STUDIES ON THE REINVASION BY *SIMULIUM DAMNOSUM S.L.* INTO THE EASTERN AREAS OF THE ONCHOCERCIASIS CONTROL PROGRAMME AND ON THE VECTORIAL CAPACITY OF DIFFERENT SPECIES OF THE *S. DAMNOSUM* COMPLEX IN TOGO AND BENIN 1982

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page:

INTRODUCTION

The extention of the Onchocerciasis Control Programme phase III towards Northern Togo and Benin faces a phenomenon of reappearing flies in the treated areas during the rainy season, comparable to the reinvasion problem in the South-Western parts of the programme (GARMS et al. 1979, 1980, 1981, WALSH et al. 1979). In Togo, the invading flies were classified to Simulium squamosum predominantly along the Mô river system with an increasing proportion of S. sirbanum/S. damnosum s.str. at the Kara river and they were almost exclusively S. sirbanum/S. damnosum s.str. along the Bouli, Alibori and Mêkrou rivers in North Benin. The proportion of S. soubrense/ S. sanctipauli amongst the reinvading flies was low and decreased from the South to the North.

Experimental treatments of the Simulium breeding sites in the upper Aniê and Mono rivers in 1980 were not satisfactory in reducing the biting densities in Togo to a tolerable level (GARMS et al. 1980). Therefore, the last year's experimental treatments were extended towards the lower regions of the Mono and Asukawkaw river systems in order to attack the suspected source areas of the reinvading flies. The results of these treatments were fully satisfactory in the mountaineous areas towards the Ghanaen border, but were rather poor along the lower Mono (GARMS et al. 1981).

No experimental treatment of rivers outside the OCP area have been done during the rainy season of 1982. Hence, the extend of this year' reinvasion can be compared to the situation during the last year without control (1979) and with the past two years of more or less effective control (1980 and 1981). Treatments of the Kara river upstream from the Kara bridge have been interrupted during the rainy season until beginning of September on the demand of the insecticide screening team.

A special problem to the OCP has raised from the appearence of Abate-resistent S. soubrense/S. sanctipauli in the Ivory-Coast (GUILLET et al. 1980). Although there were still no indications for resistence of these larvae in Togo or Benin, special attention is paid on the abundance and vectorial capacity of these species in the savanna.

Flies, coming to bite on man, were caught at five fly-catching sites in various bioclimatic zones of Togo and Benin for the evaluation of the vectorial capacity of different vector species. For this purpose, the adult female flies were classified according to their morphology into three groups: S. damnosum / S. sirbanum (S. da/si), S. squamosum (S. sq) and S. soubrense / S. sanctipauli (S. sa/sa). The last group includs the Eastern form of S. soubrense ("Beffa" form) which has been newly described as one interbreeding form of the S. soubrense/S. sanctipauli subgroup of S. damnosum s.l. (MEREDITH et al. in press). Females of this form often have pale or mixed wing tufts (GARMS et al. 1981).

S. so/sa flies were caught only at a very low proportion of the total biting rate in the savanna and all calculations of the vectorial capacity of this group are therefore based on a limited number of infected flies. In order to investigate the susceptability to the savanna strain of Onchocerca volvulus of flies of the S. so/sa group, and to compare it to the susceptability of flies of the two other groups, experimental infection of flies was performed in different bioclimatic zones by feeding the flies on the legs of two heavily infected volonteers from the savanna. These experiments were done in collaboration with Dr. Omar (OCP consultant, August to December 1982).

MATERIAL AND METHODS

Study Area:

Fly-catching sites of the OCP in Togo and Benin, used in this study, are shown in Fig. 1. The reinvasion was monitored at Mô à Mô and Bagan in the river Mô valley and at Landa Pozanda in the Kara valley in Togo and at Gbassê in Benin (river Bouli). At Landa Pozanda, local breeding continued, due to an interruption of the insecticide treatments on demand of the insecticide screening team, until the beginning of September, when the regular weekly treatments were taken up again.

For the study on the vectorial capacity of different fly-populations, five fly-catching sites were selected, four of which were outside the OCP area: Landa Pozanda within the area (r. Kara), Djodji (r. Gban Houa) and Têtêtou (r. Mono) in Togo outside the OCP, and Bêtêrou (r. Ouêmê) and Kaboua (r. Okpara) in Benin.

Supplementary information was obtained from the routine OCP fly-captures inside and outside the OCP area and from the dissections of flies in the sectors and sub-sectors of Kara, Atakpamê (Togo) and Parakou (Benin).

Prospections of Simulium breeding sites:

Occasional larvae-collections were carried out at breeding sites in Togo, but no time was available to do so in Benin. Most of the larvae samples came from the routine prospections of the OCP sector teams. No helicopter prospections have been made for this study. The larvae were fixed in Carnoy and were sent to Mr Fiasorgbor (OCP Ouagadougou) for cytotaxonomic identification.

Fig.1

(modified from GARMS et al., 1980)

Identification and dissection of the flies:

From the five fly-catching sites for the study on the vectorial capacity, once a week all flies coming to bite on man during one day (7.oo to 18.oo hrs) were send to the laboratory in Kara. Starting at the beginning of May, these flies were dissected into nulliparous and parous flies by the OCP sector staff, and the parous flies were preserved for further examination in 70% alcohol. From August 2nd to 18th, these dissections were made by Mr Nigbei and myself. All parous flies preserved have now been given to Dr. Garms (Hamburg) for further identification and dissection.
From August 19th to the end of this study (October 22nd), the flies were identified prior to their dissection according to their morphology following the description of GARMS et al. (1980, 1981). Detailed description of the proceedure of examining the flies and measuring the lengths of thorax and antennae is given in the annex. It was found from own experience, that the techniques used are crucial for the correct identification of the flies into the three groups: S. da/si, S. sq and S. so/sa. After the identification, the flies were dissected for the detection of parous rates and filarial infections. The filarial larvae, found during these dissections were given to Dr. Omar for histochemical identification.

Experimental transmission:

(in collaboration with Dr. Omar)

The flies were allowed to feed until fully engorged on the legs of two highly infected volonteers from Landa Pozanda (21 and 25 years old, both male). The flies were caught in routine fly-catching tubes and the time and site of their bloodmeal were recorded. Three experiments were carried out: at Landa Pozanda (31.8.-1.9.), at Têtêtou (11.9.) and at Djodji (17.-18.10.). Samples of flies were dissected at 5 min, 30 min 1 hr and 24 hrs after the bloodmeal to determine the numbers of microfilariae ingested and the proportion of those passing into the hemocoel (This was not done at Têtêtou). The blood-fed flies were kept at room-temperature ($\sim 25^{o}C$) and were fed on sugar solution (10%). Those flies, that died during one day, were dissected the same evening in order to determine the species group and their parasitic load. After the period of development of the worms in the flies, i.e. at the 6th day after the bloodmeal, the remaining flies were dissected.

Skin snips were taken from the two volonteers, using a Holth punch, at the shoulder, iliac crest, calf and ancles. The snips were incubated in saline and the microfilariae emerging were counted after 30 min and 24 hrs.

RESULTS :

The course of reinvasion in Togo and Benin 1982

1. The hydrological situation:

The over-all onset of rains was early this year in May, but in the following, the hydrological situation was characterized by a deficiency of rain until the end of August.
The draught was most marked at the region of Atakpamê, less towards the North and towards the South of Togo.

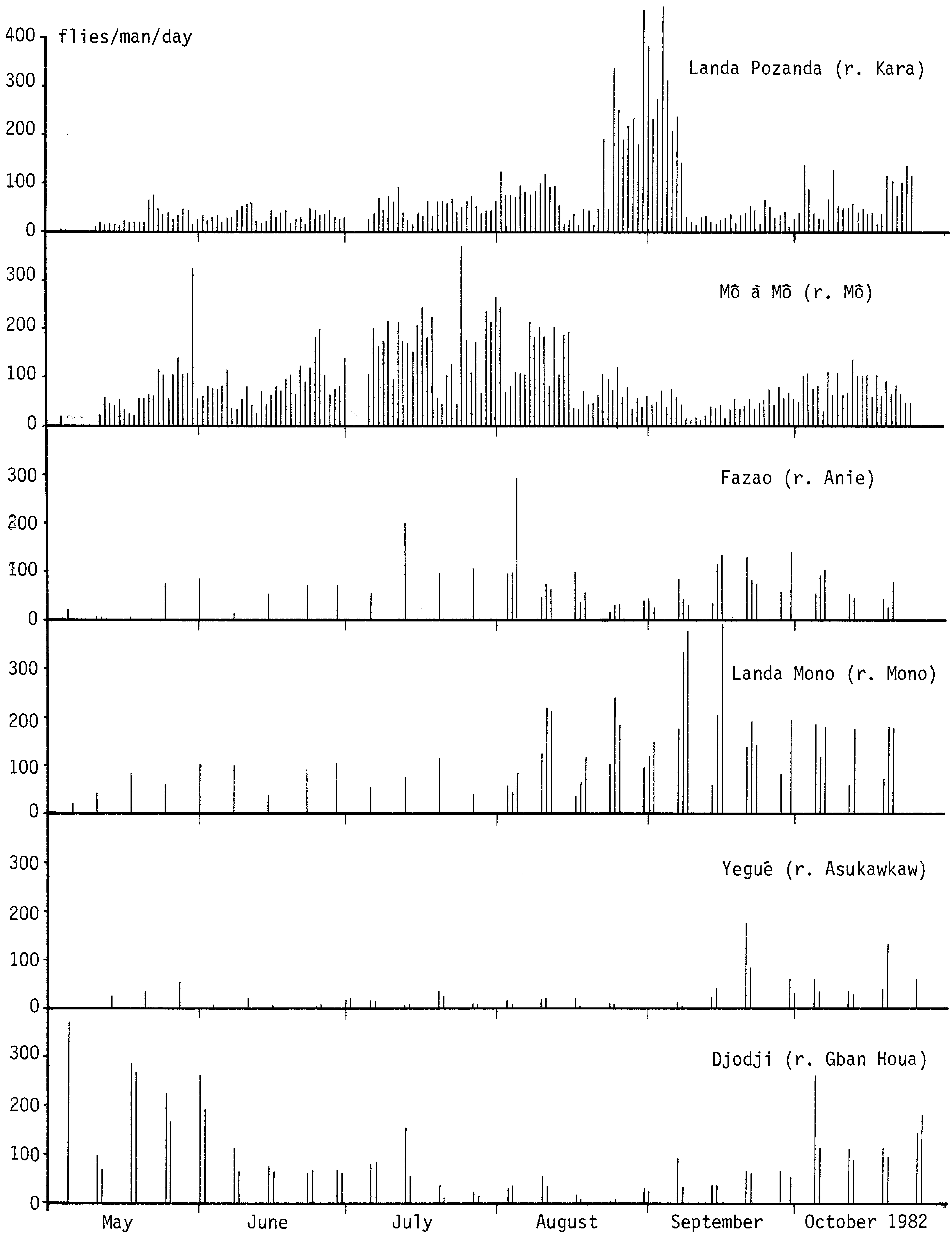
2. The daily biting rates at the fly-catching sites: (Fig. 2)

Togo:

The biting rates reflect the hydrological situation. At Landa Pozanda (no larvae-control until end of August!), the daily biting rate increased from very low rates at the beginning of May to an average biting rate of 30 flies in May, June and July but did not exceed 100 flies/man/day before the beginning of August. Maximum biting rates (465) were observed at the end of August and beginning of September. From the 3rd of September, the biting rates decreased steadily due to the insecticide application starting 1st of September and being repeated every week. However, the biting rates remained stable at about 30 flies/man/day during September and increased in October to an average rate of 67 flies/man/day and to maximal daily biting rates of 137. Nulliparous flies were found throughout this period.

The biting rates at Mô â Mô increased from 20 flies/man/day to about 100 by the end of this month, with a peak biting rate of 327 at the May 30th, 1982. During July, they were frequently above 100 and 200 and remained at this level until the end of August. In September they never exceeded 80 flies, but increased by the middle of October (138 flies/man/day, October 12th, 1982). Nulliparous flies were always present at a proportion of 30 to 50 percent. Unfortunately,

Fig. 2 : Daily fly-biting densities in Togo (May - Oct. 1982)



monthly maximum biting rates were observed at days, when the flies were preserved in alcohol, and hence it is difficult to decide, whether the proportion of parous flies increased during these periods of presumed re-invasion.

At Fazao, the biting rates were constantly below the rates of Mô à Mô, although it is situated in an uncontrolled area. At the three new catching sites Yêguê, Tinkiro and Dêguinguê along the headstreams of the Asukawkaw in the mountaineous regions biting densities were low.
The biting rates at these sites did not exceed 60 flies per day until the beginning of September, and reached maximum levels at the middle/end of this month (Tinkiro: 248 flies/man/day at September 16th, 82, Yêguê: 352 at September 20th, 82).

Similarly, the biting rates at the new site along the river Ogou, Goubi, were very low: between 0 and 3 until the end of July, then increasing slowly to a maximum of 129 by September 14th, 82.

At Landa Mono, along the upper Mono, the biting rates were comparably to those of Landa Pozanda.

At Djodji and Tétêtou, the biting rates were extremely low, as compared to previous years.

Benin

At Kaboua, the biting rate increased from 0 in the beginning of May to a daily biting rate of about 100 flies at the end of May and remained rather stable at this rate until the end of August, when it decreased for a short time before increasing to the maximum biting rate of 686 flies/man/day on the 14th of September. By the end of October, the biting rates decreased to an average rate of 240 flies/man/day. Nulliparous flies were always the majority of the flies dissected at this site.

The dynamics of the biting rates at Bêtêrou were very similar to those of Kaboua, however, they were much lower and did not exceed 100 flies/man/day before the end of July. The maximum biting rate observed was 301 flies/man/day on the 13th of September.

In contrast to the biting rates at Kaboua and Bêtêrou, the fly density at Gbassê was already high at the beginning of May (122 flies/man/day May 4th, 82), but decreased by the end of May and did not exceed 100 before the end of June. In July, the biting rate was moderately high (average 43, pik biting 150 at July 8th, 82), increased towards the middle of August and had maximum biting rates, exceeding 500 flies/man/day by the end of August. Nulliparous flies were always present, particularly at the beginning of the rainy season (no data for September and October).

Annual variations of the fly-biting densities inside and outside the OCP area during the rainy seasons of the last four years:

A comparison of the biting rates during the last four rainy-seasons (Tab. 1) shows an increase of the total biting rate in 1982 (May to October) at all catching sites within the OCP area in Togo and at Fazao and Landa Mono outside the area, if compared with the biting rates in 1981, the year of maximum vector control, although the biting rates were considerably lower if compared with the year of minimum control, 1979. Only Landa Pozanda had its highest level in 1982, due to the interruption of treatments until the beginning of September. At Djodji and Tētētou in the South of Togo, the biting rates were at their lowest level for the whole period, probably as a result of the poor rainfalls this year.

The experimental treatments outside the OCP area in 1980 and 1981 were carried out during the period from mid-June to the beginning of August (GARMS et al. 1981). It might therefore be assumed, that the reduction in the biting rates, due to these treatments, is most marked during the month of July. In fact, lowest biting rates were observed during this month and for the four years at Mô â Mô, Bagan, Landa Pozanda, Fazao and Djodji (but not at Landa Mono!)(Tab. 2). However, the increase in the biting rates in July 1982 was not very important at these sites, and similarly, all sites outside the treated areas had their lowest biting rate during this year.

In Benin, where there were never any treatments outside the OCP area, biting rates declined more or less constantly at all three places for the past years and were at their lowest level during this year`s rainy season. As it was observed in Togo, the most spectacular fall in the biting rates was observed at the sites, outside the OCP boundary (Kaboua, Bētērou).

The monthly averages of the daily biting rate at Landa Pozanda, Bētērou, Kaboua, Djodji and Tētētou (Fig. 3) reflect the seasonal variations in the fly populations. Highest biting rates were observed mainly during September and October and minimum rates in February, March and April. After the experimental treatments in 1981, the fly populations at Djodji never fully recovered and seasonal variations of the biting densities became very marked, although at an inverse pattern: it was highest in April 1982 and lowest in August 1982.

Tab. 1

Comparison of the biting densities at catching sites within and outside the OCP area during the rainy seasons (May to October) 1979, 1980, 1981 and 1982.

Locality	Total biting rate 1st May to 31 October 1979[1]	1980[2]	1981[3]	1982[4]
Landa Pozanda	6.891	5.719	3.365	12.062
Mô à Mô	36.907	22.781	10.457	17.014
Fazao	35.664	16.555	5.364	12.700
Landa Mono	36.555	30.999	12.948	20.612
Djodji	134.590	103.495	30.369	18.322
Tététou	69.632	87.824[5]	136.555	34.938
Gbassé	39.300	48.327	22.620	(dimin.)
Bétérou	35.582	45.338	17.763	15.605
Kaboua	111.360	82.818	45.132	26.229

1): No insecticide applications outside the OCP area

2): Treatment of the rivers in Togo outside the OCP area. Maximal distance of treatments ca. 100 km from the OCP area.

3): Treatment of the rivers in Togo outside the OCP area. Maximal distance of treatments ca. 200 km from the OCP area.

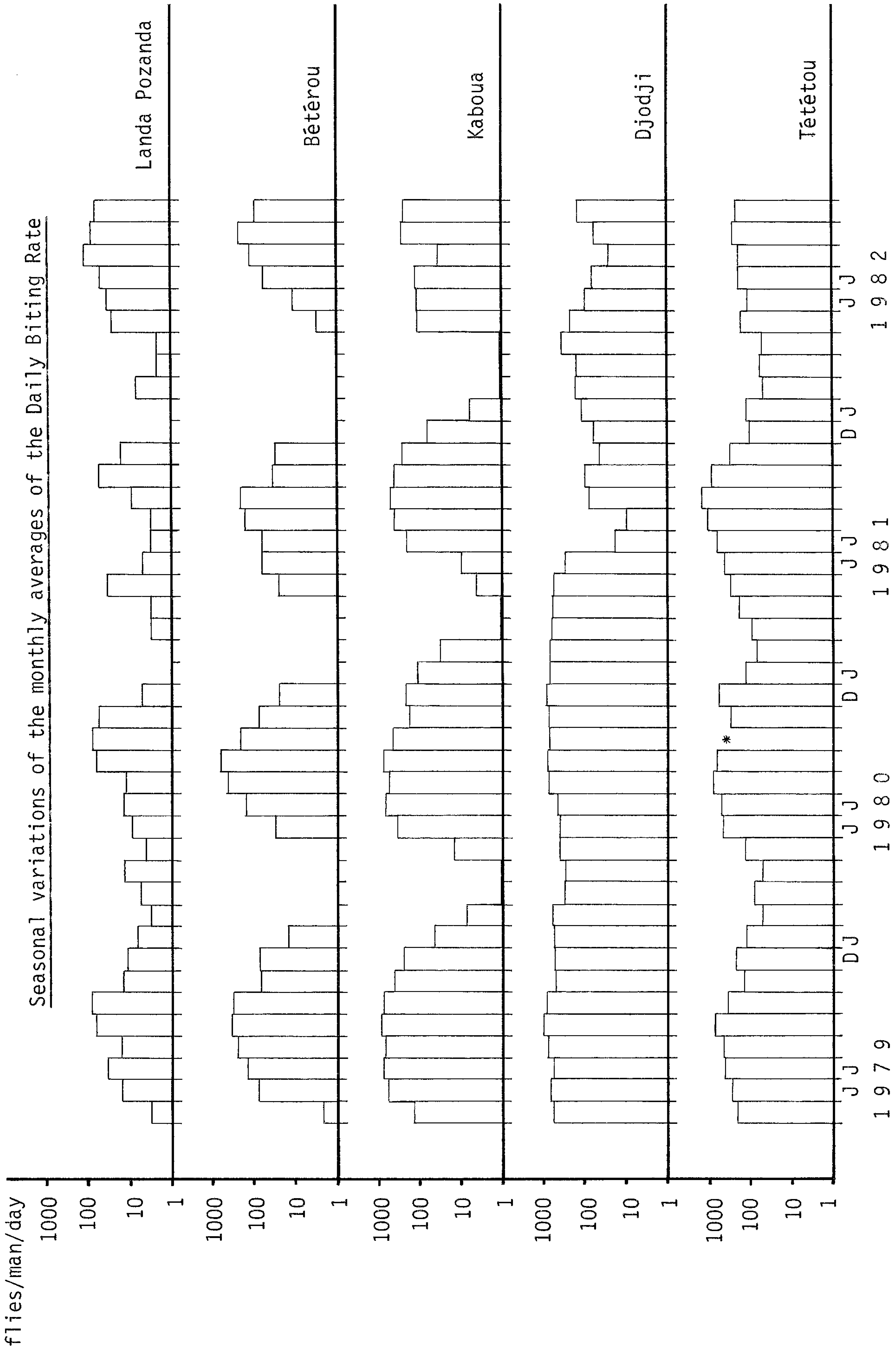
4): No treatments outside the OCP area, except some insecticide trials of the insecticide screening team.

5): No data for October 1980. The biting rate for this month was interpolated between the previous and following months.

Tab. 2 : Comparison of daily catches in July 1979, 1980, 1981 and 1982 at some catching sites in Togo and Benin

site	Average number of flies per day			
	1979	1980	1981	1982
Mô à Mô	171	110	62	160
Bagan	166	113	100	146
Landa Pozanda	35	14	3	51
Fazao	216	43	39	115
Landa Mono	202	140	107	69
Goubi	-	-	-	1
Tinkiro	-	-	-	14
Yégué	-	-	-	16
Déguingué	-	-	-	10
Djodji	559	431	17	59
Tététou	386	465	610	192
Gbassé	252	285	39	43
Bétérou	145	168	67	57
Kaboua	703	634	202	108

Fig. 3


Seasonal variations of the monthly averages of the Daily Biting Rate
Landa Pozanda
Bêtêrou
Kaboua
Djodji
Têtêtou
flies/man/day
1000
100
10
1
J J
D J
1 9 7 9
1 9 8 0
1 9 8 1
1 9 8 2
*

Identification of larvae from breeding sites in Togo and Benin:

The results from the cytotaxonomic identifications of larvae, collected during the rainy season 1982, are given in Table 3 . At breeding sites inside the OCP, S. sq was found at Bafilo (r. Sara) and Landa Pozanda (r. Kara), S. da and S. si were identified at Landa Pozanda, Alêhêridê (Boualê), Panseni (r. Oti) Gorobanda (r. Sota) and Gorges Mêkrou (r. Mêkrou). No S. so, S. sa or S. so/sa were found inside the boundary of the OCP. S. sq was the dominant species in the river Aniê (Tchêbêbê, Blitta) and in the Gban Houa (Djodji, Ayagba), and it was frequently observed in the Ogou (Goubi) and the upper Mono (at Landa Mono),as well as in the Aou (at Aou Losso), but this species was not found in samples from the Benin (r. Ouémé, r. Sota, r. Mêkrou), although it is known to occur in the Têrou (GARMS et al. 1981).

S. so/sa was only observed in the lower Mono at Têtêtou and in the Ouémé at Mbêtêkoukou, Dadjo and Aguigadji, where it is co-existing with S. so. S. sa was not found in the Mono, but in the lower Ouémé, and this might explain the higher proportion of adult female flies with dark wing-tufts in the S. so/sa group from Kaboua as compared to S. so/sa from Têtêtou.

S. ya was not observed in any of these samples.

Tab. 3 <u>Cytotaxonomic identification of larvae samples from Toga and Benin</u>

(results from the reports of Mr. G. K. Fiasorgbor.)

Date	location (river)	sq	ya	sa	so	so/sa	da	si
	Landa Pozanda (Kara)							
26. 5.82		1						
26. 5.82								16
2. 6.82							7	
4. 6.82							5	33
8. 6.82							1	14
17. 6.82								26
17. 6.82							1	
24. 6.82							3	20
24. 6.82							3	8
30. 6.82								16
9. 7.82								5
23. 7.82							5	17
29. 7.82							15	6
31. 7.82							7	1
4. 8.82							9	2
5. 8.82							1	
20. 8.82							10	5
	Landa Mono (Mono)							
24. 6.82							2	
8. 7.82		1					1	
11. 7.82		1					1	
29. 7.82					2		6	2
23. 9.82		9					3	
30. 9.82		3					6	
7.10.82							14	1
13.10.82							16	2
4.11.82		2			1		3	
	Aou Losso (Aou)							
12. 8.82		3			1		6	1
26. 8.82		29					3	
8. 9.82		42					6	
14. 9.82		34						
23. 9.82		35						
	Bafilo (Sara)							
18. 8.82		3						
21. 8.82		1						

Date	location (river)	sq	ya	sa	so	so/sa	da	si
	Goubi (Ogou)							
16. 9.82		6			1		4	
23. 9.82		21					3	
7.10.82		6					5	
14.10.82							1	
28.10.82		4					17	
	Aléhéridé (Boualé)							
5. 5.82							6	1
4. 8.82							6	
	Panseni (Oti)							
9. 7.82								2
	Koniogbo (Anie)							
8. 8.82		4			2		16	
	Tchebébé (Anie)							
3. 8.82		18					6	
	Blitta (Anie)							
11. 8.82		23					2	
	Tinkiro (Asukawkaw)							
8. 8.82		17						
	Djodji (Gban Hou)							
20. 5.82		17			2			
31. 5.82		14						
7. 6.82		20						
14. 6.82		14						
4. 8.82		26						
26. 8.82		7						
16.10.82		34						
	Ayagba (Gban Hou)							
19. 7.82		19						
28. 7.82		26						
7. 8.82		23						
7. 8.82		37						
5.11.82		38						
	Kouniohou (Gban Hou)							
7. 8.82					7			

Date	location (river)	sq	ya	sa	so	so/sa	da	si
	Tétêtou (Mono)							
25. 5.82						2	22	
31. 5.82					5		32	
10. 6.82					1	11	4	
25. 6.82						4		
7. 7.82					7	16		
26. 7.82					9	14	4	
14. 8.82					10	19	6	
	Bétêrou (Ouémé)							
24. 9.82							47	
	Mbétékoukou (Ouémé)				1			
21.10.82				1		1	29	
	Aguigadji (Ouémé)							
13.10.82				3	7	4	33	
14.10.82				1	3	1	29	
	Dadjo (Ouémé)							
21.10.82				2	5	6	28	
	Zagnanado (Ouémé)							
13.10.82							4	
	Gorobanda (Sota)							
12. 5.82								16
	Gorges Mékrou (Mékrou)							
21. 5.82								12
26. 5.82								34
16. 6.82								33

Natural infection rate and parasitic load of flies:

2.668 flies were dissected after morphological identification (see annex) and the respective parous rates and infection rates are given for the three vector groups and for the five catching sites by Table 4.

S. so/sa was found to be responsible for 100% of the transmission of O. volvulus+ at Têtêtou and Djodji, for 93% at Kaboua and for 14% at Bêtêrou. No infective larvae were observed in S. so/sa from Landa Pozanda, where the transmission is attributed at about equal proportions to S. sq and S. da/si. At Bêtêrou and Kaboua, the transmission due to S. sq was low (14% and 7% respectively), the main vectors being S. da/si at Bêtêrou (71%), together with S. so/sa (14%).

The low number of infective flies, found at each of the five sites, makes it difficult, to compare the vectorial capacity (susceptability, survival and parasitic load) of the three vector groups at the different sites. Therefore, the results from the five sites were pooled together in Table 5 for the three vector groups, although differences of the vectorial capacities of the flies in various bioclimatic zones disappear by this way of presenting the results. The parous rate was similar in the three groups such assembled, varying from 34% in S. sq to 36% in S. da/si and 43% in S. so/sa. The highest proportion of infected parous flies was found in S. so/sa (24.7%), followed by S. da/si (22.0%) and was lowest in S. sq (16.0%). An interesting phenomenon is observed, if one compares the proportions of parous flies infected with developing stages to the proportions of flies carrying infective larvae: Although the susceptability (% of parous with developing stages) is highest in S. so/sa (21.8%) and lowest for S. sq (12.6%), the proportion of infective flies is lowest for S. so/sa (3.95%) and higher for S. sq (5.12%) and S. da/si (6.00%). This might indicate, that despite of the high susceptability, the survival rate of parous S. so/sa is lower than in the two other groups.

The most significant differences in the three groups of flies were noticed in the average parasitic load per infective fly, which is 8.21 infective larvae per infective fly for S. so/sa and 1.40 for S. sq and S. da/si.

+): i.e. larvae indistinguishable from O.volvulus

Parous and infection rates of the three vector species groups at various catching sites in Togo and Benin

Tab. 4

		Total number of flies dissected	Number of parous flies (% of flies dissected)	Number of flies infected with $L_1L_2L_3$ (% of parous flies)	Number of flies with infective larvae (% of parous flies)	Average number of infective larvae L_3 per infective fly	Transmission Potential (% of Transm. Potent.)
Landa Pozanda	da/si	337	140 (41.54)	38 (27.14)	11 (7.86)	1.45	16 (47.06)
	sq	194	139 (71.65)	33 (23.74)	12 (8.63)	1.55	18 (52.94)
	so/sa	19	9 (47.37)	4 (44.44)	0 (0.00)	/	0 -
Djodji	da/si	17	0 (0.00)	0 (0.00)	0 (0.00)	/	0 -
	sq	347	51 (14.70)	1 (1.96)	0 (0.00)	/	0 -
	so/sa	80	29 (36.25)	13 (44.83)	3 (10.34)	8.00	24 (100)
Tététou	da/si	9	5 (55.56)	2 (40.00)	0 (0.00)	/	0 -
	sq	14	5 (35.71)	1 (20.00)	0 (0.00)	/	0 -
	so/sa	528	255 (48.30)	72 (28.24)	12 (4.71)	8.75	105 (100)
Bétérou	da/si	271	87 (32.10)	13 (14.94)	4 (4.60)	1.25	5 (71.43)
	sq	251	72 (28.69)	7 (9.72)	1 (1.39)	1.00	1 (14.29)
	so/sa	99	35 (35.35)	2 (5.71)	1 (2.86)	1.00	1 (14.29)
Kaboua	da/si	57	18 (31.58)	2 (11.11)	0 (0.00)	/	0 -
	sq	63	26 (41.27)	5 (19.23)	2 (7.69)	1.00	2 (7.14)
	so/sa	382	153 (40.05)	28 (18.30)	3 (1.96)	8.67	26 (92.86)

+): infective larvae ≙ fully developed third stage larvae, indistinguishable from O. volvulus, in the head, thorax and abdomen of the flies.

<u>Summary table of the numbers of flies dissected from the three species groups; the proportion of parous and infected parous flies and their parasitic load.</u>

Tab. 5

	S. so/sa	*S. sq*	*S. da/si*
Total number of flies dissected	1,108	869	691
Number of parous flies (% of flies dissected)	481 (43.4)	293 (33.7)	250 (36.2)
Number of flies infected with $L_1L_2L_3$ (% of parous flies)	119 (24.7)	47 (16.0)	55 (22.0)
Number of flies with developing larvae L_1L_2 (% of parous flies)	105 (21.8)	37 (12.6)	46 (18.4)
Average number of developing larvae L_1L_2 per infected fly	4.54	2.32	2.00
Number of flies with infective larvae (% of parous flies)	19 (3.95)	15 (5.12)	15 (6.00)
Average number of infective larvae L_3 per infective fly	8.21	1.40	1.40
Number of flies with double infections (% of parous flies)	3 (0.62)	2 (0.68)	6 (2.40)

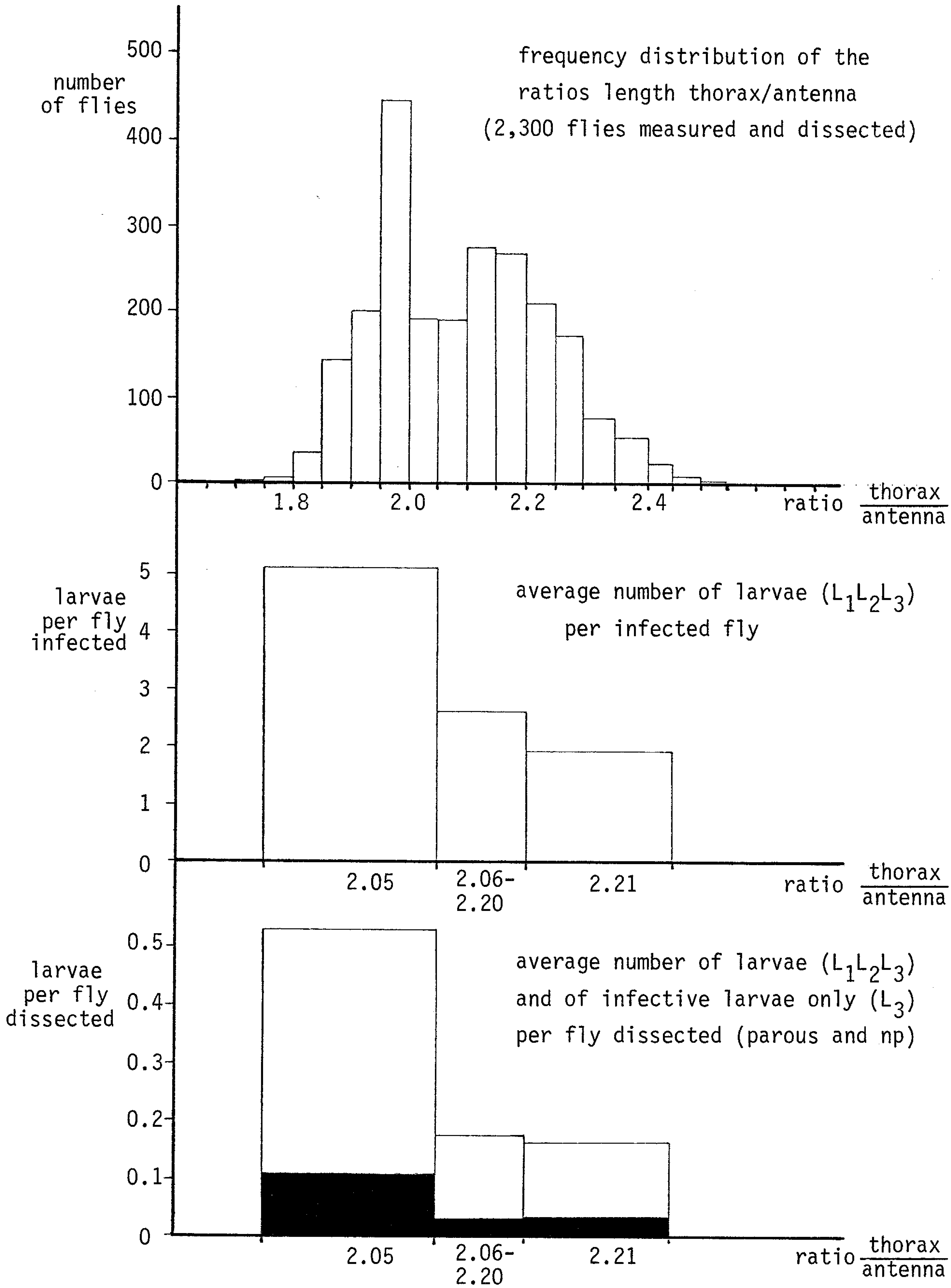
+): infective larvae L_3 ≙ fully developed third stage larvae, indistinguishable from *O. volvulus* in the head, thorax and abdomen of the flies.

In Fig. 4 and in Table 6 , the parasitic load of infected flies and the average number of larvae per dissected (parous) fly is given in dependency on a single parameter, the ratio of the length of the thorax divided by the length of the antenna. 2,300 flies measured and dissected from the five sites were used for this evaluation. Flies parasitized by mermithids, which were very frequently found at Bētērou in Benin, were not included, since the proportions of such parasitized flies appear to be changed.

High parasitic loads (5.1 larvae per infected fly) were observed mainly in flies with a thorax/antenna ratio below 2.05, presumably representing the S. so/sa part of the population, whereas the parasitic load of flies with a higher ratio (2.06 - 2.20 for S. sq and 2.21 for S. da/si) was of about the same value (2.6 and 1.9 larvae per infected fly). The proportion of infected parous flies was lowest for the group with a ratio between 2.06 - 2.20.

Fig. 4

The frequency distribution of the ratios length of thorax/length of antenna, the corresponding parasitic load per infected fly and the average number of larvae per fly dissected



Tab. 6

The vectorial capacity of flies with different ratios length thorax/antenna

	ratio length of thorax / length of antenna 2.05	2.06-2.20	2.21
number of flies dissected (% parous flies)	1,020 (42.3)	730 (40.7)	550 (39.2)
flies infected with $L_1L_2L_3$ (% of parous)	106 (24.6)	50 (16.8)	47 (21.8)
average number of larvae per infected fly	5.1	2.6	1.9
infective flies (% of parous)	17 (3.9)	16 (5.4)	13 (6.0)
average number of infective larvae L_3 per infective fly	6.7	1.4	1.4
infective larvae per fly dissected	0.112	0.032	0.033

Flies, infested by mermithids, were not included in this table.

Comparison of the parasitic load of flies from different catching sites

From the results of our dissections, it seems that S. sq has a low susceptability to O. volvulus, and that the parasitic load per infected S. sq is very similar to the group S. da/si. An high parasitic load on the other hand would indicate the involvement of the group S. so/sa. It might therefore be interesting, to compare the parasitic load and infection rate of fly-populations from various catching sites in Togo and Benin (Table 7). In order to have enough data, the own results were compiled with the results of dissections of the OCP routine teams and sites from same areas were grouped together.

Using the test of Brandt- Snedecor (SACHS, 1969), two different parasitic loads can be distinguished, one for the flies from the savanna, varying between 1.8 (Bêtêrou) and 2.5 (Landa Pozanda, Mô â Mô, Bagan, Goubi, Fazao, Landa Mono), and the other for the flies from "forest" areas: 4.9 at Djodji, 5.0 at Kaboua and 5.7 at Têtêtou. The three new catching sites in the upper Asukawkaw area, Tinkiro, Yêguê and Dêguinguê gave a result (3.6), which was significantly lower when compared to the load of the flies from Têtêtou, but was not significantly higher than the load in the savanna.

The different parasitic load in the different bioclimatic zones can be linked to the proportion of S. so/sa in the biting population: In the savanna, this proportion was low at Landá Pozanda (3.5%) and Bêtêrou (15.9%). No identifications were yet made for the flies from the other sites in the savanna, but from the reports of GARMS et al,(1980-1982) a low proportion can be assumed as well. At those sites in the South, the proportion of S. so/sa was high with the only exception of Djodji (18.0%). However, it has been shown before (page 20), that almost all infected flies at Djodji were identified as S. so/sa.

The infection rate of parous flies (%of parous flies infected) varied considerably in the different areas: It was lowest (4.7-7.5%) at those sites, where S. sq is the most frequent species (Mô â Mô, Bagan; Tinkiro, Yêguê, Dêguinguê; Djodji), but increased with the proportion of S. da/si (8.0- 11.3% at Goubi, Fazao, Landa Mono and Bêtêrou). Highest infection rates were again observed at those sites,

Tab. 7

Comparison* of the parasitic load of S. damnosum s.l. from different catching points

Compiled results from the own dissections and from dissections of the OCP staff during the rainy season 1982 (May to October)

	Landa-Pozanda	Mô à Mô, Bagan	Goubi, Fazao, Landa Mono	Bêtêrou	Tinkiro, Yêgué, Dêguingué	Kaboua	Djodji	Tétêtou
Mô â Mô, Bagan	-	x	-	-	-	+++	+++	+++
Goubi, Fazao, Landa Mono	-	-	x	-	-	++	+++	+++
Bêtêrou	-	-	-	x	-	-	+	+++
Tinkiro, Yêgué, Dêguingué	-	-	-	-	x	-	-	+
Kaboua	+++	+++	++	-	-	x	-	++
Djodji	+++	+++	+++	+	-	-	x	-
Tétêtou	+++	+++	+++	+++	+	++	-	x
% S. so/sa	3.5	-	-	15.9	-	76.1	18.0	95.8
O. volvulus Iarvae per infected fly	2.5	2.5	2.5	1.8	3.6	5.0	4.9	5.7
No infected flies ex. % of parous flies infected	315 18.6	225 7.5	90 8.0	22 11.3	36 4.7	35 17.8	41 6.7	211 19.1

* : Comparison of the frequency distributions of the number of larvae (L_1, L_2, L_3) per infected fly by the BRANDT-SNEDECOR-test (Sachs, 1969)

- : $P > 0,05$

+ : $0.05 \geqslant P > 0.01$

++ : $0.01 \geqslant P > 0.001$

+++: $P < 0.001$

where either S. da/si (18.6% at Landa Pozanda) or S. so/sa (17.8% at Kaboua, 19.1% at Tétētou) were the main vector groups.

In the savanna, a seasonal variation in the infection rate of parous flies was observable. It was the highest at the beginning and at the end of the rainy season, presumably relecting the changing proportion of S. da/si flies at these sites (Mô à Mô, Bagan, Landa Pozanda).

Experimental infections of flies at Landa Pozanda, Djodji and Têtêtou:

(in collaboration with Dr. Omar)

Uptake of microfilariae during the bloodmeal

At Djodji and Landa Pozanda (but unfortunately not at Têtêtou), flies were dissected 5 min, 30 min, 1 hr and 2 hrs after a bloodmeal on two heavily infected volonteers from Landa Pozanda. The number of microfilariae in the flies was counted by Dr. Omar.

Out of 95 bloodfed flies, only 4 did not ingest microfilariae. The average intake of microfilariae per fly was 23.1 (2194/95) microfilariae, ranging between 0 and 108. No difference was observed in the uptake of microfilariae at the two sites (Djodji m_a= 21.7, Landa Pozanda m_a= 24.5), and the same average number of microfilariae were found in flies, fed on the volonteer I (m_a= 26.4) as compared to those, fed on the volonteer II (m_a= 21.5). 59% of the flies came to bite on the ancles, where the microfilarial density varied from 29 to 60 microfilariae per mg and the rest of the flies fed on the calfes, where the microfilarial density was between 68 and 153 (Fig. 5).

Infection rates and parasitic load

From those flies, dissected 3-6 days after the bloodmeal, a varying proportion was found to carry developing (or infective) stages of O. volvulus: At Têtêtou, where all fed flies were classified as S. so/sa, 60.9% of the flies were infected, at Landa Pozanda, it was 62.5% for the group S. da/si and 44.7% for S. sq. At Djodji, only 1.2% of S. sq carried larvae, but 28.6% of S. so/sa were infected at this site (Table 8).

Although the infection rates were calculated on a very limited number of bloodfed flies, especially for S. so/sa at Djodi and Landa Pozanda, it becomes clear, that S. so/sa is a suitable vector for the microfilariae from the savanna. S. sq from Djodji did hardly allow the development of the filariae, and at Landa Pozanda, the infection rate in this species was lower than in S. da/si.

Fig. 5

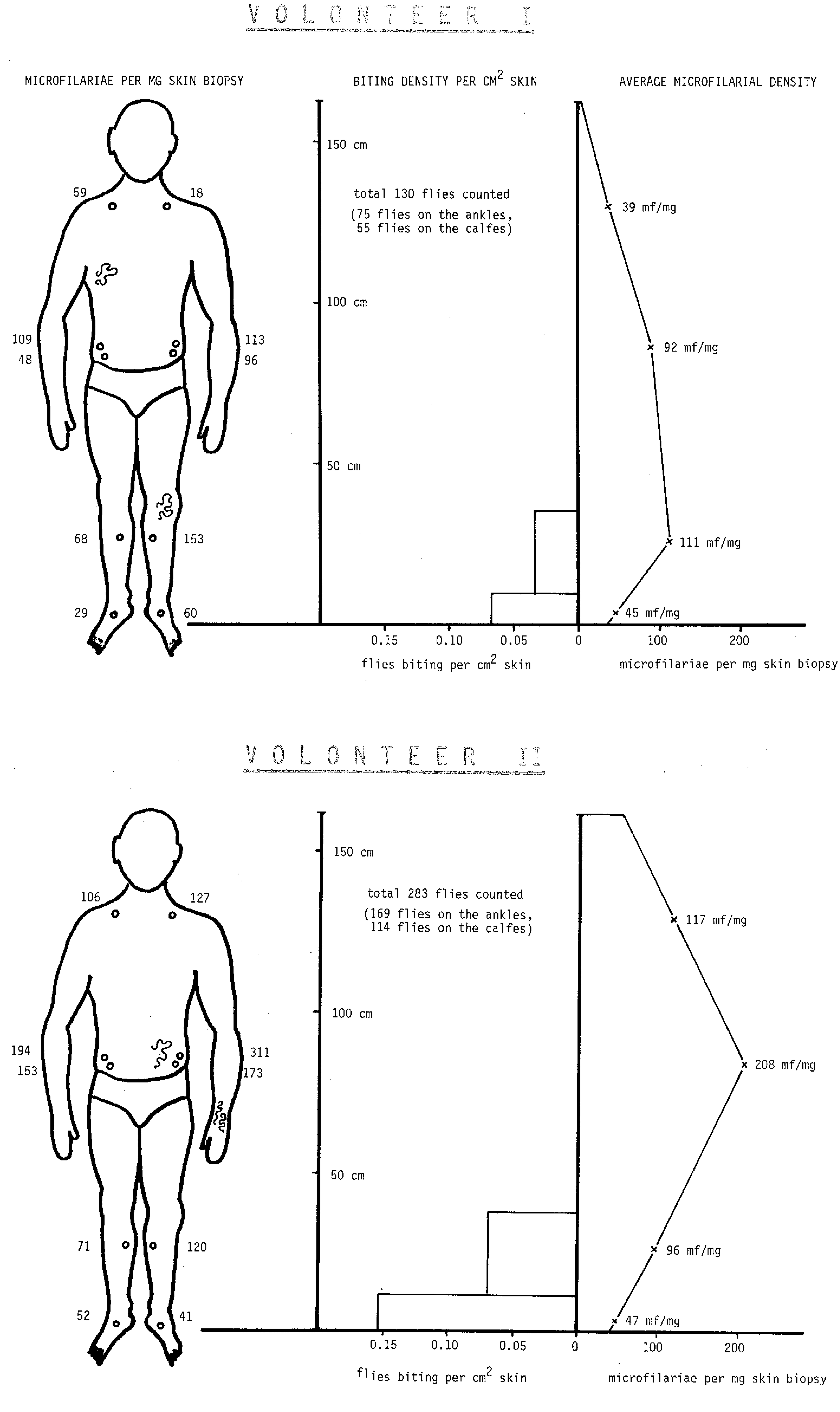


Fig. 5 : The distribution of palpable Onchocerca-nodules and microfilarial densities in the skin of two volonteers from Landa Pozanda (Togo, Sudan-savanna) as compared to the sites of the bloodmeals of the Simulium damnosum s.l. vector flies.

Table 8 : Infection rates and parasitic loads of flies bloodfed on two volonteers from Landa Pozanda (savanna)

species group	No of flies blood-fed	No of flies[1)] infected (%)	larvae $L_1L_2L_3$ per infected fly
At Landa Pozanda:			
S. da/si	64	40 (62.5%)	3.08
S. sq	38	17 (44.7%)	3.24
S. so/sa	6	0 -	-
At Tététou:			
S. so/sa	284	173 (60.9%)	7.80
At Djodji:			
S. sq	85	1 (1.2%)	1.00
S. so/sa	14	4 (28.6%)	3.50

1): Flies carrying developing or infective stage larvae only, dissected 3 to 5 days after the bloodmeal.

The parasitic load of O. volvulus larvae per infected fly was higher in the experimentaly infected flies if compared to the parasitic load of naturaly infected flies, caught at the same sites. At Landa Pozanda it was 3.12 against 2.5, and at Têtêtou it was 7.8 against 5.7. These differences can be explained by the high microfilarial density in the two heavily infected volonteers.

DISCUSSION

Most of the time has been spent during the studies in the past rainy season for the identification and dissection of flies from the five catching sites Landa Pozanda, Djodji, Tētētou, Bētērou and Kaboua for the evaluation of the vectorial capacity of different fly populations. The reinvasion was therefore only followed-up by the dynamics of the biting populations at a few selected catching sites.

Decreasing biting rates were observed at most of the catching sites, both within and outside the OCP area, over the past four years. Experimental treatments of breeding rivers outside the boundary of the OCP in Togo certainly have largely contributed to this reduction (GARMS et al. 1982), but a similar reduction was found at sites in Benin too, that were never treated. Unsufficient rainfalls might be responsible for this phenomenon, as well as there was some persisting effect of the last year's experimental treatments, as it is indicated by the fly population of Djodji, that has not yet recovered since. S. sanctipauli was found to be the main breeding species in the river Gban Houa at Djodji before the treatments (OMAR et al. 1979), but has disappeared since almost completely and the majority of larvae were identified now to be S. sq.

Reinvading flies were mainly observed at sites, where a fast flowing river provided oviposition possibility to the migrating female flies, and it seems as if the flies would hesitate to feed on man, unless there is a possibility to lay eggs. For this reason, the biting activity of reinvading flies is limited to the vicinity of fast-running rivers and the same is true for the extension of those areas, exposed to the danger of transmission of disease by reinvading flies (see Annex).

Local breeding of S. da/si in rivers inside the OCP was observed in the Sota and Mēkrou in Northern Benin, and it is still a moot point, whether the flies caught at Gbassē came really from outside the OCP area.

The breeding sites in the Kara river at Landa Pozanda were quickly repopulated at the beginning of the rainy season, after the interruption of the weekly insecticide treatments. No S.so/sa were identified in larvae samples from this site, and adult S. so/sa flies, caught at Landa Pozanda, presumably came from breeding sites in the South, where their larvae were found in the upper Mono river and its affluents Aou and Ogou. S. so/sa was identified in 3.3% of the total biting population in the savanna at Landa Pozanda during the months August to October 1982 (estimate total S. so/sa biting rate 284 flies) and for 16.3% at Bêtérou during the same period (total S. so/sa biting rate 2,189 flies).

The proportion of the transmission of onchocerciasis, due to S. so/sa in the savanna, seems to be low (0% at Landa Pozanda, 14.3% at Bêtérou) as a result of low biting rates and a rather short life-exspectancy of these flies. More data should be available, however, to verify these results.

There is no doubt, that S. so/sa is highly susceptible to infections by microfilariae of O. volvulus, and similar infection rates were observed in wild-caught flies from this group if compared to wild-caught S. da/si. The same was observed, when flies from the North (S. da/si) and flies from the South (S. so/sa) were allowed to feed on microfilariae carriers from the present OCP area. The average number of infective larvae per infective fly is about two to three times higher in S. so/sa than in S. da/si, both in natural infections as in experimental ones. However, the probability of survival of S. so/sa seems to be reduced in parous flies, if compared to the two other vector groups: The ratio of infected flies against infective flies was 6.25 : 1 for S. so/sa, 3.67 : 1 for S. da/si and 3.13 : 1 for S. sq.

S. sq is a very poor vector of O. volvulus in Togo, as it is indicated by the low infection rate of this species at Djodji and at Tinkiro, Yêguê and Déguinguê. The same was observed, when flies from Djodji were experimentaly fed on microfilariae carriers from the savanna. The higher infection rate of S. sq at Landa Pozanda might partially be due to the difficulties of separating the two species groups S. sq and S. da/si, since there is a lot of overlaping in the morphology of the two groups. The average parasitic load per infected fly is similar for S. sq and S. da/si, as well as the two groups have about the same life-exspectancy.

From other countries in West-Africa, S. sq is known to be a good vector (GARMS, pers. comm.), and the low susceptability observed in Togo would therefore support the hypothesis of geneticaly different S. sq populations in West-Africa, as it has been put forward by GARMS et al. (1982) on the base of the observation, that a much higher proportion of S. sq in the East had pale wing tufts than those in the West, and this seems to be linked to an enhanced migratory potential of the flies in the East.

In the areas of the upper Asukawkaw, where S. sq is the main man-biting species, onchocerciasis in the human population is not very troubling at Abossomkopê, the only village examined in this region (BA, 1981). Although the prevalence is high, the microfilarial density is low (7.6) and the prevalence of blindness is 0.6 %. In the focus along the rivers Gban Houa, Domi and Ove, only the situation at Djodji (Dayes-Dodzi) tended to be intolerably high (prevalence 77%, microfilarial density 18.2, blindness 2.0%), but was less severe along the Domi and Ove.

In view of the actual biting densities, that have greatly declined during the last four years, in particular at Djodji, it might therefore not even be necessary, to treat all the affluents and tributaries in this region, which was found very difficult and dangerous to do during the last year's experimental treatments (GARMS et al, 1982). This would implicate, however, that one accepts biting rates and transmission potentials along the reinvaded areas in the Mô valley, exceeding the criteria for a tolerable level of disease transmission (ATP 100, ABR 1,000). On the other hand, the results of the experimental treatments in 1979 have not prouved, that it might be possible to fulfil these criteria (MBR July 1981: 3,100 at Bagan).

It has been shown, that most of the transmission at Djodji can be attributed to S. so/sa. In the same line, many of the infective flies from Tinkiro, Yégué and Déguingué with dark wing tufts and with an high parasitic load might have been S. so/sa too. The breeding sites and population dynamics of this vector group in the Kpaza, Koué, Asukawkaw and Gban Houa river systems should therefore deserve further attention.

This years studies had to be limited mainly to Togo, and no time was available to extend the investigations to the Benin, except of the dissection of flies from Kaboua and Bétérou. Differences were found in the colour of the wing tufts of S.so/sa from Benin, those being darker than S. so/sa from the lower Mono in Togo (see annex). Infection rates were constantly lower in Benin than at our sites in Togo, but is is not yet determined, whether this is due to a lower susceptability of the flies there, or to a more scattered human population and to a lower prevalence of onchocerciasis.

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CONCLUSIONS

Reinvasion continued during the rainy season 1982 in the Eastern areas of the OCP along the Mô and Kara river systems in Togo and along the Southern affluents of the Niger in Benin at an intensity of biting and transmission, exceeding the criteria for a tolerable level. However, the biting rates in the Mô valley were much lower, if compared to the last year without treatment of the supposed source areas of the reinvading flies (1979). A general trend of decreasing biting rates can be observed in the last four years at many fly-catching sites within and outside the OCP boundary in Togo as well as in Benin.

Flies of the group S. soubrense/S. sanctipauli were present at a low proportion amongst the flies, caught at Landa Pozanda in the Sudan savanna of Togo. No larvae of this group were identified in larvae samples from a nearby untreated breeding site. S. soubrense/S. sanctipauli is highly susceptible to infections with microfilariae of O. volvulus originating from the savanna as well as from the Southern areas in Togo. Infection rates were similar to those of S. damnosum/S. sirbanum in the savanna, but S. soubrense/S. sanctipauli carried a parasitic load, about two to three times higher.

S. squamosum is a poor vector of O. volvulus in Togo. The infection rate of these flies was lower than for S. damnosum/S. sirbanum and for S. soubrense/S. sanctipauli, due to a reduced susceptability. The average number of larvae, indistinguishable from O. volvulus, per infected fly was about the same as in S. damnosum/S. sirbanum.

RECOMMENDATIONS

In view of the comparatively low biting rates, observed during the last rainy season, the dynamics of the fly-populations could be monitored in 1983 without control outside the programme area, in order to see, whether the trend of decreasing biting rates continues in Togo and Benin.

The S. soubrense/S. sanctipauli population at Djodji should by followed up closely, both in the larval and adult stages, in order to see, whether these species will repopulate their former breeding sites in the Gban Houa. Actually, these sites are mainly populated by S. squamosum which is a very poor vector, if compared to S. soubrense/S. sanctipauli.

Studies should be continued on the vectorial capacity of different members of the S. damnosum s.l. complex. The low susceptability of S. squamosum to infection with O. volvulus in Togo should be investigated further and could than be compared to the susceptability of this species in other regions, where it is known to be a good vector. The vectorial capacity of S. soubrense/S. sanctipauli in the savanna should be studied further, in particular with regard to the life-exspectancy of these flies in different bioclimatic zones.

Nothing is known about the degree of zoophilie (the rate of bloodmeals on non-human hosts) of different vector species in Togo and Benin. Filarial larvae, distinguishable from O. volvulus were found, although at low numbers, both in flies from Togo and Benin.

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