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

What is a tolerable level of Annual Transmission Potential?

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The prevalence and intensity of infection with *Onchocerca volvulus* were assessed in population surveys in nine villages, situated at different distances from *Simulium damnosum s.l.* breeding sites. The prevalence varied from 48 to 89%, the arithmetic mean densities of microfilariae per skin snip were between 16 and 109, and severe ocular lesions were found in from 1 to 22% of patients.

Annual Transmission Potentials (ATP) were measured for up to three years in the near vicinity of nine villages at several fly-catching sites.

Weighted means of the ATP over the three years, and of the sojourn times of the human population, were calculated at three of the villages, where the prevalence of onchocerciasis was 51, 61 and 89%.

An average ATP of 100 larvae or less in the head, thorax and abdomen of the flies was associated with an onchocerciasis prevalence of 50 to 60%, a mean microfilarial density below 40 microfilariae per skin-snip, less than 5% of ocular lesions, and no onchocercal blindness. This value might therefore be considered to be an indication of the level to which the transmission must be reduced in the savanna in order to prevent the occurrence of severe ocular lesions or blindness. It is lower than the present level accepted by the Onchocerciasis Control Programme in the Volta River Basin.

Previous work on the transmission potentials of *Onchocerca volvulus* and the associated intensity of onchocerciasis in the Sudan-savanna of West and Central Africa showed that hyperendemic villages with serious ocular lesions due to onchocerciasis were found where the level of the Annual Transmission Potential (ATP; Duke, 1968) was as low as 500 (Duke *et al.*, 1975) or 66 to 222 (Thylefors *et al.*, 1978). It is generally accepted that levels of ATP exceeding 1000 infective larvae per man per year will lead to severe ocular lesions and blindness in the savanna (Duke *et al.*, 1975; Philippon, 1977; Thylefors *et al.*, 1978; Prost *et al.*, 1979), whereas much higher levels are tolerated in the rain forest (Duke *et al.*, 1972).

In onchocerciasis control programmes it is important to identify the levels of transmission and of man-fly contact which must be achieved to control the *Simulium damnosum s.l.* vector flies, in order to protect the human population from becoming blind (Walsh *et al.*, 1979), or even to achieve interruption of transmission.

The present study was therefore aimed at investigating the levels of man-biting rates and transmission associated with different degrees of ocular lesions in the Sudan-savanna of Cameroon, with the purpose of defining a tolerable level of transmission.

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MATERIALS AND METHODS

Study Area and Villages

Nine villages, situated at different distances from *S. damnosum* breeding sites, were selected in the Sudan-savanna of North Cameroon in the area of Tchollíré (8°24′N, 14°14′E) and Touboro (7°46′N, 15°21′E). Details of the study area, the selection of villages and the situation of the fly-catching sites have already been presented in a previous paper (Renz and Wenk, 1987, Table 1 and Figs 1–3).

Medical and Ophthalmological Examinations

The examination of the village populations was carried out in March (Touboro) and in October 1976 (all other villages). Two skin-snips were taken from each person, using a corneoscleral punch, one from the outer canthus near the eye and the other from the left buttock. The average weight of a skin-snip was 1·4 mg. The methods of parasitological and ophthalmological examination were described by Fuglsang and Anderson (1977) and Renz and Wenk (1987). The calculation of age-specific prevalences and microfilarial densities were made by using a standard population age distribution worked out by the WHO Onchocerciasis Control Programme in West Africa (OCP) (Moreau *et al.*, 1978). Severe ocular lesions were defined as any degree of sclerosing keratitis, iritis, choroidoretinitis and optic atrophy. Blindness was defined as the inability to count fingers at 3 m with the better eye.

Entomological Data on Disease Transmission

Regular fly-catching was carried out at up to five fly-catching sites near each village for up to three consecutive years, from May 1976 to April 1979. The choice of the fly-catching sites, the methods of fly-catching and dissection were described previously (Renz and Wenk, 1987).

Annual Biting Rates (ABR) were calculated according to Walsh *et al.* (1978), and the Annual Transmission Potentials (ATP) on the basis of all infective larvae morphologically indistinguishable from *O. volvulus* (Bain, 1969) found in the head, thorax and abdomen of the flies (Duke, 1968).

The vectors of onchocerciasis identified by cytotaxonomy of larval samples* were mainly *S. damnosum s. str.* and *S. sirbanum,* together with a very small proportion of *S. quamosum* (Renz and Wenk, 1987).

The sojourn times of the human population were measured during one year (May 1978 to April 1979) at four fly-catching sites near the villages Mayo Galké, Douffing, and Rey Manga. Details of the methods and results have been presented previously (Renz *et al.*, 1987). The Daily Visiting Frequency (DVF) gives the estimated number of man-hours spent at a given site from 06.00 to 18.30 hours.

RESULTS

Transmission Potentials and Annual Biting Rates

Table 1 gives the estimated ABR and ATP for each fly-catching site. In order to obtain an average value of the ABR and ATP for one village where different fly-catching sites were visited, the values were weighted by the Daily Visiting Frequency (DVF) and by the annual variations of the ABR and ATP (Table 2). Further adjustments were made for those villages where only one or two sites were visited, e.g. at Gandi, where the proximity of the river Mayo Rey was taken into consideration by taking an average between the ATP of Mayo Galké (1318) and of the two catching sites at Gandi (ATP 105 and 0), resulting in an ATP of 474. In the same way, the ATP of Bonandiga was calculated as an average with that of Vina bridge ((2767+578)/2=1673).

*Identification by Dr. Vajime, formerly OCP, Ouagadougou.

There was a close relationship between the ABR and the ATP (Fig. 3(A)). The coefficient of correlation was higher (correlation 0·872) for a power regression (ABR = a ATP^b; $a = 282{\cdot}8$, $b = 0{\cdot}6325$) than for a linear regression (correlation 0·861; ABR = $a + b$ ATP; $a = 3365$, $b = 18{\cdot}95$). The slope for the two regression lines is not very different for moderate levels of the ATP: the ABR corresponding to an ATP of 100 or 1000 was 5206 and 22 334 flies/man/year for the power regression and 5260 and 22 315 for the linear regression. However, at low or very high values of the ATP, the differences were obvious: ATP 1 corresponds to 283 flies/man/year for the power regression and to 3384 flies/man/year for the linear regression. For an ATP of 10 000 the corresponding values were 95 825 and 192 865. Probably, the power regression describes more adequately the relationship between ATP and ATP at low intensities of transmission.

Seasons of Transmission (cf. Renz (1987*b*) and Fig. 2)

At the perennial breeding site at the Vina bridge near Touboro transmission was almost perennial, with maximum levels in July (1507 larvae per man per month), January (3107) and April (429). At Mayo Galké causeway, where breeding was only interrupted at the end of the dry season (February to April) when the river Mayo Rey stopped flowing, highest transmission rates (328 to 986) were observed in the period from May to August and again in December and January (147 to 498). A similar pattern was found at Rey Manga causeway, but at a much reduced rate (June, 25; December, 31). At the other sites, across-country away from the rivers, the transmission was mainly limited to the rainy and early dry seasons, and highest transmission potentials were observed from July to November at Douffing well (12 to 82), in August at Bonandiga (330) and from July to December at Nonozé, Tchollíré, Larki and Gandi.

Pattern of Onchocerciasis

The prevalence of onchocerciasis, as indicated by a positive skin snip at either the outer canthus or buttock, was high and varied from 48 to 89% (Table 1), corresponding to meso- and hyperendemicity of the disease (Prost *et al.*, 1979). There was, however, a wide variation in the age-adjusted arithmetical mean microfilarial density at the buttock, ranging from 16 to 109 mff/snip. In close correlation with the average microfilarial density, the prevalence of ocular lesions due to onchocerciasis ranged from 1 to 22%. Bilateral blindness from onchocerciasis was found at villages where the arithmetic mean microfilarial density was higher than 35 mff snip^{-1}.

Figure 1 gives the age-specific arthmetical mean microfilarial density at the buttock, the youngest age-group with a prevalence higher than 50% (Knüttgen and Büttner, 1969), and the age-specific prevalence of eye lesions due to onchocerciasis for all the villages. The average microfilarial density increased with age and reached its maximum in persons over 40 years. A sharp increase is also seen at the age of 15 to 19 years. The prevalence of eye lesions varied considerably from one village to the other and was mainly restricted to the older age groups, but like the microfilarial density it had already reached high levels in children at those villages where the microfilarial density was high.

In general, the male population of the villages had much higher microfilarial densities at the buttock than the females (Table 3). This difference becomes even more striking for the density of microfilariae at the outer canthus: whereas the highest density for females was 6·5 mff snip^{-1} at Mayo Galké, the male population of five villages had higher densities and at three villages (Gandi/Mayo Galké, Mayo Galké and Bonandiga) the density was as high as 14·6 to 17·6 mff snip^{-1}. These differences in the intensity of infection can be explained by the much higher degree of exposure to the transmission of disease of the male population, especially in the young (Renz *et al.*, 1987). It also shows that, even at a very low prevalence of infection, a few highly infected persons, who are exposed by their way of life (ferry- or

Nonozé	74·1	56	11·1	4·5	4·5	6 km from the river Mayo Rey. Recently built near the protestant mission. High prevalence and eye lesions probably acquired elsewhere.	Well of campment, 6·5 km from Mayo Rey (p)	+	2400	—	—	77	—	—
Gandi 1.	83·1	89	22·4	3·7	9·4	2·5 km from the breeding sites in the Mayo Rey. 1. Part of Mayo Galké until 1968	Village well, 2·5 km from Mayo Rey (n)	+ +	4200	—	—	105	—	—
2.	70·1	65	5·0	0·7	1·3	2. Local population	In the fields, 2·5 km from Mayo Rey (x)	+ + +	2100	—	—	0	—	—
Touboro	69·4	94	7·1	0·3	1·1	Administrative town and cotton factory. 2 km from perennial breeding sites along the Vina river. Three-quarters examined.	River Vina bridge (t)	+ + +	26 100	—	—	2767	—	—
							Touboro South, tributary (u)	+ +	730	—	—	0	—	—
							Touboro centre near hospital (v)	+ + +	50	—	—	0	—	—
Mayo Galké	89·5	101	20·3	7·6	11·8	500 m from breeding sites at a disused causeway across the river Mayo Rey, and 1 km from a rainy season breeding site in the tributary Mayo Dokday.	Mayo Galké causeway (a)	81	83 800	47 900	49 600	3076	2402	1609
							Tributary Mayo Dokday, 1 km from Mayo Rey (b)	1	—	37 400	27 700	—	2104	377
							250 m from causeway, fields (c)	34	—	14 400	—	—	670	—
							900 m from causeway, fields (d)	65	—	12 000	—	—	355	—
							In the village, 600 m from causeway (e)	+ + +	6000	—	—	109	—	—
Bonandiga	83·3	107	19·0	3·7	5·0	2 km from perennial breeding sites at the river Vina. Probably additional rainy season breeding in the nearby tributary Bome.	Village centre, 2 km from river Vina (w)	+ + +	7600	—	—	578	—	—

*Adjusted for age and sex, OCP standard population.
†Positive skin snip.
‡Arithmetic mean number of microfilariae at the buttock per person examined.
§Ocular lesions, due to onchocerciasis only, including sclerosing keratitis, any degree of iritis, optic nerve disease and choroidoretinitis.
‖Estimated no. of man hours per day, spent by the human population at this site (Renz *et al.*, 1987). +, + +, + + +: low, medium and high Daily Visiting Frequency.
≡Annual Biting Rate; Estimated no. of *Simulium damnosum s.l.* bites per man per year.
**Annual Transmission Potential; Estimated no. of *Onchocerca volvulus* infective larvae per man per year.

TABLE 2

The calculation of the estimated average values of the Annual Biting Rates ($\overline{ABR}$) and Transmission Potentials ($\overline{ATP}$) for the nine study-villages in the Cameroon Sudan-savanna

Village	*Calculation*	$\overline{ABR}$	$\overline{ATP}$
Tcholliré	r (1976)	1000	17
Rey Manga	$\overline{\text{jkl}}$ (DVF, 1976–1978)	3053	49
Larki	q (1976)	10 700	79
Douffing	$\overline{\text{fghi}}$ (DVF, 1976–1978)	2507	55
Nonozé	p (1976)	2400	77
Gandi	$\overline{\overline{\text{nx}}}$ (1976), $\overline{\overline{\text{abcd}}}$	14 152	474
Touboro	$\overline{\text{tuv}}$ (1976)	8960	922
Mayo Galké	$\overline{\text{abcd}}$ (DVF, 1976–1978)	36 157	1318
Bonandiga	$\overline{\text{wt}}$ (1976)	16 850	1673

The letters a–x refer to the fly-catching sites used for weighting the results from different years (1976–1978) and to the values of the Daily Visiting Frequency (DVF), where available.

TABLE 3

Mean microfilarial densities at the buttock and at the outer canthus in males and females of the study-villages

	Arithmetic mean microfilarial density per skin snip			
	Buttock		*Outer canthus*	
Village	*Males*	*Females*	*Males*	*Females*
Tcholliré	19·1	12·0	0·2	0·4
Rey Manga	25·0	8·3	1·0	0·5
Larki	37·6	11·2	2·4	0·5
Douffing	41·6	28·9	0·9	1·4
Nonozé	64·3	47·1	4·0	2·2
Gandi, Dourou	84·3	45·2	7·6	4·8
Gandi, Mayo Galké	87·9	89·3	14·7	4·9
Touboro	119·6	69·2	9·3	3·8
Mayo Galké	126·4	75·6	19·3	6·5
Bonandiga	134·6	82·9	17·6	3·5

fishermen) to a maximum of exposure, could maintain the cycle of transmission, so providing a constant source of infected flies.

Correlation between Entomological and Parasitological Parameters

There was a close relationship between the ATP and the average microfilarial density (Fig. 3(B)) and the prevalence of ocular lesions (Fig. 3(C)). Both sets of data fitted a regression line at logarithmic scale of ATP. Because of the close relationship between the ATP and the microfilarial density, the correlation between the prevalance of ocular lesions and the intensity

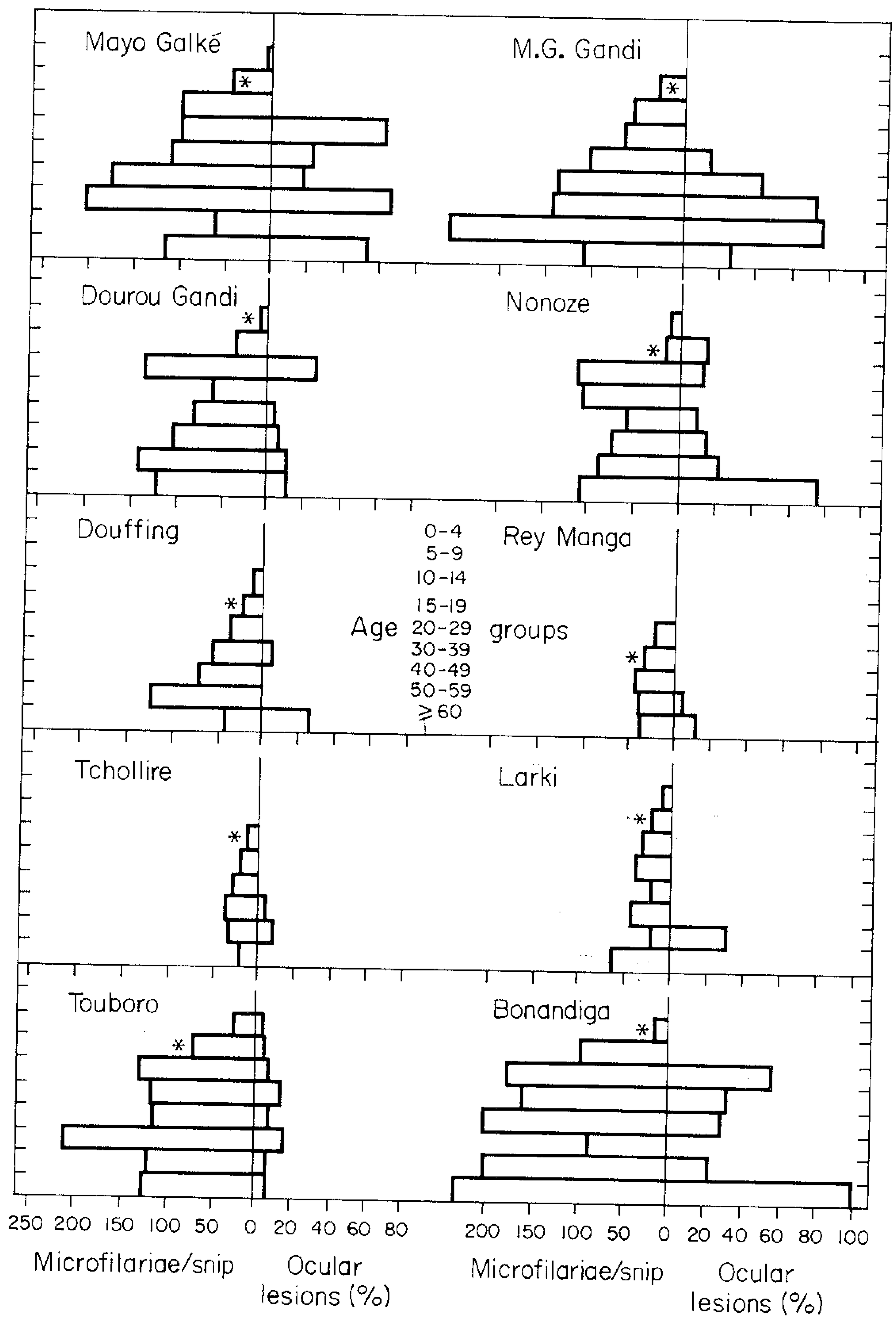

Fig. 1. Age-specific microfilarial densities at the buttock (m_a mff snip^{-1}; 1 snip$\triangleq$1·4 mg) and prevalence of ocular lesions. The values were adjusted for age and sex to a standard OCP population. Values for missing age-groups were interpolated. The asterisk indicates the youngest age-group in which the prevalence exceeds 50% (Knüttgen and Büttner, 1969).

of infection is very similar to that of the correlation between the ATP and the prevalence of ocular lesions (Fig. 3(B),(C)). Deviations from this correlation could be explained by either the low number of infective flies available for the calculation of the ATP (Tchollíré: one infective fly caught, coefficient of variation of the ATP is ±124%) or the unrepresentative sample of the population (Nonozé: too recently set up, eye lesions acquired elsewhere; Touboro: no one of a suitable age examined, see Discussion).

At an ATP below 500 there was hardly any locally acquired blindness, and below 100 there were few ocular lesions. Arithmetical mean densities were 40 mff snip^{-1} corresponding to an

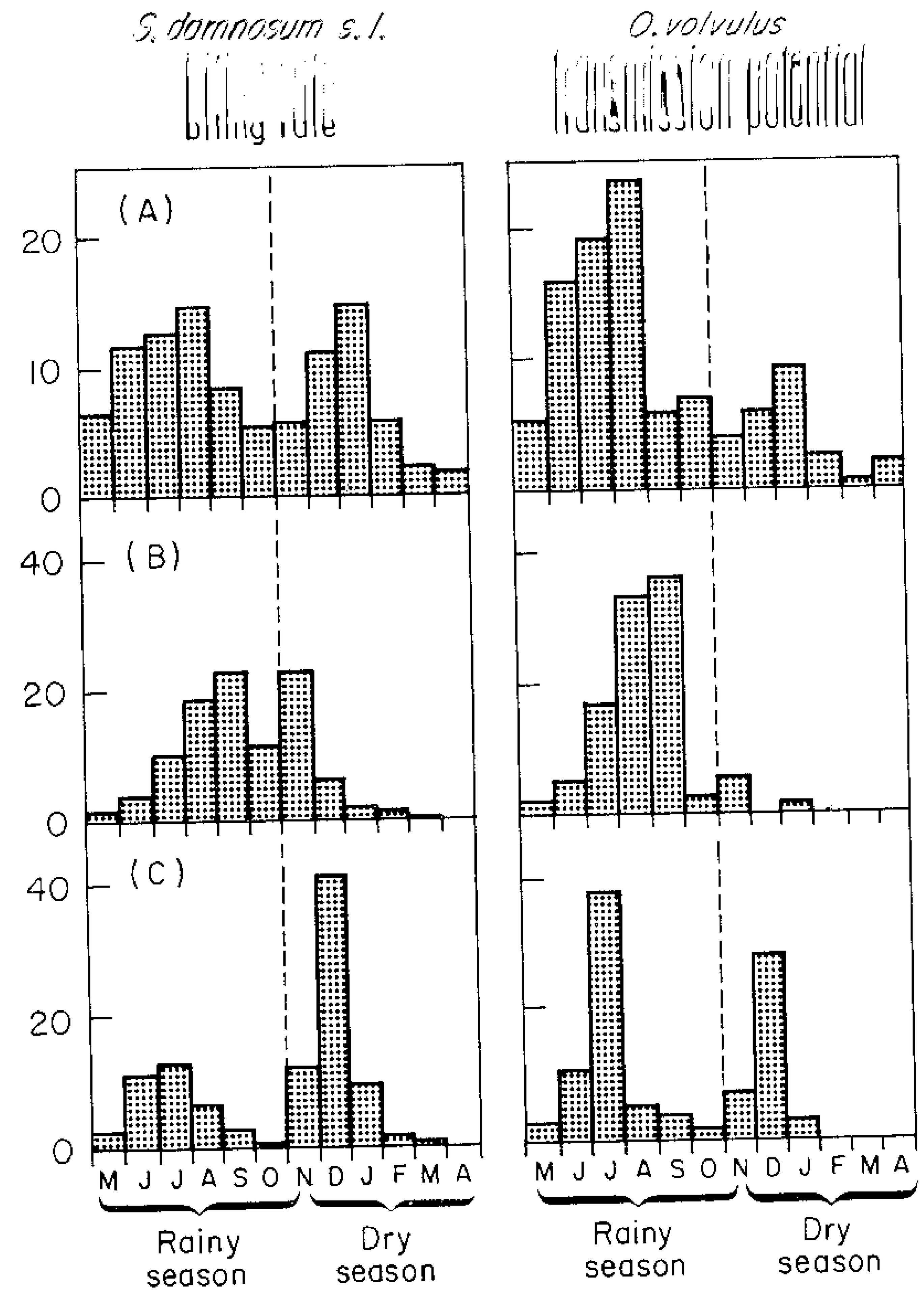

Fig. 2. Showing the variation of the fly-biting rate and of the *O. volvulus* transmission potential over the year, as a percentage (%) of the total annual value (ABR, ATP). (A) At Mayo Galké, near an almost perennial *Simulium* breeding site in the river Mayo Rey, the biting rate shows a bimodal pattern, whilst transmission is highest during the months of June to August. 8 place-years; Σ ABR = 279 000; Σ ATP = 10 737. (B) At Douffing, 7–10 km crosscountry away from the nearest breeding sites; the occurrence of the flies and the transmission is limited to the rainy season (July to October). 7 place-years; Σ ABR = 23 000; Σ ATP = 555. (C) At Rey Manga, about 9 km downstream from the breeding sites, the biting rate and transmission is highest in July and December. 7 place-years; Σ ABR = 44 000; Σ ATP = 636.

ATP of 100, 100 mff snip^{-1} for an ATP of 1000, 200 mff snip^{-1} for an ATP of 10 000. The prevalence of onchocerciasis was higher than 50% with an ATP of 100, and reached 90% with an ATP of 1000 (Fig. 4).

DISCUSSION

The parasitological and ophthalmological data from the area of Tcholliré were similar to those previously published on the endemicity of onchocerciasis in the Touboro area (Anderson *et al.*, 1974), showing that the prevalence reached hyperendemic levels as defined by Prost *et al.* (1979) at all villages with the exception of Tcholliré and Rey Manga. In view of the life span of about ten years of the adult *O. volvulus* (Büttner *et al.*, 1983), one may assume that almost everybody will contract the infection within this time in an endemic area, whilst carrying out normal outdoor activities. Hypoendemicity, corresponding to a prevalence below 33% (Prost *et al.*, 1979), was not found in any of 25 villages examined in the Tcholliré–Touboro focus by

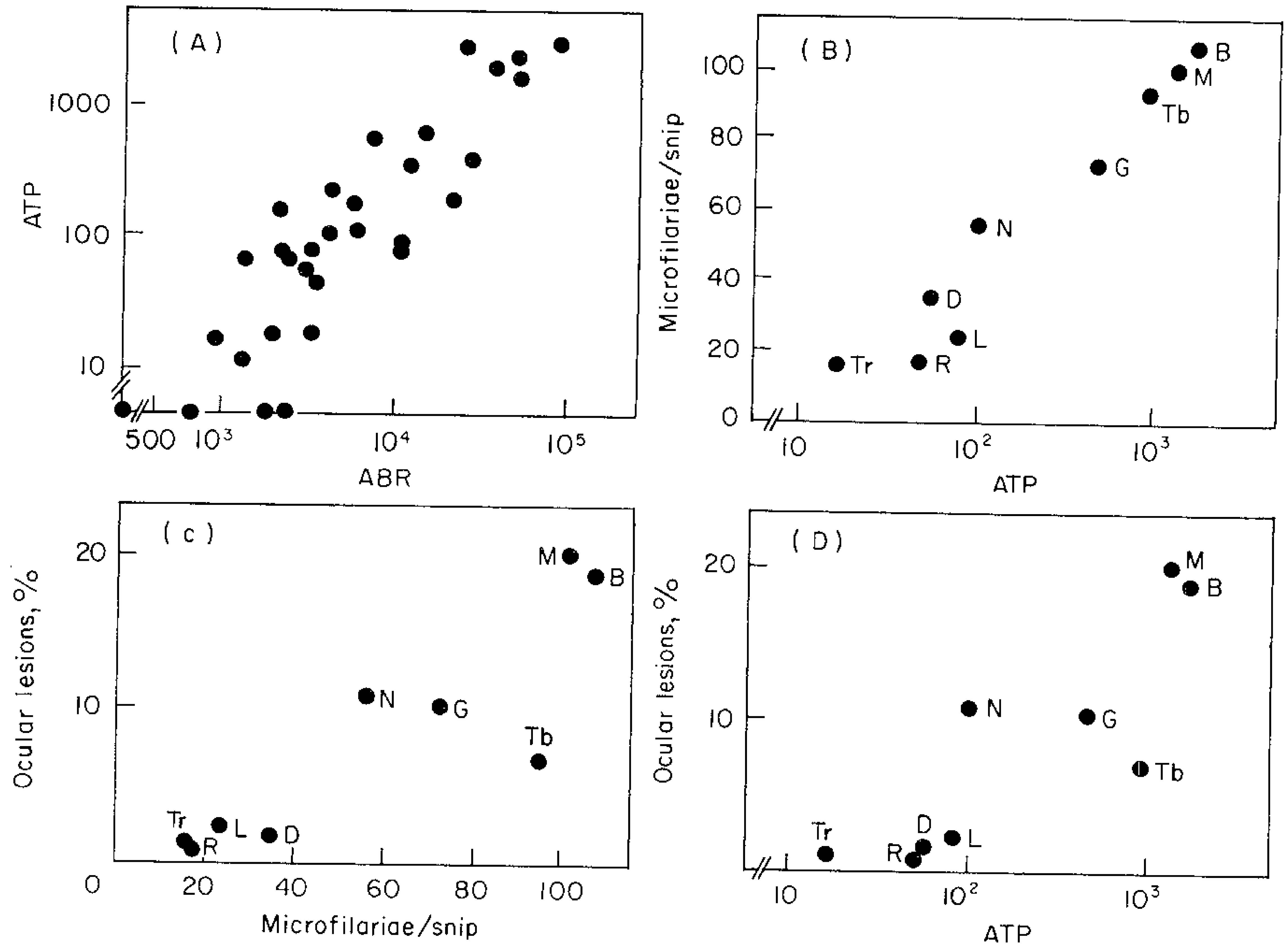

Fig. 3. (A) The relationship between the Annual Biting Rate (ABR) and the Annual Transmission Potential (ATP). The ATP is below 20 infective larvae/man/year for an ABR of less than 1000 flies. (B) The arithmetic mean microfilarial density at the buttock compared with the ATP. Data from nine villages (B,Tr). The microfilarial density is below 20 mff/snip for an ATP below 50. (C) and (D) Ocular lesions, due to onchocerciasis, in relation to the arithmetic mean microfilarial density at the buttock (C) and the ATP (D). Ocular lesions were found even at low values of the microfilarial density and ATP.

Tr, Tchollíré; R, Rey Manga; L, Larki; D, Douffing; N, Nonozé; G, Gandi (average of Gandi Dourou and Mboum); Tb, Touboro; M, Mayo Galké; B, Bonandiga.

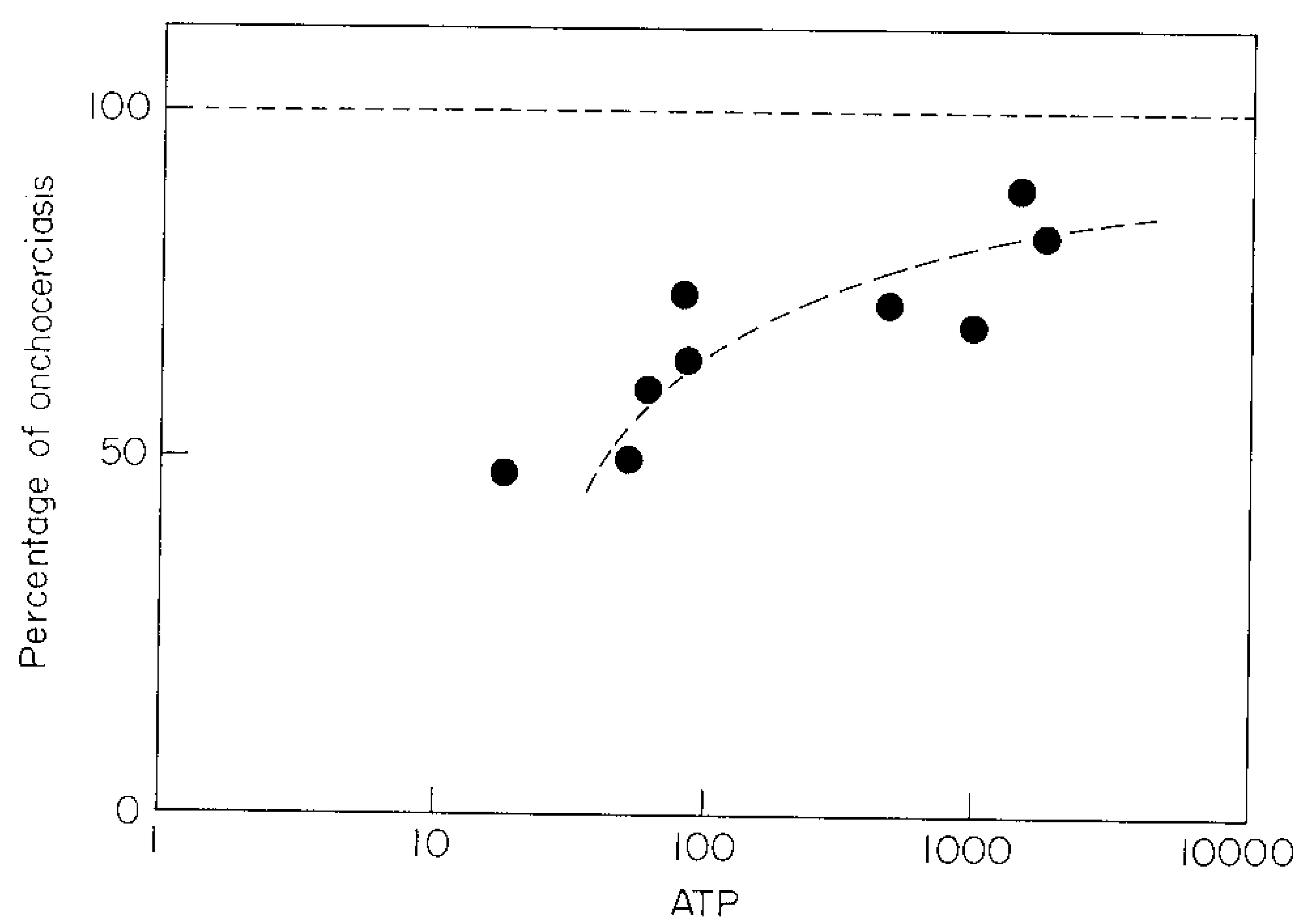

Fig. 4. The relationship between the intensity of transmission (ATP) and the prevalence of onchocerciasis. Even at low intensity of transmission, the endemicity of onchocerciasis is high.

TABLE 1

Parasitological, ophthalmological, sociological and entomological results, calculated per village and per fly-catching site

Village	Prevalence of onchocerciasis*† (%)	Mean mff-density per snip*‡	Prevalence of ocular lesions*§ (%)	Prevalence of blindness due to onchocerciasis: Bilateral (%)	Prevalence of blindness due to onchocerciasis: Uni- or bilateral (%)	Remarks	Fly-catching site	Daily visiting frequency‖	ABR≡ 1976	ABR≡ 1977	ABR≡ 1978	ATP** 1976	ATP** 1977	ATP** 1978
Tchollirć	48·4	16	1·2	0·0	0·0	Administrative town, 8 km from the river Mayo Rey. Only the population of one quarter near the sultan's palace examined.	Tchollirć East at Mayo Doudja (r)	+	1000	—	—	17	—	—
							Tchollirć centre at banana garden (s)	+++	360	—	—	0	—	—
Rey Manga	50·7	17	0·9	0·0	0·0	9 km downstream from breeding sites in the river Mayo Rey. 500 m from causeway.	Rey Manga causeway (j)	121	3600	1400	2000	46	[illegible]	19
							2 km upstream from the causeway (k)	28	—	4500	—	—	[illegible]	—
							Village fields, 1·5 km from the river (l)	52	—	1400	—	—	[illegible]	—
							Tributary Mayo Lougougnel (m)	25	—	11 100	20 500	—	[illegible]	185
Larki	64·4	24	2·3	0·0	1·1	6 km from perennial breeding sites along the river Benoué. During the dry season, the inhabitants are hunting and fishing.	Village well, 100 m from the village (q)	++	10 700	—	—	79	—	—
Doufling	60·8	35	1·7	0·0	0·7	10 km from the river Mayo Rey and 7 km from rainy season breeding sites in the tributary Mayo Bodo.	Village well, at tributary (f)	50	2600	5800	3400	68	[illegible]	19
							Waterhole (g)	41		3200	2500	—	[illegible]	4
							Village fields (h)	51		3400	—	—	[illegible]	—
							Small tributary (i)	50		2300			[illegible]	

various authors (Anderson *et al.*, 1974, Duke *et al.*, 1975, Le Bras *et al.*, 1976), and would only exist in a population with a very low sporadic influx of infected flies or persons.

The present data further suggested that it is difficult to find a form of onchocerciasis without the occurrence of sporadic ocular lesions, due to the very different individual exposure (Renz *et al.*, 1987), or to the possible localization of adult worms near the eye (Anderson *et al.*, 1975).

In the present study an overall arithmetical mean microfilarial density of 20 mff snip^{-1} (14 per mg) seemed to be the maximum tolerable level of infection, associated with a low prevalence of ocular lesions without blindness. Such a degree of infection was found at places where the transmission potentials were 100 per year, or rather less.

The exception was Nonozé, a settlement too young to represent an endemic equilibrium. However, the low infection rates among children indicated that the transmission there was not responsible for the high infection rates found in the adult population, which had acquired its infection elsewhere. All blind persons moved in some ten years ago from the village of Mayo Galké.

A stay of only one day at the river Mayo Galké during a period of maximum transmission, when the ATPs there were 15 to 30 times higher than in the villages more than 5 km distant across-country, would result in the same exposure as a stay of almost one month at the villages.

The low prevalence of ocular lesions at Touboro is explained by the fact that the only person aged over 50 years examined was not affected by ocular lesions. According to the standard age-distribution from the other villages, one would have expected some 57 persons in this age-group, of which about 30% (17 persons) would have ocular lesions (cf. Table 4 in Renz *et al.*, 1987). Hence the expected overall prevalence of eye lesions would be as high as 12%.

The calculation of the ATP in the present study was based on the total number of infective larvae in the head, thorax and abdomen of the flies, in order to allow comparison with previous work (Duke *et al.*, 1975; Thylefors *et al.*, 1978; Garms, 1973) and because it has shown that larvae from the thorax and the abdomen can leave the vectors during a bloodmeal (Duke, 1973; Philippon, 1977; Renz, 1987*b*). In order to make comparisons with the ATP based on the number of head-larvae only, as in the OCP (Walsh *et al.*, 1978), a scaling factor of 0·54 (Renz, 1987*b*) to 0·56 (Philippon, 1977) should be used. For such a comparison it can be concluded that in the Tcholliré focus the value of a tolerable ATP, calculated on head-larvae only, would be only about 54 to 56 infective larvae per man per year. This value is lower than 100 head-larvae, accepted as a provisional maximum permissible level of transmission in the OCP in West Africa (WHO, 1977; Walsh *et al.*, 1979). However, there is some difference in the way of relating ATPs to the danger of transmission. In this study the ATP was an average of the value at the breeding sites and near the villages, whereas the ATPs in the OCP were measured only at the river-sites, i.e. at sites where the fly-densities were likely to be highest, but where villages were not found. If the ATP at Mayo Galké causeway had been only 100 head-larvae, then the village Mayo Galké, 500 m distant from the river, would have been exposed to an average ATP of only 50 and the ATP would have been even lower further away from the river.

It is interesting that Wada (1982), in his mathematical approach to the epidemiology of onchocerciasis in Guatemala, calculated a critical ATP of 54 larvae (in head, thorax and abdomen of the flies) for the threshold level of an ABR of 7665. Corresponding threshold levels of the ABR for a non-zero endemic level of onchocerciasis in Africa were much lower, being 288 bites per man per year of calculation for a highly anthropophilic fly population in the OCP area, and 720 for the area of Tcholliré (Dietz, 1982, who based his calculations partially on data from the present study).

Most data on the transmission of onchocerciasis pertain to the intensity of transmission during a very limited period of time, compared to the life span of the parasite. Hydrological data, dating back to 1950, suggest that the average waterflow was lower during the early 1970s and has increased since, but the marked reduction in the waterflow during the dry season (Renz and Wenk, 1987) might indicate a reduced breeding possibility during this period. In

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the same way, changes in human behaviour and clothing as well as the use of insecticides in the

cottonfields around the villages, and the construction of primary schools and of deep wells near the villages, are factors likely to have reduced both fly populations and man–fly contact. Further longitudinal investigations should provide evidence on the evolution of the endemicity of onchocerciasis in this non-controlled area.

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