Journal of the American Mosquito Control Association, 15(1):15–23, 1999
Copyright © 1999 by the American Mosquito Control Association, Inc.

MALARIA TRANSMISSION IN A REGION OF SAVANNA–FOREST MOSAIC, HAUT-OGOOUÉ, GABON

N. ELISSA,[1] S. KARCH,[2] PH. BUREAU,[3] B. OLLOMO,[1] M. LAWOKO,[1] P. YANGARI,[1]
B. EBANG[1] AND A. J. GEORGES[1]

ABSTRACT. During the 2 years 1993 to 1995, an entomological survey was carried out in the savanna–forest area of Franceville, Gabon, investigating malaria transmission in one suburban district of Franceville (Akou) and in one rural village (Benguia). The biting rates of the *Anopheles* vectors were 10 times higher in the rural zone compared to the suburban zone. *Anopheles funestus* Giles was the predominant species in both zones followed by *Anopheles gambiae* s.l. Giles. The densities of *Anopheles nili* Theobald and *Anopheles moucheti* Evans were very low. In the suburban zone, transmission was maintained throughout the year by *An. funestus* and *An. gambiae* s.l., whereas in rural zones the secondary vectors *An. nili* and *An. moucheti* were also involved in transmission. Humans in a suburban setting received one infective bite per person every 4 days, whereas in the rural area the infective biting rate was 4 times higher. Considering each vector, the observed entomological inoculation rates (EIRs) were one infective bite per person every 6 and 17 days for *An. funestus* and *An. gambiae* s.l., respectively, at Akou. At Benguia, the EIRs were one infective bite per person every 2, 3, 6, and 19 days for the 4 *An. funestus, An. gambiae* s.l., *An. nili,* and *An. moucheti,* respectively. The predominance of *An. funestus* over *An. gambiae* s.l. and its high EIR make it the most important malaria vector in this region of Haut-Ogooué.

KEY WORDS Malaria vectors, *Anopheles, Anopheles funestus, Anopheles gambiae* s.l., biting rate, entomological inoculation rate, Gabon

INTRODUCTION

Malaria is the major parasitic disease in the world. Fifty percent of the world population, particularly in Africa (90%), lives in zones with malaria (Gentilini et al. 1993, WHO 1994). On the African continent morbidity and mortality are very difficult to estimate accurately because of fragmentary records and reporting (WHO 1994). The raw data do not take into account the heterogeneity of the distribution of malaria in relation to vectorial factors (e.g., the impact of urbanization), parasites (e.g., chemoresistance), or human activity (e.g., rural migration, access to antimalarial medication, irrigation projects), which may modify the incidence of malaria. These data reflect even less host–vector–parasite dynamics. The recent appreciation of such interrelationships explains the renewed interest in epidemiologic studies (Coosemans and Mouchet 1990, Mouchet et al. 1993). Curiously, few entomological studies have been carried out in Gabon (Gaillard 1931a, 1931b, 1932; Nguy Van Duong et al. 1962; Mouchet 1971; Lancien et al. 1975; Service 1976; Service et al. 1977) in comparison with other areas of Central and West Africa.

The aim of the present study was to evaluate the intensity and rhythm of malaria transmission in 2 areas, a suburban and a rural zone, of southeastern Gabon. We illustrate some essential aspects of local malaria transmission by identifying the *Anopheles* vector species implicated and by evaluating the frequency of transmission in relation to the climatic conditions of the region.

STUDY AREAS

The province of Haut-Ogooué is located between 0°25′N and 2°S, in southeastern Gabon and is delimited to the east and south by the Congolese border (Fig. 1a). The Franceville basin is a large region of undulating hills with an average altitude of 400 m. A mosaic landscape is created by narrow gallery forests following the watercourses, although savanna remains the predominant vegetation type. Franceville (population ca. 30,000) nestles in a curve of the River M'passa, which is one of the main tributaries of the River Ogooué. The city is formed of numerous small communities, which are separated by the hilly relief but linked by a network of tracts (Fig. 1b). Preliminary night catches on human bait were made in different zones of Franceville and the 2 study sites were then selected. The first site is one of the peripheral northern suburban districts within Franceville (Akou); the second is a traditional village (Benguia) (Fig. 1b).

Akou (population ca. 1,000) is located on the highest hill of Franceville with a slope of about 20%. The only road serving Akou is bordered by 2 streams that drain into swampy areas. Benguia (population ca. 180) is a traditional Pygmy village situated in a rural zone 15 km to the west of Franceville. It is bordered on one side by a road and on the other by a river with its gallery forest. The construction of a local road has interfered with the local drainage pattern and led to the creation of a semipermanent pond.

[1] International Center for Medical Research, CIRMF BP 769, Franceville, Gabon.
[2] SIAAP, 14 allée François ler, Aulnay s/s bois, France.
[3] Service des Grandes Endémies, Franceville, Gabon.

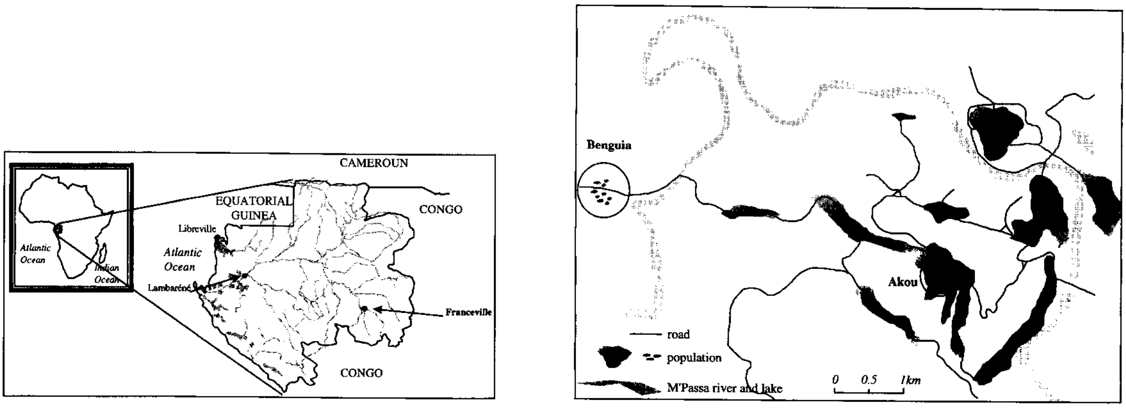

Fig. 1. a. Gabon. b. Study sites in Franceville.

CLIMATE

The climate is of Guinean–equatorial type with 4 seasons. The short dry season (January–February) corresponds to a decline in precipitation in comparison to the strong rains of the long rainy season (March–June). Between June and October there is the long dry season, in which there is insignificant precipitation followed by the short rainy season (October–December). Rainfall for the past 5 years averaged 2,200 mm per year. The annual mean daily temperature was 25.2°C. Monthly variation was low, ranging from 26.2°C (August 1994) to 23.3°C (July 1995) (Fig. 2).

MATERIALS AND METHODS

To estimate human-biting rates, mosquitoes were collected using all-night, voluntary human-bait catches indoors and outdoors at 3 different places in each of the 2 study zones. The night was divided into 2 6-hr periods (1800–0000 h and 0000–0600 h). The catchers, with the aid of torches, collected the mosquitoes that landed on their naked legs and placed them at hourly intervals inside haemolysis tubes. These tubes were then put inside hour-bags. At Akou, 2 night catches were carried out every month from July 1993 to July 1995 except for May, November, and December 1994, when only one catch was possible each month, and January 1995,

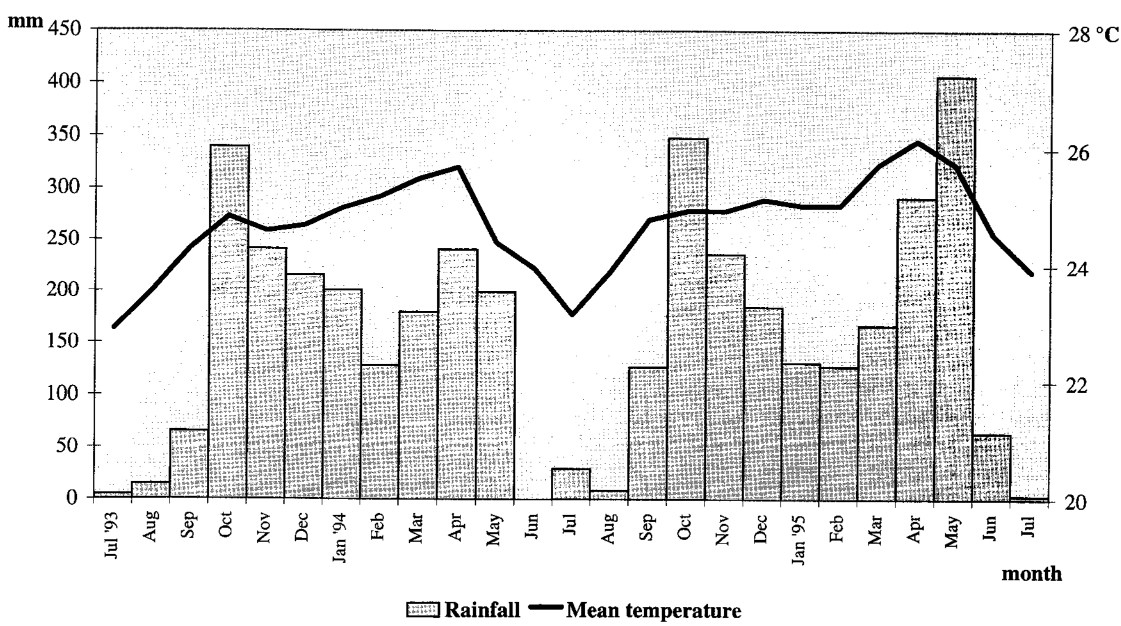

Fig. 2. Rainfall and mean temperature from July 1993 to July 1995 in the Franceville region.

Table 1. Culicid species captured at Akou and Benguia.

Species[1]	Akou (45 night catches, 116 men nights)			Benguia (40 night catches, 116 men nights)		
	No. females	% of capture	% of *Anopheles*	No. females	% of capture	% of *Anopheles*
An. funestus Giles, 1900	463	16.84	59.13	3,641	44.81	45.96
An. gambiae s.l. Giles, 1902	265	9.64	33.84	2,253	27.73	28.44
An. nili Theobald, 1904	35	1.27	4.47	1,233	15.17	15.56
An. moucheti Evans, 1925	7	0.25	0.89	592	7.29	7.47
An. paludis Theobald, 1900	2	0.07	0.26	90	1.11	1.14
An. coustani Laveran, 1900	6	0.22	0.77	36	0.44	0.45
An. ziemanni Grünberg, 1902	5	0.18	0.64	16	0.20	0.20
An. rufipes Gough, 1910	0	0	0	4	0.05	0.05
An. hancocki Edwards, 1929				38	0.47	0.48
An. squamosus Theobald, 1901				19	0.23	0.24
Culex sp.	1,265	46.02		10	0.12	
Aedes sp.	674	24.52				
Mansonia sp.	27	0.98		194	2.39	
Total capture	2,749			8,126		
Total *Anopheles*	783	28.48		7,922	97.49	

[1] *An., Anopheles.*

when none was performed. At Benguia, from August 1993 to July 1995, two night catches were carried out every month except for August to October 1993, May 1994, and November 1994 to January 1995, when only one catch was possible each month.

Mosquito identification (Gillies and De Meillon 1968, Gillies and Coetzee 1987) and female anopheline dissections were performed in the laboratory the following morning. Sporozoite infection was recognized by the presence of sporozoites in freshly dissected salivary glands. The entomological inoculation rate (EIR), obtained by multiplying the human-biting rate (*ma*) by the sporozoite index (*s*), was expressed as the number of infected bites per man per night (b/m/n) and was calculated for the whole study period, as well as for each of the rainy and dry seasons.

RESULTS

Mosquito fauna

Eighty-five night catches on voluntary human baits were performed at Akou and Benguia from July and August 1993, respectively, to July 1995. At Akou, the catches resulted in the capture of 2,749 female mosquitoes representing 28.48% *Anopheles* spp., of which 7 species were identified, 46.02% *Culex* spp., 24.52% *Aedes* spp., and 0.98% *Mansonia* spp. (Table 1). At Benguia, 8,126 female mosquitoes were collected representing 97.49% *Anopheles* spp., of which 10 species were found, 0.12% *Culex* spp., and 2.39% *Mansonia* spp. (Table 1). The average biting rate for all Culicidae was 23.69 b/m/n at Akou and 70.05 b/m/n at Benguia.

Anopheline population biology

Biting rates: At Akou, the mean biting rate of *Anopheles* vectors (*Anopheles funestus* Giles, *Anopheles gambiae* s.l. Giles, *Anopheles nili* Theobald, and *Anopheles moucheti* Evans) was 6.64 b/m/n (Table 2) with a maximum of 17.25 b/m/n (Fig. 3a). At Benguia, the mean rate was 10 times higher (Table 2) and varied from 13.33 to 196.70 b/m/n (Fig. 3b). *Anopheles funestus* was always the predominant biting species, followed by *An. gambiae* s.l. The populations of *An. nili* and *An. moucheti* were less aggressive. Biting rates for all species were always higher in the rural zone than in the suburban setting.

Fluctuation of the anopheline populations: The total aggressivity of the 4 vectors cited previously was similar during the dry and the rainy seasons in both zones (Table 2). Comparing biting rates between the different seasons, *An. funestus* was 2-fold and 1.5-fold more aggressive in the dry season than in the rainy season at Akou and Benguia, respectively; in contrast, *An. gambiae* s.l. was 1.3-fold and 2.2-fold less aggressive. At Benguia, *An. nili* and *An. moucheti* aggressivity rates were approximately equal during the 2 seasons.

Sporozoite index

At Akou, 633 *Anopheles* (353 *An. funestus,* 238 *An. gambiae* s.l., 28 *An. nili,* 6 *An. moucheti,* and 8 from 3 other species) were dissected; 3 anopheline species had sporozoites, giving a mean sporozoite index of 3.36% for the 4 main vectorial species (Table 2). At Benguia, 5,984 anopheline specimens (2,998 *An. funestus,* 1,643 *An. gambiae* s.l.,

Table 2. *Anopheles* vectors and entomological parameters at Akou and Benguia.[1]

	Rainy season				Dry season				Total			
	No. dissected mosquitoes	*ma*	*s* (%)	EIR	No. dissected mosquitoes	*ma*	*s* (%)	EIR	No. dissected mosquitoes	*ma*	*s* (%)	EIR
Akou	25 night catches, 65 men nights				20 night catches, 51 men nights				45 night catches, 116 men nights			
An. funestus	134	2.74	2.99	0.082	219	5.59	4.57	0.255	353	3.99	3.97	0.158
An. gambiae s.l.	158	2.57	1.27	0.033	80	1.92	5.00	0.096	238	2.28	2.52	0.058
An. nili	19	0.29	0	0	9	0.31	11.11	0.035	28	0.30	3.57	0.011
An. moucheti	2	0.05	0	0	4	0.08	0	0	6	0.06	0	0
Total	313	5.65	1.92	0.108	312	7.90	4.81	0.380	625	6.64	3.36	0.223
Benguia	23 night catches, 68 men nights				17 night catches, 48 men nights				40 night catches, 116 men nights			
An. funestus	1,324	26.04	1.41	0.374	1,674	38.96	1.37	0.535	2,998	31.39	1.40	0.440
An. gambiae s.l.	1,229	25.13	1.38	0.348	414	11.33	2.90	0.329	1,643	19.42	1.77	0.343
An. nili	488	10.99	1.23	0.135	345	10.13	2.03	0.205	833	10.63	1.56	0.166
An. moucheti	131	4.87	0	0	244	5.44	1.64	0.089	375	5.10	1.07	0.054
Total	3,172	67.03	1.32	0.888	2,677	65.85	1.72	1.132	5,849	66.54	1.50	1.001

[1] *ma*, human-biting rate; *s*, sporozoite index; EIR, entomological inoculation rate; *An. Anopheles*.

833 *An. nili,* 375 *An. moucheti,* and 135 from the 6 other species) were examined and sporozoites were found only in the 4 main vectorial species, giving a mean sporozoite index of 1.50% (Table 2).

Entomological inoculation rates

As shown in Fig. 4b, transmission in the rural zone was maintained throughout the study period (with the exception of May 1995) with an average EIR of 1.001 infective bite per man per night (ib/m/n) (Table 2) reaching 2.697 ib/m/n in October 1994 and falling to 0.177 ib/m/n in April 1994; from August 1993 to July 1995, each person received an estimated 733 infective bites, corresponding to 366.5 ib/m/year. In the suburban zone (Fig. 4a), transmission was less intense with an average inoculation rate of 0.223 ib/m/n (Table 2) and a maximum of 1.128 ib/m/n in September 1994; from July 1993 to July 1995, each person from Akou received an estimated 163.5 infective bites, corresponding to 81.8 ib/m/year.

The EIR values of the rural vectors were always higher than those recorded for the suburban vectors (Table 2): in the suburban zone, one person received one infective bite every 6 days from *An. funestus,* one infective bite every 17 days from *An. gambiae* s.l., and one infective bite every 91 days from *An. nili,* whereas in the rural zone each individual received on average one infective bite every 2 days from *An. funestus,* one infective bite every 3 days from *An. gambiae* s.l., one infective bite every 6 days from *An. nili,* and one infective bite every 19 days from *An. moucheti.*

Seasonal variations in EIR: During the rainy season, the EIR for Akou was approximately 9-fold lower than in Benguia (Table 2). During the 14-month survey, each person was submitted to a total of 47 infected bites in the suburban zone, whereas in the rural zone, we estimated a total of 381 infected bites per person. During the dry season, the EIR for Akou was only one third of that for Benguia (Table 2). In the suburban zone, each person was exposed to a potential 127 infective bites during the 11 months of the dry season; whereas in the rural zone, we calculated a total of 343 infective bites per person for the 10 months studied.

In the rural zone, during the dry season, malaria transmission was due to *An. funestus, An. gambiae* s.l., *An. nili,* and *An. moucheti,* whereas *An. moucheti* was not implicated in transmission during the rainy season. In the suburban zone, the first 3 vectors were implicated in the transmission, whereas only the first 2 were involved during the rainy season.

Daily survival rate

The average parity rate of the vectors (p) was calculated according to the Davidson formula:

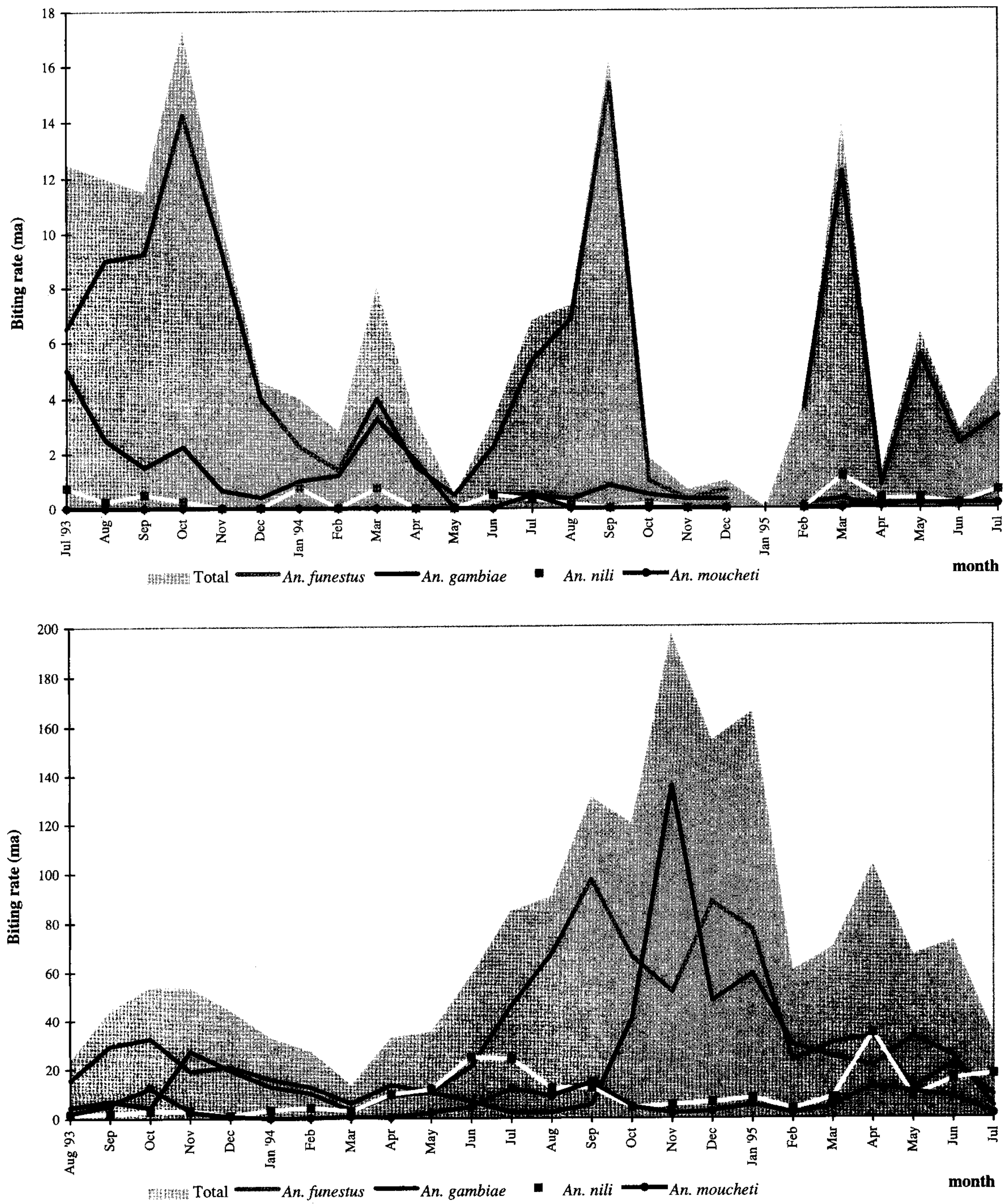

Fig. 3. Biting rates of *Anopheles* vectors at (a) Akou and (b) Benguia.

$$p = \sqrt[d]{\frac{P}{P + N}},$$

where d is the duration of the gonotrophic cycle and P and N are the proportions of parous and nulliparous females. The duration of the gonotrophic cycle varies between 2 and 3 days, according to local climatic conditions. Taking into account the results of Brengues and Coz (1973) from West Africa, Trape (1987), and specifically Carnevale (1979) from the Popular Republic of Congo, we have assigned the value d = 2.5 days.

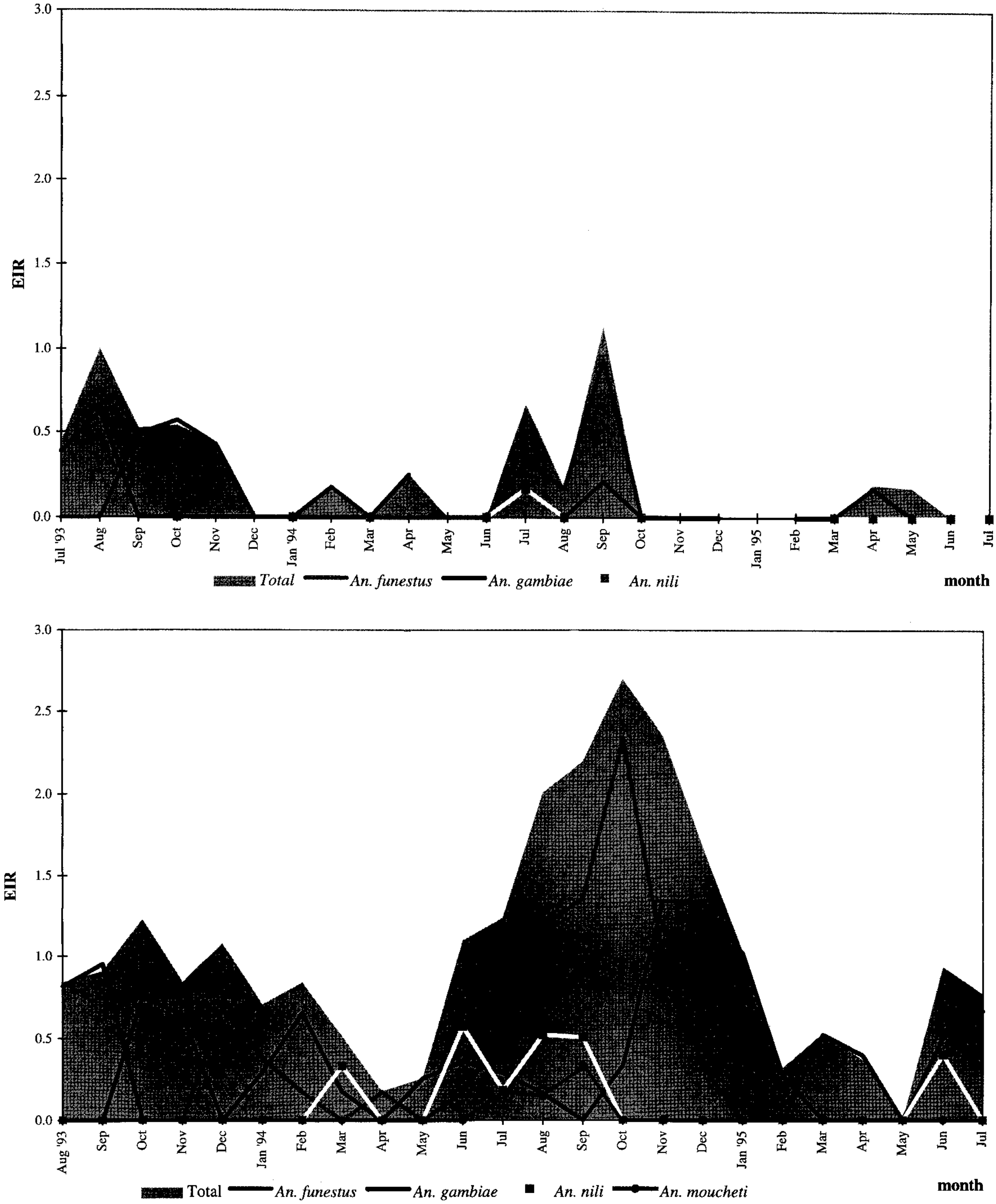

Fig. 4. Entomological inoculation rates of *Anopheles* vectors at (a) Akou and (b) Benguia.

In the suburban zone, the average parity rate of *An. funestus* is about 93% (n = 353), that is, a daily survival rate of p = 0.97; for *An. gambiae* s.l. it is 90% (n = 238) and p = 0.96; and for *An. nili* the parity rate is 95% (n = 28) with p = 0.98. In the rural zone, the average parity rate of *An. funestus* is about 87% (n = 2,998), that is, a daily survival rate of p = 0.95; for *An. gambiae* s.l. it is 84% (n = 1,643) and p = 0.93; for *An. nili* the parity rate is 77% (n = 833) with p = 0.90; and for *An. moucheti*, it is 72% (n = 375) and p = 0.88.

Expectation of infective life and vectorial efficiency

The vectorial capacity (*VC*) represents the expected quantity of new infections induced per day from a single nonimmune infective case. Using the density rate, the anthropophilic index, and the longevity of each vector, *VC* was calculated according to Macdonald's formula (1952):

$$VC = ma^2 \frac{p^n}{-\log_e p}$$

where $p^n/-\log_e p$ is the total life expectancy after survival through *n* days, *ma* is the number of people bitten per day, *a* is the average number of human blood meals per mosquito per day (= anthropophilic index/duration of the gonotrophic cycle), *p* is the daily survival rate, and *n* is the length in days of the *Plasmodium* sporogonic cycle.

In this study all the mosquitoes captured were on human bait. However, a few sheep were present in the capture areas, which could influence the vectorial trophic activity. This potential deviation has been estimated at 2%. Hence, the anthropophilic index can be considered as 98%. The duration of the gonotrophic cycle was calculated as 2.5 days. Therefore, $a = 0.392$. At 25°C, the length of the sporogonic cycle (*x*) is 13 days for *Plasmodium falciparum* and 15 days for *Plasmodium malariae* (Molineaux and Gramaccia 1980). The vectorial capacity of each vector species is higher in the rural zone than the suburban zone. With regard to *P. falciparum,* the vectorial capacity of *An. funestus* is 36.7 at Akou and 113.5 at Benguia; that of *An. gambiae* s.l. is 11.8 at Akou and 49.5 at Benguia. The vectorial capacity of *An. nili* is 4.1 at Akou and 9.2 at Benguia; that of *An. moucheti* is 2.7 at Benguia, whereas *An. moucheti* is not a vector at Akou. With regard to *P. malariae,* the vectorial capacity for *An. funestus* is 34.6 at Akou and 101.4 at Benguia, for *An. gambiae* s.l. it is 10.8 at Akou and 43 at Benguia, for *An. nili* it is 4 at Akou and 7.5 at Benguia, and for *An. moucheti* it is 2.1 at Benguia. These results give the optimal vectorial potential for all rural *Anopheles,* of which *An. funestus* has the highest vectorial capacity in rural as well as suburban zones.

DISCUSSION AND CONCLUSION

This survey carried out in the Franceville region of Gabon allowed us to define some aspects of malaria transmission, particularly the variations observed between a suburban and rural zone, including seasonal effects. In the suburban zone, the anopheline fauna was composed of 7 species representing 28.48% of the captured Culicidae. In the rural zone, 10 species of anophelines represented 97.49% of the captures. The aggressivity rate is 10 times higher in the rural zone than in the suburban zone: *An. funestus* was always the predominant species of the anopheline fauna caught on humans during the night catches, followed by *An. gambiae* s.l. The population of *An. funestus* and *An. gambiae* s.l. fluctuated with seasonal rainfall. These important variations may be accounted for by differences in the terrain and the bioecology of the vectors. *Anopheles funestus* has the ability to adapt to a wide range of habitats (Gillies and De Meillon 1968; Gillies and Coetzee 1987), and the presence of large numbers of this species may be due to the existence of riverine gallery forest, which passes through the rural zone, and a tributary of the River M'passa, which borders the suburban zone. *Anopheles gambiae* s.l., which develops in temporary puddles, was reduced in numbers because of the disappearance of its breeding sites during both the dry (decrease in the number of small water collections) and the rainy seasons (strong rains sweep aside the breeding sites). The presence of large numbers of the secondary vectors, *An. moucheti* and *An. nili,* in the rural zone may also be due to the presence of the river bordered by a gallery forest.

The mean values of the sporozoite index found at both sites are similar to those mentioned in the literature for Central Africa (Adam 1956, Trape et al. 1987, Fondjo et al. 1992, Karch et al. 1992). The mean sporozoite index for the suburban zone was 2.2 times higher than that for the rural zone. Nevertheless, transmission was 4.5 times less intense than in the rural zone with more frequent interruptions, particularly at the end of the rainy season. This overall reduction in transmission at Akou may be related to the smaller number of *An. gambiae* s.l.

At both sites, malaria transmission was maintained essentially by the 2 species *An. funestus* and *An. gambiae* s.l. The latter is the more classically recognized major vector for malaria in Central Africa, but in this instance, it takes a secondary role to *An. funestus.* This species is often presented only as a secondary vector in other countries, having no role at Kinshasa in Karch et al. (1992) and Yaoundé in Fondjo et al. (1992), and a very secondary role at Brazzaville in Trape et al. (1987). In the present study, *An. funestus* plays the principal role in transmission with an EIR 1.3 or 3 times higher than that of *An. gambiae* s.l. in the rural or the suburban zone, respectively. *Anopheles nili,* usually described as a main local vector (Hamon and Mouchet 1961, Carnevale et al. 1992) or as a temporary vector (Gillies and Coetzee 1987), was considered in the rural zone as a secondary vector with *An. moucheti,* whereas in the suburban zone these 2 species play a very minor role. Seasonal factors did not influence the importance of *An. funestus* as the major vector in this area.

This work presents the first data on malaria vectors in Gabon. Only one previous study gave an indication of the malarial vectors in Lambaréné

(Fig. 1a) (Service 1976). The most recent studies concern the epidemiology of malaria in Gabon (Richard-Lenoble et al. 1986, 1987), chloroquine resistance of *P. falciparum* (Brandicourt et al. 1986, Richard-Lenoble et al. 1989), and the development of antimalarial antibodies (Richard-Lenoble et al. 1989). This study defines the vector population involved in malaria transmission as well as the regional and seasonal variations in transmission existing between a suburban and a rural zone. Important differences observed over very small distances confirm the high heterogeneity of vector distribution from one site to another and characterize the entomological situation for each malaria investigation site.

ACKNOWLEDGMENTS

Centre International de Recherches Médicales de Franceville is supported by the Gabonese Government, Elf Gabon, and the Coopération Française. We are grateful for the hospitality and generous collaboration of the populations of Akou and Benguia. We thank Jean Wickings, Tim Williams, Philippe Deloron, and 2 anonymous reviewers for examining the manuscript.

REFERENCES CITED

Adam, J. P. 1956. Note faunistique et biologique sur les anophèles de la région de Yaoundé et la transmission du paludisme en zone forestière du Sud-Cameroun. Bull. Soc. Pathol. Exot. 49:210–220.

Brandicourt, O., P. Druilhe, P. Brasseur, P. Turk, B. Diquet, A. Datry, M. Danis and M. Gentilini. 1986. High level of chloroquine resistance in seven *Plasmodium falciparum malariae* cases from the Congo and Gabon. Trans. R. Soc. Trop. Med. Hyg. 80:906–907.

Bregues, J. and J. Coz. 1973. Quelques aspects fondamentaux de la biologie d'*Anopheles gambiae* Giles (sp. A) et d'*Anopheles funestus* Giles, en zone de savane humide d'Afrique de l'Quest. Cah. ORSTOM sér. Ent. méd. et parasitol. 11:107–126.

Carnevale, P. 1979. Le paludisme dans un village des environs de Brazzaville, République Populaire du Congo. Thèse de Doctorat ès Sciences. l'Université Paris–Sud, Paris, France.

Carnevale, P., G. Le Goff, J. C. Toto and V. Robert. 1992. *Anopheles nili* as the main vector of human malaria in villages of southern Cameroon. Med. Vet. Entomol. 6: 135–138.

Coosemans, M. and J. Mouchet. 1990. Consequences of rural development on vectors and their control. Bull. Soc. Belge Med. Trop. 70:5–23.

Fondjo, E., V. Robert, G. Le Goff, J. C. Toto and P. Carnevale. 1992. Le paludisme urbain à Yaoundé (Cameroun). Etude entomologique dans deux quartiers peu kurbanisés. Bull. Soc. Pathol. Exot. 85:57–63.

Gaillard, H. 1931a. Culicides du Gabon. I. Culicines, avec la description d'une espèce et de deux variétés nouvelles. Ann. Parasitol. Hum. Comp. 9:225–232.

Gaillard, H. 1931b. Culicides du Gabon. II. Culicines (suite). Remarques sur la biologie des *Mansonoides* et d'*Aedes* (*Stegomyia*) *argentus* Poiret. Ann. Parasitol. Hum. Comp. 9:514–529.

Gaillard, H. 1932. Culicides du Gabon. III. Anophélines. Ann. Parasitol. Hum. Comp. 10:85–95.

Gentilini, M., E. Caumes, M. Danis, J. Mouchet, B. Duflot, B. Lagardère, D. Richard-Lenoble and G. Brucker. 1993. Médecine Tropicale. Édition Médecine Sciences. Flammarion, Paris, France.

Gillies, M. T. and M. Coetzee. 1987. A supplement to the anophelinae of Africa south of the Sahara. Publ. S. Afr. Inst. Med. Res. 55:1–143.

Gillies, M. T. and B. De Meillon. 1968. The anophelinae of Africa south of the Sahara (Ethiopian zoogeographical region). Publ. S. Afr. Inst. Med. Res. 54:1–343.

Hamon, J. and J. Mouchet. 1961. Les vecteurs secondaieres du paludisme humain en Afrique. Med. Trop. 21: 643–660.

Karch, S., N. Azidi, Z. M. Manzambi and J. J. Salaun. 1992. La faune anophélienne et la transmission du paludisme humain à Kinshasa (Zaire). Bull. Soc. Pathol. Exot. 85:304–309.

Lancien, J., P. Carnevale and M. Bosseno. 1975. Répartition des vecteurs potentiels de fièvre jaune en République Gabonaise. Document du Centre ORSTOM de Brazzaville, EMP/JL/172/75 (unpublished report).

Macdonald, G. 1952. The analysis of the sporozoite rate. Trop. Dis. Bull. 49:569–586.

Molineaux, L. and G. Gramaccia. 1980. The Garki project. Research on the epidemiology and control of malaria in the sudan savanna of West Africa. WHO/OMS, Geneva, Switzerland.

Mouchet, J. 1971. Surveys of potential yellow fever vectors in Gabon and Tchad. WHO/VBC/71.279 (Unpublished report).

Mouchet, J., P. Carnevale, M. Coosemans, D. Fontenille, C. Ravaonjanahary, A. Richard and V. Robert. 1993. Typologie du paludisme en Afrique. Cah. Santé 3:220–238.

Nguy, V. D., J. N. Brady and A. I. Baggott. 1962. République du Gabon. Rapport Entomologique–Biologie (1960–1961). Mimeographed report of the Organisation Mondiale de la Santé, No. S. 779 (62). OMS. Geneva, Switzerland.

Richard-Lenoble, D., F. Klotz, M. Kombila, M. Martz, J. L. Reges and M. Fromantin. 1989. Enquête bioclinique chez des sujets européens non immuns en court séjour et attitude prophylactique. Bull. Soc. Pathol. Exot. 82: 359–367.

Richard-Lenoble, D., M. Kombila, J. Chandenier, E. Engohan, M. Gannier and C. Dubourg. 1986. Le paludisme au Gabon. 1. Etude de 500 enfants fébriles de Libreville. Bull. Soc. Pathol. Exot. 79:284–287.

Richard-Lenoble, D., M. Kombila, J. Chandenier, F. Gay, X. Billiault, C. Nguiri, M. Martz, F. Boyer and M. Bauzou. 1987. Le paludisme au Gabon. 2. Evaluation des prévalences parasitaires qualitatives et quantitatives sur l'ensemble du pays en milieu scolaire et préscolaire. Bull. Soc. Pathol. Exot. 80:532–542.

Service, M. W. 1976. Contribution to the knowledge of the mosquitoes (Diptera: Culicidae) of Gabon. Cah. ORSTOM sér. Ent. méd. et parasitol. 14:259–263.

Service, M. W., S. J. S. Martin and J. F. Invest. 1977. *Anopheles moucheti* Evans as a malaria vector in Gabon. Cah. Sante ORSTOM sér. Ent. méd. et parasitol. 15:263–264.

Trape, J. F. 1987. Malaria and urbanization in Central Africa: the example of Brazzaville. Part I: description of the town and review of previous surveys. Trans. R. Soc. Trop. Med. Hyg. 81:1–9.

Trape, J. F., M. C. Quinet, S. Nzingoula, P. Senga, F. Tcicelle, B. Carme, D. Candito, H. Myanda and A. Zoulani. 1987. Malaria and urbanization in Central Africa: the example of Brazzaville. V. Pernicious attacks and mortality. Trans. R. Soc. Trop. Med. Hyg. 81(Suppl. 2): 34–42.

World Health Organization (WHO). 1994. Weekly epidemiological records. 69:309–316.