Annals of Tropical Medicine and Parasitology, Vol. 81, No. 3, 253–262 (1987)

Studies on the dynamics of transmission of onchocerciasis in a Sudan-savanna area of North Cameroon IV

The different exposure to *Simulium* bites and transmission of boys and girls and men and women, and the resulting manifestations of onchocerciasis

By A. RENZ

Institute of Tropical Medicine, Wilhelmstrasse 31, University of Tübingen, D-7400 Tübingen, F.R.G.

H. FUGLSANG AND J. ANDERSON

Langvadvej 60, DK-7741 Frøstrup, Denmark

Received 30 January 1985

The sojourn times of the human population were monitored over one year at 12 sites in the vicinity of three villages in the Cameroon Sudan-savanna, where the *Onchocerca volvulus* transmission potentials had been measured one year previously.

Boys stayed longer outside the villages, and were exposed 2·1 to 2·7 times more than girls to transmission of onchocerciasis, whereas the exposure of men was similar or only moderately higher than the exposure of women.

In boys, the onset of infections and ocular lesions was earlier and the average microfilarial density at the buttock (2·2, 9·4 and 79·3 mff snip^{-1}) was much higher than in girls (0·1, 5·8 and 42·2 mff snip^{-1} at the three villages respectively). These differences were maintained in the adult population, where the average microfilarial density was 52·3, 80·4 and 183·1 mff snip^{-1} in men and 15·6, 49·6 and 114·7 mff snip^{-1} in women. Ocular lesions due to onchocerciasis were found in 5, 13 and 55% of the male population in the three villages, as compared with 2, 3 and 8% of the female population.

There was a close relationship between the degree of exposure to the transmission of disease and the resulting microfilarial load in the skin which was not different for the two sexes, and a similar trend was seen for the occurrence of ocular lesions due to onchocerciasis. The influence of an early and heavy infection on the evolution of disease manifestations is discussed.

In the Sudan-savanna of North Cameroon the prevalence of severe ocular lesions and blindness due to onchocerciasis is much higher in the males than females (Anderson *et al.*, 1974). Hormonal differences and different exposure rates of the sexes have been suspected.

In a previous paper the intensity of transmission of onchocerciasis (*Onchocerca volvulus* Annual Transmission Potential, ATP) was described at four sites in the vicinity of three villages in the Sudan-savanna of North Cameroon (Renz, 1987*b*). The ATP varied considerably at the different sites around the villages, and the exposure of the human population to transmission might therefore depend on the sojourn times of the population at the different sites. During one year the numbers of boys and girls and men and women were recorded, and the sojourn times were weighted with the ATP to calculate the exposure rates of different sex-

These investigations received financial support from the WHO/UNDP/World Bank Onchocerciasis Control Programme and from the Filariasis component of the UNDP/World Bank/WHO Special Programme for Research and Training in Tropical Diseases.

0003–4983/87/030253+10 $03.00/0

and age-groups. These were then compared to the manifestation of onchocerciasis in the populations of the three villages.

MATERIALS AND METHODS

The villages Mayo Galké, Douffing and Rey Manga are situated in the Sous-Préfecture of Tcholliré (8°24′ N, 14°10′ E) in a Sudan-savanna area, where the main vectors of onchocerciasis are *Simulium damnosum s. str.* and *S. sirbanum* (Renz and Wenk, 1987). Mayo Galké lies at about 500 m distance from the nearest *Simulium* breeding sites in the almost perennially flowing river Mayo Rey, and at the same distance from a rainy season breeding site in a tributary of the Mayo Rey, the Mayo Dokday. The fly-catching sites were at the causeway crossing the river Mayo Rey, at the tributary Mayo Dokday, and at 200 m and at 600 m distant from the Mayo Rey in the fields along the road leading to the causeway.

Douffing is located some 10 km distant from the breeding sites in the Mayo Rey and 7 km from rainy season breeding sites in a tributary, the Mayo Bodo. The fly-catching sites were situated at a distance of 0·1 to 0·8 km around the village, one near the village well, and the others at the waterhole, in the village fields, and at a small rainy season tributary of river Mayo Bodo where no breeding of *S. damnosum s.l.* was found.

Rey Manga lies at 500 m from the causeway crossing the river Mayo Rey some 9 km downstream from the nearest *Simulium* breeding sites. Fly-catching sites were visited at the causeway, at 1·5 km distant from the river in the village fields, 2 km upstream from the causeway towards the breeding sites, and at a rainy season tributary of the Mayo Rey, the Mayo Lougougnel.

The four fly-catching sites in the vicinity of each village were selected at places where the man–fly contact rate was supposed to be highest (at the main river or tributary), intermediate (near dense vegetation along small water-courses or near a waterhole) or low (in the open fields). *Simulium damnosum s.l.* biting rates on man were measured at weekly intervals from 06.00 to 18.30 hours between May 1977 and April 1978, and from the dissection of the flies caught the Annual Transmission Potential (ATP) was calculated (see Duke, 1968) and records were kept of all infective larvae morphologically indistinguishable from *O. volvulus* found in the head, thorax and abdomen of the flies (see Renz, 1987*b*, for details).

The population of the three villages was examined clinically, parasitologically and ophthalmologically in October 1976, and the prevalence of onchocerciasis, the arithmetic mean microfilarial density per skin snip at the buttock (approx. 1·4 mg skin per biopsy) and the prevalence of ocular lesions and blindness were assessed (see Fuglsang and Anderson, 1977 for details).

During the years 1978 and 1979, hourly records were made at each of the four catching sites around the three villages throughout the rainy and dry seasons of the year, from 06.00 to 18.30 hours, relating to: the number of boys and girls, and men and women, who came to visit the area (within 100 m) of the fly-catching site ('came'); the number who stayed for one hour or longer and the number of hours they stayed ('hours'). An estimated age of 17 years was used to differentiate between children and adults. These records were made by the vector collectors (but not during their normal duty) in half-day shifts. Two to four complete days of observations were made in each of the four seasons (early rainy season, May–July; late rainy season, August–October; early dry season, November–January; late dry season, February–April). In order to get a simple index of the 'Daily Visiting Frequency' (DVF) of a catching site, an arbitrary assumption was made assigning to every person staying less than one hour ('came') an average sojourn time of five minutes. This time was added to the number of hours of those who stayed for at least one hour or longer ('hours'):

$$\text{Daily Visiting Frequency} = \frac{\text{'came'} \times 5}{60} + \text{'hours'} \ (\text{Man} \times \text{hours/day}).$$

RESULTS

The Sojourn Times of Boys and Girls, Men and Women at the Fly-catching Sites

From July 1978 to April 1979 the sojourn time of the human populations was monitored by a total of 120 days of observation at the 12 fly-catching sites around the villages Mayo Galké, Douffing and Rey Manga. Table 1 gives, by age and sex, the annual averages of the Daily Visiting Frequency (DVF, man × hours/day), together with the estimates of the Annual Biting Rates (ABR, *S. damnosum s.l.* bites/man/year) and Annual Transmission Potentials (ATP, infective larvae *O. volvulus*/man/year) at the same sites.

The total DVF (sum of four places around each village) has about the same level around the three villages (181; 192; 226), but within the four sites of each village the variance of DVF was most marked at Mayo Galké (1; 34; 65; 81), followed by Rey Manga (25; 28; 52; 121). Around Douffing, the DVF was more uniform (41; 50; 50; 15), probably due to the relative close vicinity of the four sites and to the uniformity of the surroundings where there was no important watercourse nearby.

Differences in the DVF between men and women were in general not large, but they were pronounced between boys and girls. Boys were more frequently outside the villages, and they stayed nearly twice as long at the catching sites, in particular near the river sites with a high *Simulium* biting density, at the banks of the river Mayo Rey at Mayo Galké and Rey Manga causeways.

The estimated values of the ABR and of the ATP varied considerably at the different sites around the three villages, often being high at sites where the DVF was low. For illustration, Fig. 1 shows the values of the various parameters as observed around the village Rey Manga. The location of the other villages and fly-catching sites has been presented in a previous paper (Renz and Wenk, 1987).

Taking into consideration the variation of the transmission (ATP) and of the sojourn time (DVF) at the different sites around the villages, and weighting it by the number of persons in the corresponding age- and sex-groups (census, Table 2), the degree of the actual exposure of boys and girls, men and women can be calculated as follows:

$$\text{Index of exposure} = (\Sigma \text{DVF} \times \text{ATP})/\text{census} \quad (\text{hours/day} \times \textit{O. volvulus} \text{ infective larvae per year})$$

This index gives the average number of hours per day spent by one individual at the four sites around the village, multiplied by the corresponding ATP. The index for boys and girls, men and women, was:

Mayo Galké: 1722/786/3061/1887 (= 1·0/0·5/1·8/1·1);
Douffing: 283/116/183/211 (= 1·0/0·4/0·6/0·7);
Rey Manga: 312/115/224/146 (= 1·0/0·4/0·7/0·5).

At all three villages boys were more than twice as much exposed to the transmission than were the girls, whereas men were less at risk than women at Douffing but were slightly (0·7/0·5) or moderately (1·8/1·1) more exposed at Rey Manga and Mayo Galké.

Sex-specific Manifestations of Onchocerciasis in the Three Villages

The numbers of persons examined in the three villages are given by age and sex in Table 2, together with the prevalence of onchocerciasis, the average microfilarial density at the buttock (arithmetic mean number of microfilariae per skin snip, age-adjusted to an OCP standard population, Moreau *et al.*, 1978) and the prevalence of ocular lesions due to onchocerciasis.

There was little difference in the prevalence of onchocerciasis between the sexes, but microfilarial densities and the prevalence of ocular lesions were far higher in the males. At Mayo Galké the microfilarial densities amongst boys were 43·3% of that of the adult male

TABLE 1

The Daily Visiting Frequency (DVF), the Annual Biting Rate (ABR) and the Annual Transmission Potential (ATP) at four sites around three villages in the Sudan-savanna of North Cameroon

Village	*Fly-catching site*	*ABR*	*ATP*	*Daily visiting frequency (DVF) of*				*Total DVF*
				Boys	*Girls*	*Men*	*Women*	
Mayo Galké	Mayo Galké causeway	47 900	2 402	22·6	11·0	25·0	22·5	81·1
	Tributary Mayo Dokday	37 400	2 104	0·2	0·1	0·8	0·1	1·2
	250 m from causeway, fields	14 400	670	7·4	4·5	13·5	8·2	33·6
	900 m from causeway, fields	12 000	355	16·2	11·7	24·7	12·4	65·0
	ΣDVF (ΣDVF/census)			46·4 (1·22)	27·3 (0·64)	64·0 (2·46)	43·2 (1·27)	180·9
Douffing	Village well, at tributary	5 800	177	16·2	12·7	10·6	10·7	50·2
	Waterhole	3 200	54	4·1	4·4	14·4	17·6	40·5
	Village fields	3 400	77	6·8	5·1	18·2	21·1	51·2
	Small tributary	2 300	157	9·4	6·8	13·8	20·0	50·0
	ΣDVF (ΣDVF/census)			36·5 (2·03)	29·0 (1·32)	57·0 (1·68)	69·4 (1·93)	191·9
Rey Manga	Rey Manga causeway	1 400	65	27·4	14·1	42·6	37·3	121·4
	2 km upstream from causeway	4 500	220	3·8	1·2	9·8	13·3	28·1
	1·5 km from the river, fields	1 400	12	6·8	3·4	15·9	25·6	51·7
	Tributary Mayo Lougougnel	11 100	91	4·6	4·2	7·9	8·5	25·2
	ΣDVF (ΣDVF/census)			42·6 (4·26)	22·9 (1·64)	76·2 (2·94)	84·7 (1·93)	226·4

The DVF gives the number of man-hours per day, spent by the human population (boys and girls, men and women) at the fly-catching sites. See text for the calculation of the DVF. The ABR is an estimated number of *S. damnosum s.l.* bites per man per year.

The ATP is the estimated number of infective larvae. *O. volvulus* which could be inoculated into one man in one year, if all infective flies biting him were to transmit their total load of infective larvae (Duke, 1968).

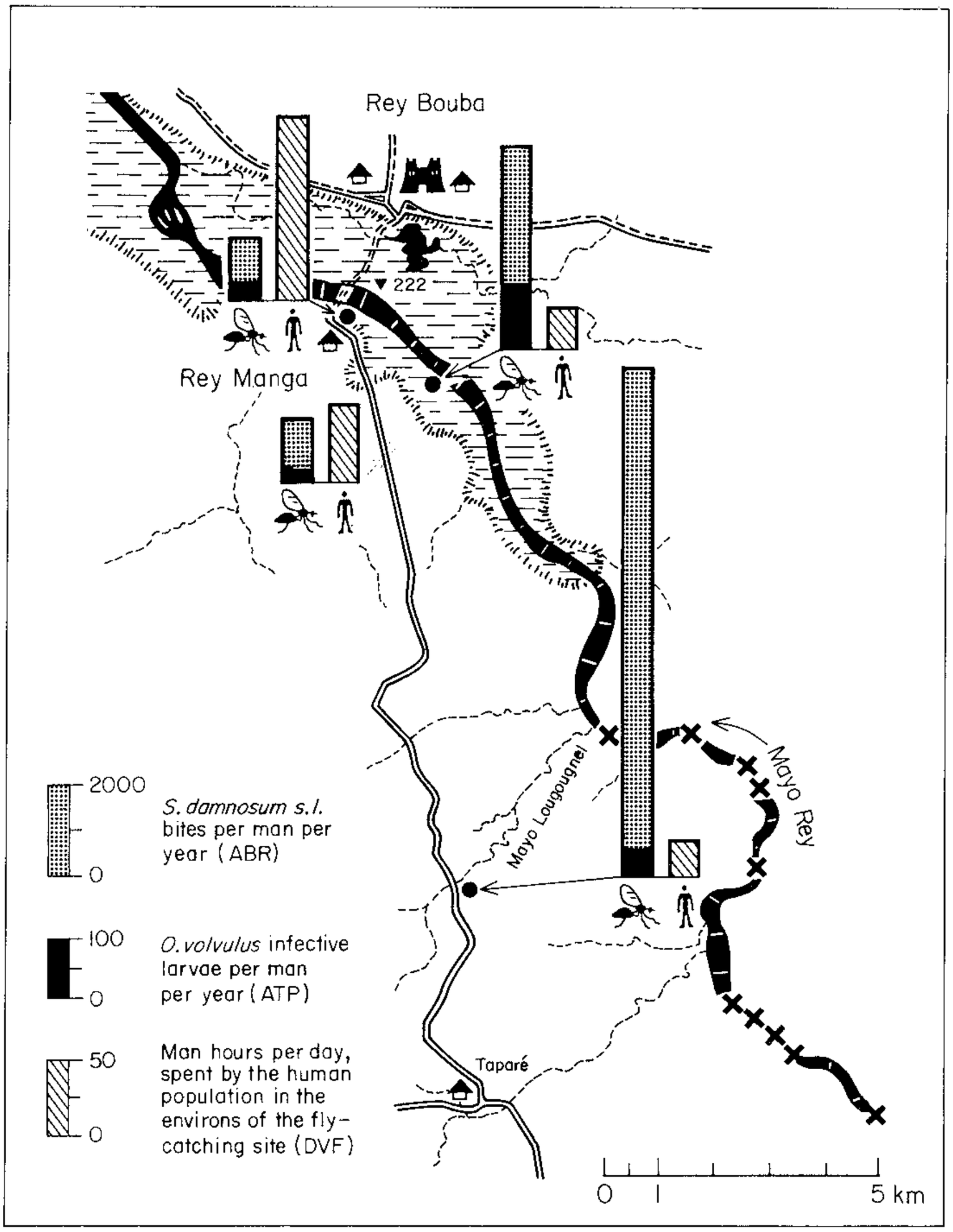

Fig. 1. Sojourn-times of the human population, *S. damnosum s.l.* biting rates and *O. volvulus* transmission potentials at four sites around the village of Rey Manga. X, *S. damnosum s.l.* breeding site; ●, fly-catching site.

population whereas the corresponding percentage for girls was 36·8% of that of the adult female population. At Douffing, these figures were 11·7 and 11·7%, and at Rey Manga, 4·2 and 0·9%. Ocular lesions due to onchocerciasis appeared in both sexes at microfilarial densities exceeding 15 mff snip^{-1}, and these densities were not seen in boys and girls under the age of 20 years except at Mayo Galké.

The mean number of microfilariae per snip by age and sex is shown, as an average for the three villages, in Fig. 2. Until the age of ten years girls had similar or even higher microfilarial densities than boys, but the marked increase which was seen in males between ten to 29 years was not followed by the females, and the densities in the higher age-groups were considerably lower in women than in men.

In order to compare the degree of exposure to transmission of different age- and sex-groups in the three villages with the resulting microfilarial densities in the skin, the index of exposure (calculation, see above) is correlated with the microfilarial density (Fig. 3). Since infections acquired at young ages might still contribute to the microfilarial load of adults, the index of exposure for adults is taken to be the sum of the values for boys and men and for girls and

TABLE 2

Age- and sex-specific manifestation of onchocerciasis

		*Boys**	*Girls**	*Men*	*Women*
Mayo Galké	No. examined/census	32/38	37/43	20/26	25/34
	Prevalence (%)†	66	81	100	100
	mff/snip‡	79·3	42·2	183·1	114·7
	Prevalence of ocular lesions (%)§	6	3	55	8
Douffing	No. examined/census	15/18	17/22	30/34	31/36
	Prevalence (%)	27	24	93	90
	mff/snip	9·4	5·8	80·4	49·6
	Prevalence of ocular lesions (%)	0	0	13	3
Rey Manga	No. examined/census	10/10	14/14	22/26	42/44
	Prevalence (%)	40	7	91	69
	mff/snip	2·2	0·14	52·3	15·6
	Prevalence of ocular lesions (%)	0	0	5	2
Total census of study –					
Village populations		66 ≙ 19%	79 ≙ 23%	86 ≙ 25%	114 ≙ 33%
Additional six villages		148 ≙ 20%	160 ≙ 22%	183 ≙ 25%	231 ≙ 32%
OCP standard population		27%	24%	23%	27%

*Up to the age of 19 years.
†Prevalence of onchocerciasis (mff-positive skin-snip).
‡mff/snip per age-group, weighted by OCP standard population.
§Ocular lesions including any degree of sclerosing keratitis, iritis, choroidoretinitis and opitic atrophy.

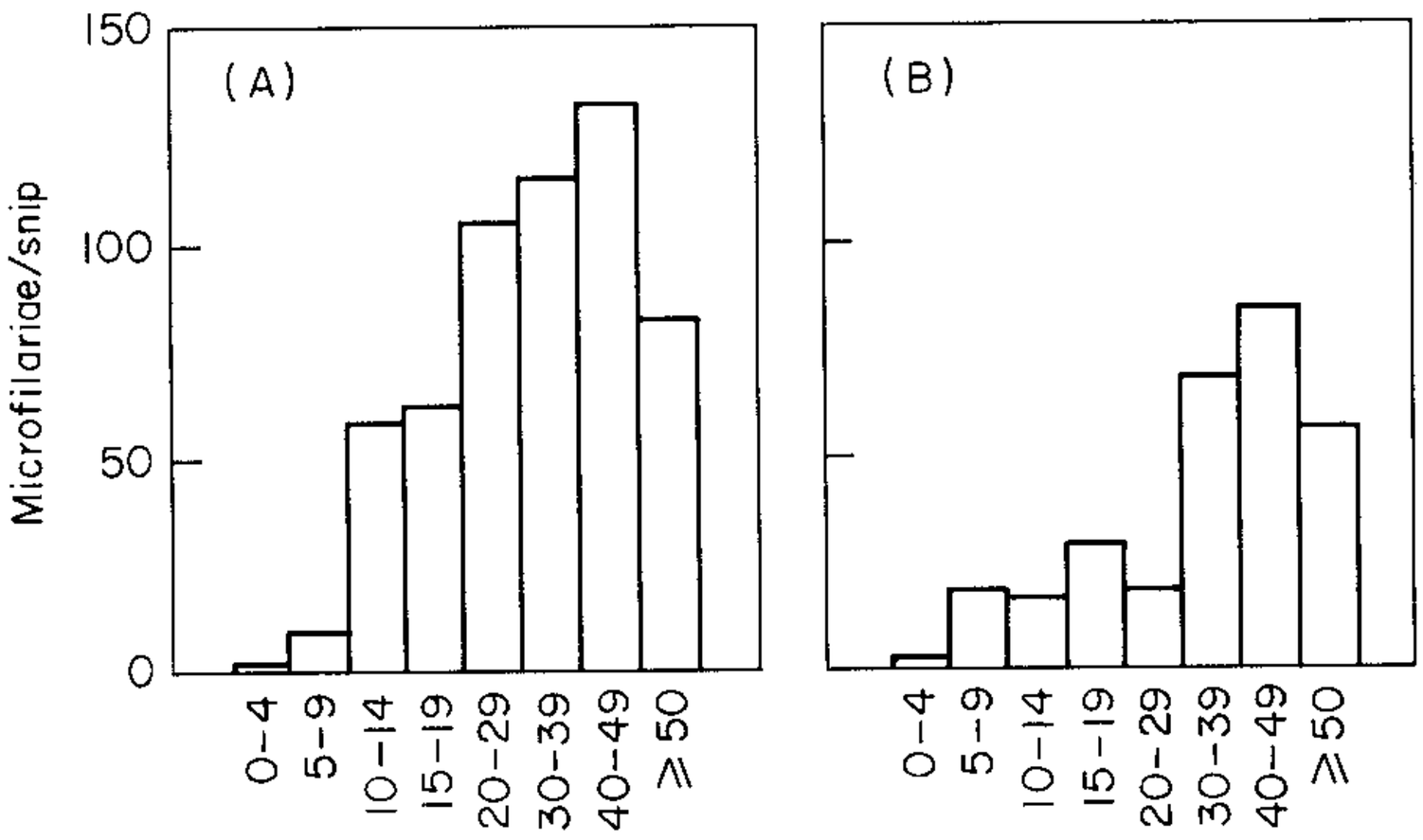

Fig. 2. Mean number of microfilariae per biopsy at the buttock (mff/snip^{-1}) by sex and age, (A) males; (B) females.

women respectively. At all three villages there was a linear relationship between the index of exposure and the resulting microfilarial densities, when children and adults were considered separately. The differences between the regression lines for children and adults at Douffing and Rey Manga indicate either that the exposure rate for children was overestimated or that of the adults was underestimated. At Rey Manga, where many children came to wash and swim from the village Rey Bouba, situated on the other side of the river at a distance of 2·5 km, the rate of

exposure for children was certainly greatly overestimated by dividing the DVF by the number of children from Rey Bouba only. However, since the sex-distribution in the three villages was similar to that of a larger sample of persons examined in the same area by the same investigators (census in Table 2), the ratios of the degree of exposure for the two sexes remain unchanged in the same age-groups.

A close relationship between the microfilarial load at the buttock and the prevalence of ocular lesions is obvious (Table 2), although the numbers of persons with ocular lesions were rather low due to the small size of the three villages. Therefore, in order to have a broader size for the analysis of the age- and sex-specific prevalence of ocular lesions or blindness in the Sudan-savanna of North Cameroon, the data from the three villages were pooled together with the data gathered by the same investigators (J.A. and H.F.) during the same period (March–October 1976) at six additional villages in the same area, so that a total of 961 persons examined was available (see Renz and Wenk, 1987 for details of the villages). In this collective, the prevalence of ocular lesions due to onchocerciasis (Fig. 4) and the prevalence of blindness (persons having one or two blind eyes, Fig. 5) was much higher in males than in females, in particular amongst the young adults. Blindness due to onchocerciasis appears for the first time in boys aged ten to 14 years, but in females only above the age of 30. Blindness due to other non-onchocercal causes (trachoma, cataract, glaucoma, injury) was responsible for 19% of the bilateral blind cases (4/21, + 1 undetermined case) and for 52% of the unilateral cases (14/27). The over-all prevalence of ocular lesions (including blindness) due to onchocerciasis was 13·9% for males (61/438) and 4·2% for females (22/522, + 1 undetermined case). The corresponding figures for unilateral or bilateral blindness due to onchocerciasis were 4·8% of males (21/438) and 1·7% of females (9/522, + 1 undetermined case).

DISCUSSION

Though the numbers of persons examined in the three villages were rather low, the sex- and age-specific manifestations of onchocerciasis were similar to results of other more detailed studies carried out in the same area by the same investigators (Anderson *et al.*, 1974; Fuglsang and Anderson, 1977). Similarly, the prevalence of blindness in males, which was more than twice as high as in females, corresponded well with the results of Kirkwood *et al.* (1983*a*), which were based on an analysis of epidemiological data gathered by the Onchocerciasis Control Programme in West Africa. However, the higher prevalence of eye 'damage' in females than in males, reported in their study, was not seen in our data, where males were more frequently affected by ocular lesions than were females. These differences might be due to the fact that Kirkwood *et al.* (1983*a*) defined the eye 'damage' by Sjögren's hand test for visual acuity (Thylefors, 1977) and since the cause of visual impairment was not defined.

The age- and sex-specific variation of the microfilarial density in the skin was proportional to the degree of exposure to the transmission of disease of the different sexes at increasing age. As long as the very young children are still carried by their mother, boys and girls are not differently exposed, and the resulting microfilarial densities were similar until the age of ten years. By increasing age, and in particular after puberty, differences became apparent. Boys aged eight to 15 years often spent much of the day standing fishing in the water, or swimming. This corresponded to a maximum exposure to transmission of onchocerciasis, and was underlined by the finding of a ten-year-old boy already blind from onchocerciasis. Girls were more occupied by work in the household or in the fields, and were not outside as long as boys. Like the women, they came mainly to the river to collect water or to wash. A more regular attendance at school might contribute to a reduced exposure rate of these age-groups, and the availability of deep wells inside the villages would significantly reduce the contact of all age-groups with the river.

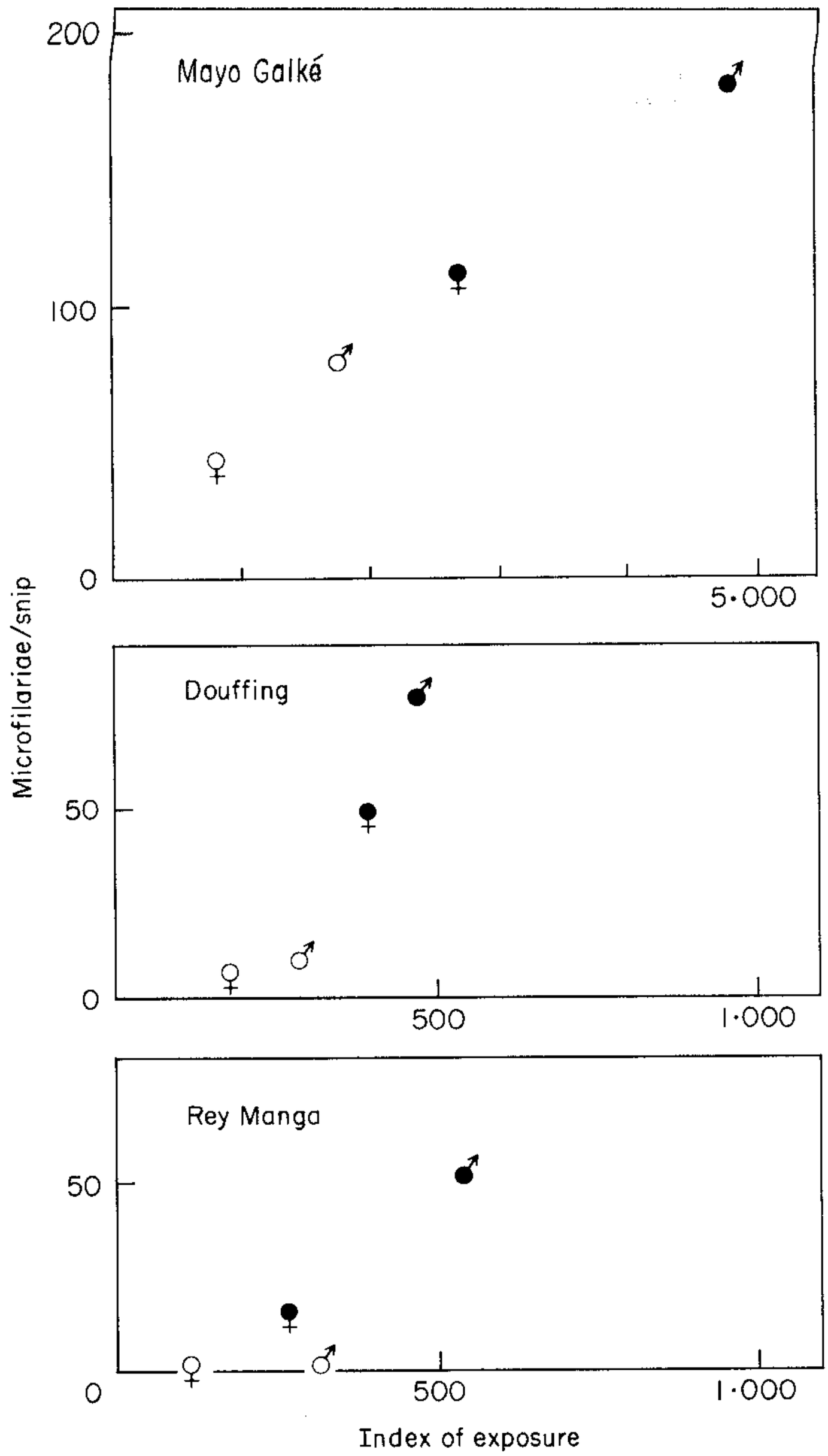

Fig. 3. The relationship between an index of the exposure to the transmission of *O. volvulus* (DVF × ATP) of boys (♂), girls (♀), men ♂ and women ♀ and the corresponding microfilarial density (mff/snip) at the buttock. The index of exposure is obtained by dividing the sum of the products of the DVF and ATP at the four sites around each village by the number of persons (census) of the respective age- and sex-group. For men and women, this index is added to the corresponding value for boys and girls respectively.

As a result of the high degree of exposure of boys and young men, the microfilarial density in this group already reached high levels by the age of ten to 30 years. The highest microfilarial levels were observed in the age-group of 40 to 49 years for both males and females of the three study-villages, two of which had only low to moderate levels of infection. However, on examining a larger population sample from exclusively hyperendemic villages in the same area of North Cameroon, it appeared that the microfilarial density in males had already reached maximum values in the age group 15 to 19 years (Anderson *et al.*, 1974). In the area of the Onchocerciasis Control Programme in West Africa, it was highest in males of 35 to 39 years

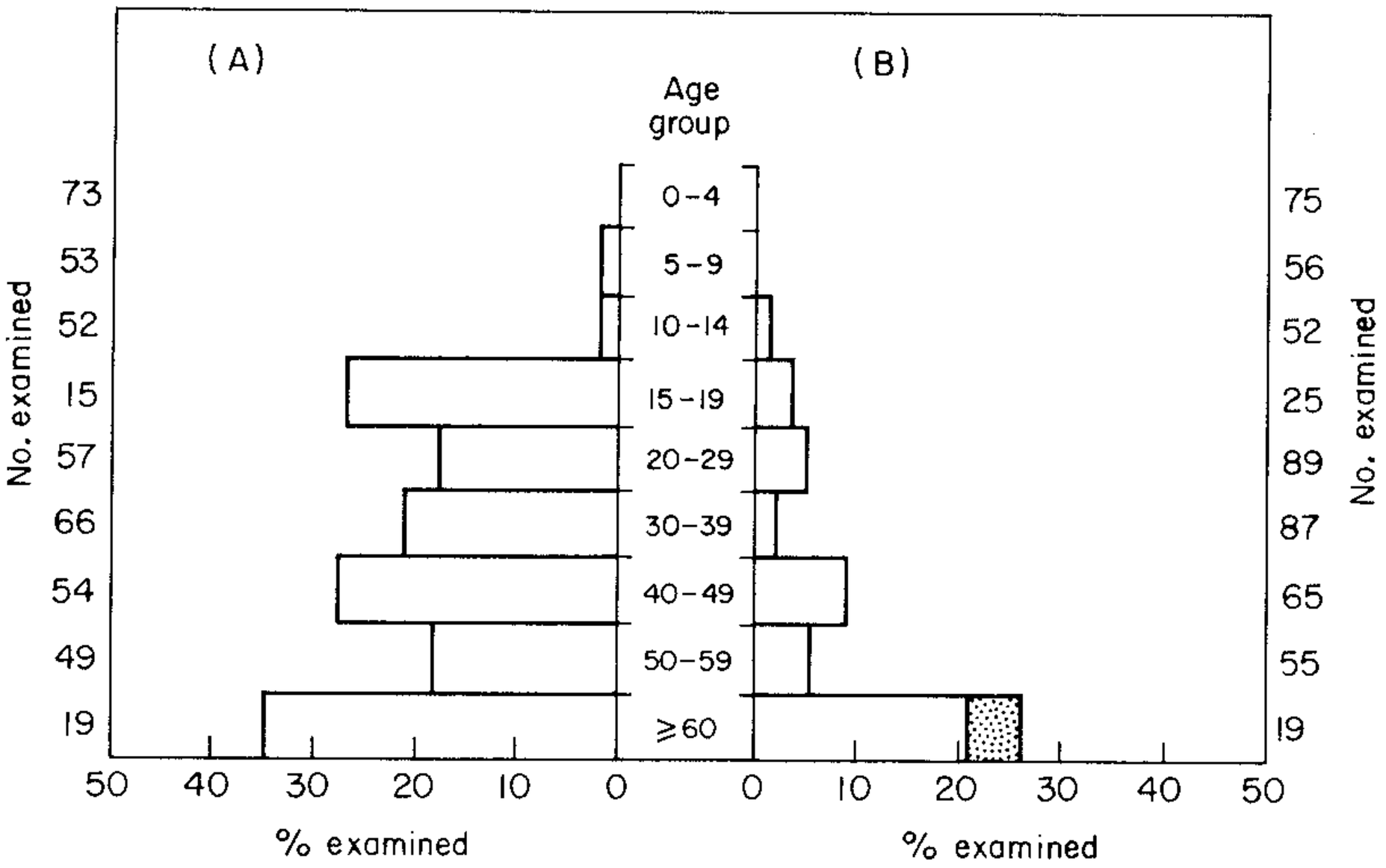

Fig. 4. Age-specific prevalence (% of examined) of ocular lesions, due to onchocerciasis in (A) males and (B) females. ▨, Not determined.

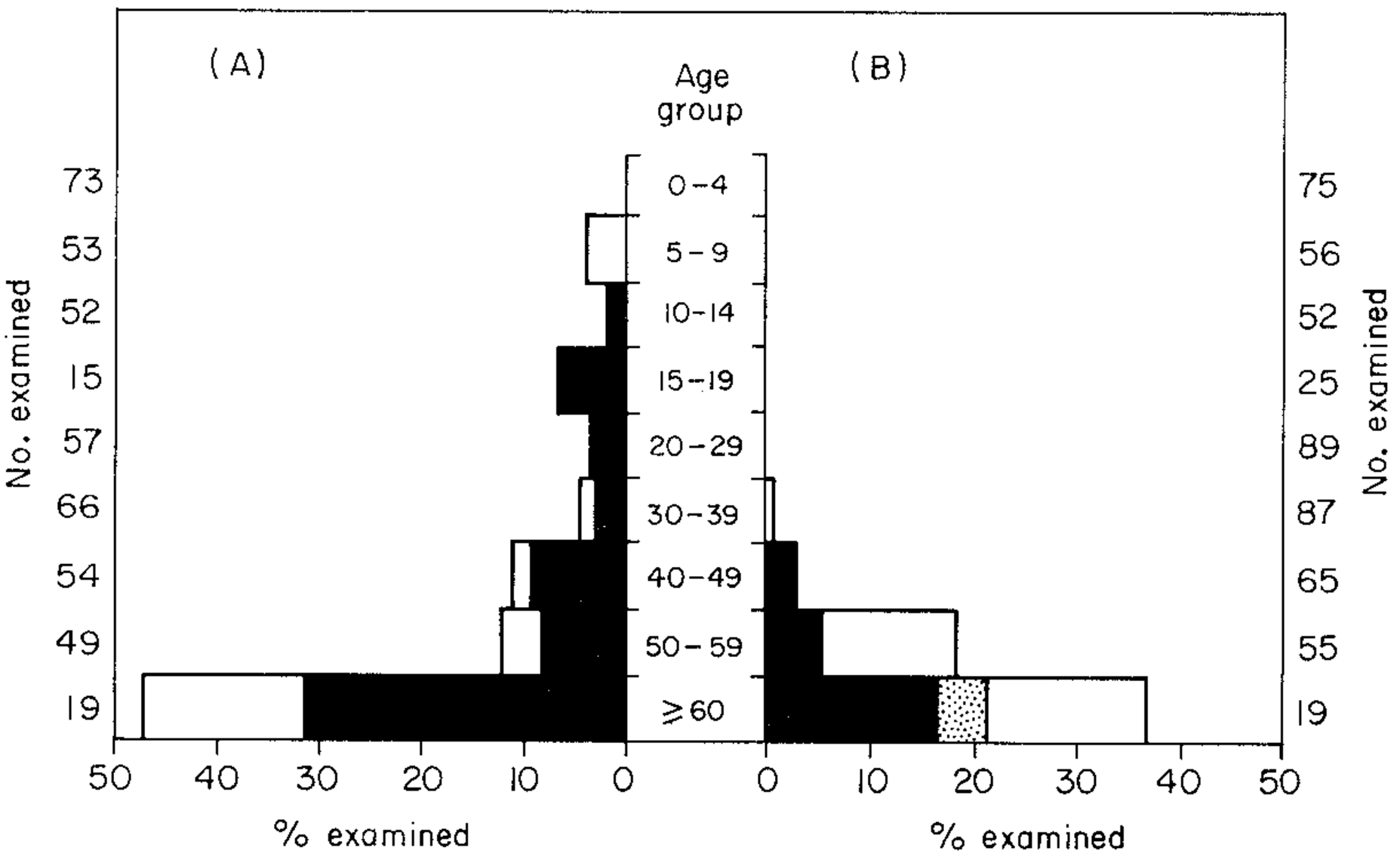

Fig. 5. Age-specific prevalence (% of examined) of loss of sight, due to onchocerciasis or to other causes, in (A) males and (B) females. Both uni- and bilateral blindness are included in this figure. Loss of sight due to ■, onchocerciasis; □, other causes; ▨, not determined.

(Kirkwood *et al.*, 1983*b*). In both these studies the density in the female population increased, as in the present study, more or less steadily with age, reaching maximum values only at 50 years of age or higher. Old women had similar or even higher microfilarial densities than males of the same age.

These differences in the course of infection of males as opposed to females should be considered, if a sex-specific probability of developing onchocercal eye-lesions is estimated by a risk-factor, composed of the age and the microfilarial density of an individual (Kirkwood *et al.*,

1983*a*). Blindness appears mainly at advanced ages, when the microfilarial densities in the two sexes were rather similar, thus giving an equal product of age and microfilarial density. Nevertheless, men had suffered from much higher parasitic loads earlier in their life and this may account for the higher prevalence of blindness in males as opposed to females of the same risk-group.

A higher susceptibility of male jirds than of female jirds with *Brugia pahangi* has been documented (Ash, 1971), and hormonal factors have been suggested to explain the higher infection rate of *Wuchereria bancrofti* in males in Africa, but the findings of the present study strongly indicated that the difference in clinical manifestations of onchocerciasis between the two sexes could be explained by different exposure in children before puberty.

In the present study severe ocular lesions were mainly found at the village of Mayo Galké, where transmission was almost perennial (Renz, 1987*a*) and where the microfilarial density had already reached high levels in the young age-groups. This is in line with the results of Duke *et al.* (1975), who thought that ocular lesions in the savanna were more the result of high intensities of infection than of seasonal patterns of transmission, as opposed to continuous perennial transmission.

REFERENCES

Anderson, J., Fuglsang, H., Hamilton, P. J. S. & Marshall, T. F. de C. (1974). Studies on onchocerciasis in the United Cameroon Republic. I. Comparison of populations with and without *Onchocerca volvulus*. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, **68,** 190–208.

Ash, L. (1971). Preferential susceptibility of male jirds (*Meriones unguiculatus*) to infections with *Brugia pahangi*. *The Journal of Parasitology*, **57,** 777–780.

Duke, B. O. L. (1968). Studies on factors influencing the transmission of onchocerciasis. IV. The biting cycles, infective biting density and transmission potential of "forest" *Simulium damnosum*. *Annals of Tropical Medicine and Parasitology*, **62,** 95–106.

Duke, B. O. L., Anderson, J. & Fuglsang, H. (1975). The *Onchocerca volvulus* transmission potentials and associated patterns of onchocerciasis at four Cameroon Sudan-savanna villages. *Tropenmedizin und Parasitologie*, **26,** 143–154.

Fuglsang, H. & Anderson, J. (1977). The concentration of microfilariae in the skin near the eye as a simple measure of the severity of onchocerciasis in a community and as an indicator of danger to the eye. *Tropenmedizin und Parasitologie*, **28,** 63–67.

Kirkwood, B., Smith, P., Marshall, T. & Prost, A. (1983*a*). Variations in the prevalence and intensity of microfilarial infections by age, sex, place and time in the area of the Onchocerciasis Control Programme. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, **77,** 857–861.

Kirkwood, B., Smith, P., Marshall, T. & Prost, A. (1983*b*). Relationships between mortality, visual acuity and microfilarial load in the area of the Onchocerciasis Control Programme. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, **77,** 862–868.

Moreau, J. P., Prost, A. & Proud'hon, J. (1978). Essai de normalisation de la méthodologie des enquêtes clinico-parasitologiques sur l'onchocercose en Afrique de l'Ouest. *Médécine Tropicale*, **38,** 43–51.

Nelson, G. S. (1966). The pathology of filarial infections. *Helminthological Abstracts*, **35,** 311–336.

Renz, A. (1987*a*). Studies on the dynamics of transmission of onchocerciasis in a Sudan-savanna area of North Cameroon. II. Seasonal and diurnal changes in the biting densities and in the age-composition of the vector populations. *Annals of Tropical Medicine and Parasitology*, **81,** 229–237.

Renz, A. (1987*b*). Studies on the dynamics of transmission of onchocerciasis in a Sudan-savanna area of North Cameroon. III. Infection rates of *Simulium* vectors and *Onchocerca volvulus* transmission potentials. *Annals of Tropical Medicine and Parasitology*, **81** 239–252.

Renz, A. & Wenk, P. (1987). Studies on the dynamics of transmission of onchocerciasis in a Sudan-savanna area of North Cameroon. I. Prevailing *Simulium* vectors, their biting rates and age-composition at different distances from their breeding sites. *Annals of Tropical Medicine and Parasitology*, **81,** 215–228.

Thylefors, B. (1977). Visual screening of illiterate populations. *Bulletin of the World Health Organization*, **55,** 115–119.