosystem (e.g. forest edge, plantation, or village).

Trapping technique

Biconical traps (CHALLIER and LAVEISSIÈRE, 1973; CHALLIER *et al.*, 1977) were set up in sites cleared of vegetation in the morning and left for 2 days. Cages were removed once or twice a day. To cope with

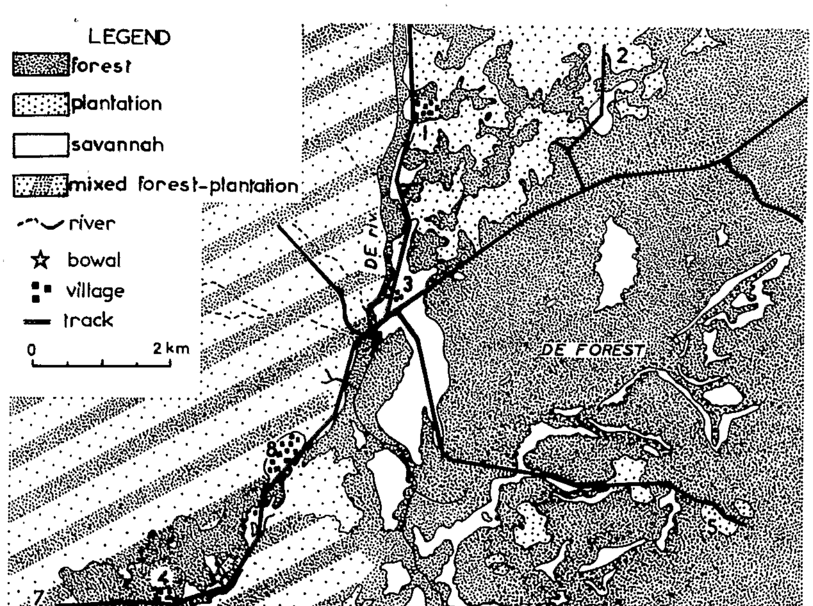

Fig. 1. Area of the Vavoua focus. 1. Koetinga village; 2. Coffee plantations A and B; 3. Koudougou-Carrefour village; 4. Koudougou-PK5 village; 5. Coffee plantations C and D; 6,7. out of the figure (plantation E, field and stream); 8. Koudougou-PK8 village.

attacks by ants, the bases of trap poles were coated with grease.

Examination of samples and dissection of flies

Fly cages were taken to the entomological station in Vavoua and put into a box with a cotton wool plug impregnated with chloroform to kill the flies quickly. Tsetse flies were numbered by sex and by subspecies; samples from certain trapping sites were dissected to study the age composition of populations. The method of SAUNDERS (1960), as improved by CHALLIER (1965), was used to determine the physiological age of females. The number of stable flies and horse flies collected was also recorded.

Apparent density

Apparent density as determined by trapping (ADT), is defined as the number of trapped flies caught over a period of 10 hr; this period corresponds to the diurnal activity cycle of *G. palpalis*. Flies from traps which had been attacked by ants were rejected.

RESULTS

Species trapped in the area

For 5 months (about 12 days per month), the numbers of trapped flies were as follows:

Palpalis group: *G. palpalis* (Rob.-Desv.), 1830 14,658 (9202 females and 5197 males); *G. pallicera pallicera* Bigot, 1891 834 (364 females and 463 males);

Morsitans group: *G. longipalpis* Wiedemann, 1830 a few specimens only;

Fusca group: *G. fusca fusca* Walker, 1849 114 (64 females and 50 males); *G. nigrofusca nigrofusca* Newstead, 1910 1011 (314 females and 686 males).

In this paper, only the results dealing with 8071 *G. palpalis* for 6500 trapping hours are considered.

Eco-distribution and apparent density

The results from each trapping site (or trap) were very variable from day to day, and when related to the whole sector they fluctuated according to the different observation periods.

Along the forest edge and tracks, the traps taking the greatest number of flies were those at the exit to forest tracks, track intersections within and outside the forest, as well as on pond sides. In plantations, the best trapping sites were small clearings between cocoa and coffee trees and along paths. In villages, traps on the peripheral edge were most productive. Some flies followed paths running between houses, but most others were concentrated around small ponds freqented by domestic pigs. Along streams, catches were relatively high near bridges and in small open areas of river banks.

From October to March (end of wet season) and into the dry season the density varied in different sectors (Table 1). In relation to the level of density and its pattern of variation the following sector groups may be distinguished:

(i) High density sectors (ADT: 45 to over 80): only one sector, a water hole at the forest edge, fell in this category;

(ii) Mean density sectors (ADT: 10 to 40): these consist of forest and plantation tracks as well as some riverine sites;

(iii) Mean to low density sectors (ADT: 10 to 1): plantations and most riverine sites are dense; these are sectors intermediary between the forest and open areas;

(iv) High to mean density sectors (ADT: 55 to 10): the peripheral forest edge of villages and their continuation along tracks are concentration sites in the wet periods of the year;

(v) High to low density sectors (ADT: 40 to 5): the tracks that emerge on interstitial savannahs collect flies to the open areas in the wet season but very few in the dry season;

(vi) Low density sectors (ADT: 0.1 to 10): some plantations as well as the insides of villages and tracks from villages located in small interstitial savannahs belong to this group.

For the first three groups, density decreased from the end of the wet season until the middle of the dry season (January); from February, density increased, so that by March, a density level as high as that in October was reached. For the 3 other groups, density decreased during the dry season (except in February), in the peripheral edge and village sectors.

Sex ratio

Sex ratio (percentage of females) nearly always exceed 50%. It was higher and more varied in the more open trapping sites. In Koetinga village, it exceeded 80% in October, but was only 30% in February. Along forest edges it decreased, but remained at relatively high level. Along savannah and village tracks, it was relatively high. In plantations and along forest tracks, it was lower than in open areas but increased during the second part of the dry season. The lowest levels (less than 50%) were observed along River Dé.

Age composition of the population

In December, the physiological age of samples of female flies from various sites was determined. In the analysis of the data (Table 2), three groups were recognised: nulliparous, young parous (I-II-III groups), and old parous (IV and over groups) females.

(i) *Intra-zone/inter-sector*. Koudougou-Carrefour: periphery/inside/Dé River: $\chi^2 = 50.725$ ($P < 0.01$; 4*df*); Koetinga: periphery/inside: $\chi^2 = 3.370$ ($P = 0.20$; 2 *df*); Plantations A and B: plantation/track: $\chi^2 = 2.877$ ($0.30 > P > 0.20$; 2 *df*); Plantation E: cocoa/coffee: $\chi^2 = 2.813$ ($0.30 > P > 0.20$; 2 *df*).

(ii) *Intra-sector/inter-zone*. Plantations: A and B/E: $\chi^2 = 1.152$ ($0.90 > P > 0.50$; 2 *df*); Periphery: Koudougou-Carrefour/Koetinga: $\chi^2 = 2.616$ ($0.30 > P > 0.20$; 2 *df*); Inside: Koudougou-Carrefour/Koetinga: $\chi^2 = 2.953$ ($0.10 > P > 0.05$; young and old parous females; 1 *df*).

From these results a clear cut difference appears between open areas (villages, forest edge) with a deficit of young flies, and wooded areas (riverine vegetation, plantation) with a normal population composition with a high percentage of young females (Fig. 2).

Table 1. Trapping of *G. palpalis* in the Vavoua focus (T. hr, trapping hours, ADT: apparent density by trapping, F: forest, S: savannah, Pl: plantation, E: east, W: west, (1) zone number, see Fig. 1)

Trapping zone	Trapping sector	Number of traps	19–26 October T. hr	19–26 October %♀	19–26 October ADT	8–20 December T. hr	8–20 December %♀	8–20 December ADT	11–21 January T. hr	11–21 January %♀	11–21 January ADT	14–17 February T. hr	14–17 February %♀	14–17 February ADT	16–22 March T. hr	16–22 March %♀	16–22 March ADT
Koetinga vil. (1)	F. edge	12	288	74.0	42.1	216	70.9	37.6	224	58.1	15.2	220	50.0	15.8	240	52.3	9.2
	Track (F.)	5	75	62.1	57.3	90	55.4	47.6	98	46.5	15.9	100	52.9	28.7	100	47.6	17.3
	Inside	10	135	83.9	10.3	351	68.7	4.8	195	8/14	0.7	200	6/20	1.0	200	4/9	0.45
Zuenoula road (2)	F. track	6	57	59.1	16.7	100	56.8	14.0	133	63.2	11.7	111	59.6	20.7	120	56.0	27.25
	Track (S/F)	2	19	62.3	40.5	36	61.0	23.1	46	72.7	7.2	37	17/22	5.9	40	8/17	4.25
	Pl. track	4	38	55.8	36.3	72	64.0	26.4	71	61.1	15.2	74	59.7	31.6	80	69.6	34.6
	Pl. A	3	30	57.1	16.3	54	58.5	7.6	69	61.1	8.7				60	46.0	12.3
	Pl. path	5	50	38.6	8.8	90	57.1	8.7							100	78.8	28.1
	Pl. B	7	70	52.2	9.7	126	63.6	6.2							140	73.6	18.0
Koudougou-Carrefour vil. (3)	F. edge (W.)	7	144	74.2	22.9	97	65.1	15.7									
	S. edge (E.)	6	174	55.0	1.7	165	5/7	0.4									
	Inside (W.)	4	60	8/17	2.8	110	84.3	3.0									
	Inside (E.)	5	75	3/3	0.4	138	5/6	0.4									
	Track (S.)	4	116	50.9	4.6	110	48.3	2.8									
	Stream	1/10	15	11/23	15.3	180	50.8	6.8									
Koudougou-PK 5 vil (4)	F. edge	10				125	64.7	19.0									
	Pl.	2				25	56.9	48.7									
	Waterhole	1	9	48.7	82.2	12.5	58.9	46.4							20	56.6	56.5
	Inside	5				63	6/9	1.4									
	Track (F.)	1				12.5	14/25	20.0									
	Bowal	9/6				113	56.9	4.5				105	5/8	0.8			
Koetinga	Forest	3							30	9/15	5.0						
Dé Forest (5)	F.S. track	9	108	60.3	12.6	153	45.9	4.0									
	Pl.C	8	96	10/13	1.3												
	Pl.D	6	96	7/10	1.0												
Daloa road Pl.E (6)	Cocoa	17				153	60.9	7.0									
	Coffee	11				99	46.0	5.1									
Vavoua road (7)	Field	2	19	79.3	27.9												
	Stream	2	14	57	20.0												
Koetinga to Koud.	Track	13				(216)	(57.1)	(10.4)									

Table 2. Age grading of *G. palpalis* females: numbers of nulliparous, young parous (1–3 groups), old parous (4 and over groups); percentages of nulliparous

Trapping zone	Trapping sector	% Teneral	Nullip.	Young P.	Old P.	Total
Koudougou-	Periphery	4.8	21	45	38	104
Carrefour vil.	Inside	6.5	2	5	24	31
	Track	3 10	7	3	0	10
	Steam	27.9	39	36	11	86
Koetinga vil.	Periphery	4.9	28	49	66	143
	Inside	6.7	2	10	18	30
Zuenoula road	Pl	14.3	34	24	26	84
	Track	20.8	103	99	62	264
Daloa road	Pl	15.3	50	49	9	150

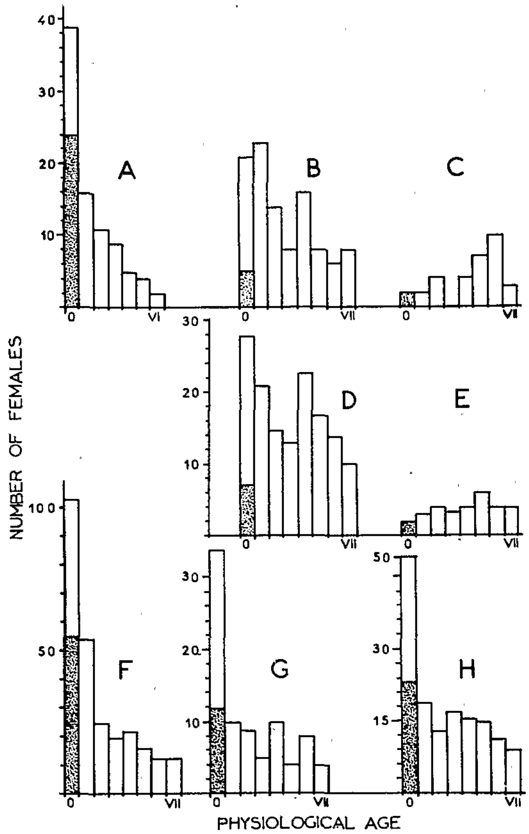

Fig. 2. Physiological age of females from different sampling areas: Koudougou-Carrefour (A: stream, riverine forest; B: forest edge; C: within village); Koetinga (D: forest edge; E: within village); F: forest track and plantation; G: plantations A and B; H: plantation E, Daloa road.

Teneral flies were scarce inside villages (2/31, 2/30) but more numerous in wooded areas (24/86).

Pregnancy rates

No significant difference was observed between young and old parous females and between different sectors or zones with regard to females with an empty uterus or bearing an egg and females bearing larvae. The distribution for 611 females trapped in December is shown in Table 3.

Table 3. Pregnancy stages in females trapped in December

Females with	Egg	Larva (stages I–II)	Larva (stage III)	Empty uterus
Number	237	222	46	106
Percentage	38.8	36.3	7.5	17.4

DISCUSSION

Eco-distribution

G. palpalis palpalis was trapped at all sites (forest, plantations, and open areas) throughout the dry season. These areas constituted permanent hibitats. The forest was used as a breeding and resting haunt and open areas as feeding grounds; between these two areas was a third zone, the forest edge ecotone, where flies concentrated and from where they dispersed through interstitial savannah (field, villages and tracks) in search of hosts. Plantations were semi-open areas where flies found breeding and resting sites as well as feeding grounds.

Apparent density

Apparent density was progressively lower as the trapping sites were moved further from the forest edge. Any opening through this edge facilitated the flight of tsetse flies, particularly tracks and paths which provided long flight ways to open areas. Certain sites were very attractive (water holes and ponds frequented by pigs), but in large open areas flies disperse so that density was low (villages and interstitial savannahs). Since plantations contained the 3 basic habitat components (breeding, feeding, and resting sites), flies were constantly present but dispersed, which explains the low mean density levels. A few samples from the forest indicated low density, due probably to wide dispersal (ADT: 5.0 in January). The more open the trapping sites, the larger the density variation range. In the dry season, vegetation was far less dense; flies found their hosts more easily than before, so that they ventured less into open areas. Along forest edges and tracks, as well as in villages and interstitial savannahs, density decreased constantly from October to March. Conversely, density increased from January to February in forests and plantations. The fluctuation of tsetse populations probably followed that of rainfall which showed a minimum in December–January.

Sex ratio

Sex ratio varied in relation to the trapping sites. It was high in open areas probably because these were feeding grounds. Females left resting sites only when hungry; moreover they lived longer than males, which explains their higher proportion in samples A relatively high percentage of males indicated breeding and resting sites (forests, plantations).

During the dry season, the sex ratio constantly decreased in open areas and increased slightly in forests and plantations, because females were less inclined to leave their resting haunts (see above).

Age composition

Young and old females dispersed farther away from forests than did teneral flies. Very few teneral flies were caught in villages, whereas many were caught in plantations and forests.

In the forest zone, due largely to climate, teneral flies did not quickly exhaust their fat reserves. They did not need to feed during the days following emergence; and they stayed in their emergence sites for a few days before leaving to take their first bloodmeal in the open areas.

In plantations, teneral, young and old flies found resting and breeding sites as well as feeding grounds.

Pregnancy rates

The distribution of females between different stages of pregnancy suggests that two bloodmeals were taken during a reproductive cycle: the first one at the beginning of larviposition, and the second one in the middle of the cycle when a larva was in the uterus. In the field, females urgently needed a bloodmeal after larviposition, when the uterus was empty or contained an egg. A few females, bearing heavy III-instar larvae were active.

In Table 4, the percentages of females in different stages of pregnancy are compared with those observed of *G. morsitans* bred at 25°C in the laboratory (DENLINGER and MA, 1974). In the laboratory, 80% *G. morsitans* females fed on the first day of the reproduction cycle. The utilisation of nutritional reserves to feed larvae started on day 4. From day 6, a few flies fed but none did so the day of larviposition.

The *G. p. palpalis* females (611) should be distributed according to a 50%–50% proportion between 'empty + egg' and 'larva -I-II-III' for two meals; the deficit for the second meal might originate from the low activity of the females bearing III-instar larvae; these females were too heavy to fly to open areas. For 'egg' and 'larva I + II' the percentages from Vavoua agree with those from the laboratory *G. morsitans.*

Epidemiological importance of G. p. palpalis *populations*

In the Vavoua area, *G. p. palpalis* is present in all places frequented by man: villages, tracks, fields and plantations, and also in forest islands. The population density of flies is always and everywhere sufficient for close contact with man. However, local populations do not exhibit the same epidemiological importance in the different components of the ecosystem. Transmission of *T. brucei* subgroup trypanosomes is possible only if tsetse flies become infected within the very first days after emergence (WIJERS, 1958). Therefore, the active fraction of populations has to include very young (teneral) flies. The age composition of population differs according to the place where populations are sampled. Almost all flies caught in open areas (villages, forest edges, tracks and interstitial savannah) are old flies which cannot become infected. The number of teneral flies is doubtlessly too small to enable flies to become infected.

Very few trypanosomiasis cases originate from infected flies in villages. This agrees with data from medical surveys: all patients are inhabitants working in the plantations. If transmission occurred in villages, most villagers would be ill, particularly women, children, and old people because of the great numbers of flies inside and around the villages.

In plantations, the number of teneral flies is relatively high. Since flies breed, rest, and feed in the same place, they stay there. Resting teneral flies can be disturbed and still find a host, particularly a man working in a plantation. A high proportion of the fly populations are succeptible to infection and thus capable of infecting man.

Anthropophyly of G. p. palpalis

Though *G. p. palpalis* is not a very anthropophylic subspecies in forest situations permanent, close contact with man in plantations enables the anthropophylic fraction of populations to find opportunities to bite man, particularly workers and their families living in camps. If anthropophyly is a hereditary character, flies that bite man would come back to him.

In the Nigerian forest zone, *G. p. palpalis* is not an anthropophylic subspecies. No trypanosomiasis focus occurs there. This situation does not agree with the presence of several foci in the Ivory Coast forest zone. A possible explanation is that in the Ivory Coast *G. p. palpalis* populations are hybrids from *G. p. gambiensis* and *G. p. palpalis* (MACHADO, 1954). Biometrical studies on populations of West African flies (CHALLIER, in preparation) corroborate Machado's results.

In the forest zone of the Ivory Coast, the *gambiensis* population fraction (*G. p. gambiensis* is very anthropophylic) would be the only human trypanosomiasis vector. The presence of this *gambiensis* fraction of populations would explain why very few flies are caught by fly-boys whereas traps catch plenty of *G. p. palpalis* and *G. p. gambiensis*; similarly, this result explains why man is scarcely bitten.

Role of man

Plantations are often contiguous, and the flies of one plantation have no difficulty in dispersing and encountering man in another plantation. Thus, transmission from plantation to plantation is easy. Small tracks and paths through plantations are good fly-ways and thus facilitate movement. Moreover, workers who help their friends in other parts of the focus, or who work in several plantations, can intro-

Table 4. Comparison between the duration of *in utero* development stages in *G. morsitans* females (as a percentage of the total reproduction cycle) and the proportion of *G.p.palpalis* trapped in different pregnancy stages

Species	Egg	Larva (stages I–II)	Larva (stage III)	Empty uterus
G. morsitans	41.7	33.3	24.4	0.6
G. p. palpalis	38.8	36.3	7.5	17.4

duce trypanosomes into places hitherto free of infected flies (some observed cases).

Role of pigs

Pigs are very important in providing animal proteins to forest-dwelling people. Their elimination in a region of Ivory Coast (CHALLIER, 1971) was doubtless the cause of the disappearance of tsetse flies. In trypanosomiasis foci, this animal might divert flies from man, but it might also play the part of a trypanosome reservoir.

CONCLUSION

This study underlines the part played by tsetse fly behaviour in trypanosomiasis transmission. Forested areas (plantation and rain forest) yield breeding and resting sites, while open situations (villages, tracks, fields, and grasslands) are used as feeding grounds, mainly by non-teneral flies. Plantations constitute a complete habitat, where teneral flies are in close contact with man, become infected, and transmit trypanosomes to man. Plantations represent the main places of human trypanosomiasis transmission; places to which control measures should be applied as a priority. That is why trials of insecticidal treatments are currently being carried out in this part of the ecosystem.

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