Urban malaria in the Brazilian Western Amazon Region I. High prevalence of asymptomatic carriers in an urban riverside district is associated with a high level of clinical malaria

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Cross sectional studies on malaria prevalence was performed in 2001, 2002, and 2004 in Vila Candelária, an urban riverside area of Porto Velho, Rondônia, in the Brazilian Western Amazon, followed by longitudinal surveys on malaria incidence. Vila Candelária is a working class district, provided with electricity, water supply, and basic sanitation. Previous preliminary surveys indicated high malaria incidence in this community. At the end of year 2000 regular diagnostic and treatment measures for malaria were introduced, with active search of febrile cases among residents. Despite of both rapid treatment of cases and relative good sanitary and housing conditions, the malaria incidence persisted at high levels during the following years with an annual parasite index of 150 to 300/1000 inhabitants. Parasite surveys in 2001, 2002, and 2004 achieved through microscopy and polymerase chain reaction to diagnose malaria showed a constant high prevalence of asymptomatic carriers for both Plasmodium falciparum *and* P. vivax *parasites. It was concluded that asymptomatic carriers represent an important reservoirs of parasites and that the carriers might contribute to maintaining the high level of transmission. Comparing our findings to similar geo-demographic situations found in other important urban communities of the Brazilian Amazon, we propose that asymptomatic carriers could explain malaria's outbreaks like the one recently observed in Manaus.*

Key words: malaria - asymptomatic carrier - urban malaria - Brazilian Amazon

The opening of roads and the establishment of agricultural and mining settlements in the Western Amazon Region of Brazil in the last decades of the XX century promoted an important migration of people from other areas of Brazil. In the state of Rondônia the population increased from 110,000 in 1970 to 1,200,000 in 1990. Migrants were essentially coming from Southern and Northeast areas of the country, where malaria had been previously eradicated. This was followed by an increase in malaria outbreaks and recorded cases increased from less than 10,000 to almost 300,000 (Ministério da Saúde 2002). This explosion in malaria cases was associated with the uncontrolled establishment of rural agricultural and mining settlements in the rain forest known as "frontier malaria" (Sawyer 1986), characterized by an high annual parasite index (API) with values of 1000 or more,

with higher prevalence of *Plasmodium falciparum* than *P. vivax* infections and with a risk group represented by male adults who are in close contact with the rain forest due to their professional activities.

The introduction of control measures by the Federal Public Health services, with establishment of ambulatory units for diagnosis and treatment, associated with vector control measures progressively reduced incidence of malaria to the level of 50,000 cases a year from 1996 onwards. However, the introduced control measures did not reduce the level of residual malaria. Localized outbreaks in new settlements have been recorded in the last years (Ministério da Saúde 2004) indicating the fragility of the unstable situation, and the need for new tools and effective methods for residual malaria control.

Previous studies by our team have defined two main profiles for the residual malaria epidemiology persisting in Rondônia. A first model, found in dry land agroindustrial settlements and urban communities in peripheral areas is characterized by an hypo-endemic profile with prevalence of *P. vivax* over *P. falciparum* infections and the presence of epidemic outbreaks starting at the end of the rainy season and extending throughout the dry season (Camargo et al. 1994, Camargo 1998, Gil et al. 2003). A second model was seen in isolated stable native populations in rural riverside areas characterized by hypo- and meso-endemic profiles, with outbreaks following the peak of the rainy season (Camargo 1998, Alves et al. 2002). In the first model, asymptomatic malaria infections are rare, or absent as previously ob-

served by Prata et al. (1988) and the population group at risk, similar to that of "frontier malaria", consists of male adults who due to their professional activities are more exposed to being bitten during dusk, when the *Anopheles darlingi* vector is more active (Gil et al. 2003). In the rural riverside situation, the risk group consists of children and young adolescents following a profile similar to that observed in meso and hiperendemic areas of Africa (Trape et al. 1993, 1994, Alves et al. 2002, Alves 2003, Gil et al. 2003). In parallel, with the higher malaria transmission rates and sedentary behavior of the people living in riverside areas, the prevalence of asymptomatic infections of *P. vivax* and *P. falciparum* malaria was observed in 20 to 65% of the local populations (Camargo 1998, Alves et al. 2002, Alves 2003).

Asymptomatic malaria infections occurring in other areas of the Amazon Region are also frequent and have been recently reviewed by Coura et al. (2006) that claim for the necessity of studies to evaluate their epidemiological importance for maintenance of malaria transmission.

The Brazilian Ministry of Health reports on urban malaria in areas of Amazon include important cities, state capitals such as Manaus, Belém, Porto Velho, Rio Branco, and Macapá (Ministério da Saúde 2002). Urban malaria eradication is, therefore, proposed as a Public Health priority. However, the epidemiologic profile of the disease in urban areas has been poorly investigated. The present study analyzes the situation of urban malaria in the riverside areas of Porto Velho, the capital of the state of Rondônia. The results show a high incidence of vivax and falciparum malaria, associated with a high prevalence of asymptomatic malaria infections among stable urban residents, mimicking previously observed situations in rural riverside areas.

MATERIALS AND METHODS

Study area and population - The study was developed in the urban neighborhood of Vila Candelária (8º47'08" S, 63º55'04" W), situated at only 2 km from the area of central streets of Porto Velho, capital of the state of Rondônia, Brazil. The climate is typically tropical humid from the Amazon Region with a rainy season from October to April (around 2500 mm of rain precipitation) and a relatively dry season from May to September (500 mm or less of rain precipitation). The temperature is in the range from of 18 to 38ºC and the humidity, with the exception of short periods in the dry season, is higher than 80%. Vila Candelária, extending from the right bank of the Madeira River to more elevated areas, distant about 400 m from the riverbank. At the beginning of the XX century the neighborhood was the area of residence of the qualified personnel working on the construction of the Madeira Mamoré railroad. After interruption of the railroad traffic in the 1970s, ancient employees and/or their family descendents continued to occupy the original houses. A few constructions have been added and all the houses are provided with electricity, water supply, basic sanitation, and window protection against mosquitoes. The local resident population is relatively stable and belongs on average to the poor middle class. Most adult inhabitants work in nearby city center area and have cars, motorcycle, or bicycles for transportation. Residents of other Porto Velho neighborhoods frequently visit and circulate in Vila Candelária which has restaurants and small markets. Other Vila Candelária visitors also come to the riverbanks for fishing, especially on weekends.

Malariometric population surveys - Previous data from the National Health Foundation (Funasa) had indicated a high incidence of both vivax and falciparum malaria among inhabitants of the locality. The present study, extended from January 2001 to April 2004, consisted of a longitudinal survey of malaria incidence and four clinical-parasitological cross sectional analysis of the malaria prevalence performed in 2001, 2002, and 2004. During this period, all the inhabitants had free access to a clinic unit created for diagnosis and treatment of malaria. A health service agent performs regular searches of febrile cases in the locality and collects finger-prick blood samples for thick smears from patients with fever or other symptoms associated with malaria. A physician was present at the clinic two days a week and for the other days could be summoned by telephone from the Cepem headquarters in Porto Velho. The surveys were performed in April and October 2001, April 2002, and April 2004. Informed consent was obtained from all subjects who volunteered to participate and signed a written agreement approved by an Ethical Committee of Cepem. The cross-sectional studies consisted of a limited clinical and physical examination, preparation of two thick blood smears and collection of blood samples by venous puncture for serologic testing and performing polymerase chain reaction (PCR) analysis for identification of malaria parasites.

Microscopy and PCR analysis for malaria parasites: their search and identification - Thick blood smears were Giemsa stained. Each blood smear was examined for the presence of malaria parasites by experienced technicians screening at a minimum of 100 fields at 1000 x magnification (immersion optic). DNA was extracted from blood samples using the phenol-chloroform protocol (Schlichtherle et al. 2000). The nested PCR used was based on the 18S rRNA gene target and genus and species-specific primers proposed by Snounou et al. (1993) and Snounou (1996) were used with minor modifications, as previously described (Alves et al. 2002). Although all inhabitants of the Village were encouraged to participate in the cross-sectional study, participation varied from 40 to 70% of the population in the four surveys. A control group of 100 residents in the district of Triunfo, in the municipality of Candeias, 150 km from Porto Velho, was examined using the same protocol of clinical, parasitological, and PCR examinations. The Triunfo district is a typical agro-industrial settlement in the dry land areas of Rondônia where previous studies by our team have failed to identify asymptomatic malaria carriers by microscopy examination of blood thick smears (Camargo et al. 1994). This control group was chosen because its API value was 340 in 2002, equivalent to the one we observed in Vila Candelária (see Results).

Surveillance between surveys studies and asymptomatic definition - A trained health agent was in charge of surveillance of the locality with instructions on how to prepare finger-prick thick smear blood samples for malaria parasite identification in all cases of fever, or other potential malaria symptoms, such as muscular pain, malaise, or headache. Special attention was given to the follow up of subjects previously identified as parasite carriers at the time of each cross-sectional study. When no symptoms were observed during 60 days following the positive examination by microscopy, or PCR, the subject was considered asymptomatic, as identified in earlier studies (Alves et al. 2002, Alves 2003).

Only subjects presenting symptoms and positive by microscopy or PCR were submitted to malaria therapy, using the Ministério da Saúde (2002) protocols for *P. vivax* and *P. falciparum* infections.

RESULTS

Demographic analysis - A demographic survey performed in October 2001 estimated the population of Vila Candelária to be 270 inhabitants distributed among 52 families. Eighty six percent of the adult inhabitants (over 16 years old) had been living in the Amazon region for more than 15 years, or were born in the Rondônia and 62% had been living since then in Vila Candelária. The age distribution of the population was close to that of the whole state of Rondônia (IBGE 2000) and is as follows: 12.2% < 6 years of age; 9.6% 6-10 years; 10.7% 11-15 years; 57% 16-40 years; 20.4% > 40 years. The male/female sex ratio was 1.04. Before performing the parasite survey in April 2004 we performed a new demographic survey, in order to review changes in the local population and included an additional group of 32 people living in a peripheral area of Vila Candelária who had not participated in the three previous surveys. Consequently, the total number of inhabitants increased from 270 in 52 families to 323 in 61 families, but the age group distribution did not change significantly.

Prevalence of asymptomatic malaria infections in the surveys - The results of the surveys regarding the prevalence of asymptomatic malaria infections in Vila

Candelária are summarized in Table I. In the four surveys the number of individuals enrolled had been 187, 125, 125, and 223 respectively, corresponding to 69.2, 47.1, 47.1, and 69% of the total population. The lower numbers in the second and third surveys were essentially due to lower participation of male adults over 16 years of age who could not be reached due to their professional activities. The numbers in Table I represent true asymptomatic carriers that did not present malaria symptoms in the clinical development. The prevalence of asymptomatic carriers was greater than 10% of the participants in the four surveys. *P. vivax* and *P. falciparum* malaria parasites were found in approximately equal proportion. In the first survey in April 2001, in spite of a high prevalence of *P. falciparum* malaria parasites (over 15 cases) the exact number could not be established due to technical accidents. The control group represented by 100 residents of the Triunfo locality, with ages varying from 6 to 82 years, was examined and showed no malaria symptoms on the day of the blood collection (see Materials and Methods). All samples were negative excepting one from an adult female of 46 years of age, who had been living many years in different localities of Rondônia.

Age distribution of people with asymptomatic malaria infections - As shown in Table II asymptomatic infections were manly observed in adults over 16 years of age. Few cases of asymptomatic infections were detected in the age groups from 0 to 5 and 6 to 10 years of age. However, positive PCR reactions for *P. vivax* and *P. falciparum* malaria parasites were consistently observed in children bellow 5 years of age. Children with positive PCR reactions were followed closely in the following two months. If fever or other malaria symptoms (which happened in few cases) were detected, the malaria infection was treated. On two occasions *P. falciparum* parasites could be isolated by culturing blood samples of children with 2 and 3 years of age, respectively, and in a third case, microscopic examination showed *P. falciparum* parasites in a blood smear of a 3 year-old boy. Higher prevalence was found in adults between 16 and 40 years of age, in whom the frequency of asymp-

TABLE I

Asymptomatic malaria infections in Vila Candelária and Triunfo, Rondônia, Brazil

Locality/ infections	Date	Number examined [a] n (%)	*Pf* infection[b] n (%)	*Pv* infection[b] n (%)	Mix infection[b] n (%)	Total[b] n (%)
Vila Candelária	Apr 2001	187 (69.2)	(***)	20 (10.6)	7 (3.7)	> 20 (> 10.6)
	Sep 2001	125 (47.1)	9 (7.2)	13 (10.4)	2 (1.1)	24 (19.2)
	Apr 2002	125 (47.1)	8 (6.4)	9 (7.2)	2 (1.1)	19 (15.2)
	Apr 2004	223 (69.0)	15 (6.7)	15 (6.7)	3 (1.3)	33 (14.7)
Triunfo (d)	Apr 2004	100	1 (1.0)	0	0	1 (1.0)

a: percent calculated from the number of examined persons in relation to the total number of inhabitants in the locality; *b*: percent calculated from the number of examined persons in relation to the total number of inhabitants examined; *c*: the number of asymptomatic infections was higher than 15 but could not be precisely identified because of accidental tecnhical failures; *d*: the habitants of Triunfo examined (dry land controls) were randomly taken among residents of the line 3 of the agricultural assessment of Triunfo (see text). In last column, first line the total number is indicate as > 20 since falciparum asymptomatic cases were not compatibilized; *Pf*: *Plasmodium falciparum*; *Pv*: *P. vivax*.

TABLE II

Age distribution of asymptomatic malaria infections in Vila Candelária, Rondônia, Brazil

A-April 2001

Age group (years)	N-population positive n (%)[a]	N-sample N[b]	Pf positive n (%)[d]	Pv positive n (%)[c]	Mix positive n (%)[c]	Malaria n (%)[c]
0-5	33	22 (66.6)	...	1 (4.5)	0	...
6-10	26	16 (61.5)	...	0	0	...
11-15	29	22 (75.8)	...	1 (4.5)	0	...
16-40	127	90 (70.8)	...	13 (14.4)	5 (5.5)	...
>40	55	37 (67.2)	...	5 (13.5)	2 (5.4)	...
Total	270	187 (69.2)	...	20 (10.7)	7 (3.7)	...

B-September 2001

Age group (years)	N-population positive n (%)[a]	N-sample N[b]	Pf positive n (%)[d]	Pv positive n (%)[c]	Mix positive n (%)[c]	Malaria n (%)[c]
0-5	33	8 (24.2)	1 (12.5)	3 (37.5)	0	4 (50.0)
6-10	26	8 (30.8)	0	0	0	0
11-15	29	14 (48.3)	4 (28.6)	2 (14.3)	0	6 (42.9)
16-40	127	67 (52.8)	4 (6.0)	7 (10.4)	2 (3.0)	11 (16.4)
>40	55	26 (47.3)	1 (3.8)	2 (7.7)	0	3 (11.5)
Total	270	123 (45.6)	10 (8.1)	14 (11.4)	2 (1.6)	24 (19.5)

C-April 2002

Age group (years)	N-population positive n (%)[a]	N-sample N[b]	Pf positive n (%)[d]	Pv positive n (%)[c]	Mix positive n (%)[c]	Malaria n (%)[c]
0-5	33	7 (21.2)	0	0	0	0
6-10	26	8 (30.8)	0	0	0	0
11-15	29	19 (65.5)	1 (5.3)	0	0	1 (5.3)
16-40	127	61 (48.0)	3 (4.9)	9 (14.8)	2 (3.3)	12 (19.7)
>40	55	23 (41.8)	5 (21.7)	1 (4.3)	0	6 (26.1)
Total	270	118 (43.7)	9 (7.6)	10 (8.5)	2 (1.7)	19 (16.1)

a: number of persons of the age group living in the locality; b: number of examined persons of the age group and percentage in relation to the corresponding number living in the locality; c: number of examined or positive persons of the age group and percentage in relation to the corresponding number N-sample; d: data concerning *Plasmodium falciparum* (*Pf*) infections not presented (see text). Results of cross section in April 2001 show that frequency of asymptomatic infections are significantly high in adult age groups (16-40 and > 40 years of age) with a $c^2 = 9.2$ (p = 0.06); no statistic significant differences were observed in cross sections from September 2001 and April 2002), but samples of the adult age groups were not representative of the real population (see Table and text); *Pv*: *P. vivax*.

TABLE III

Age and sex distribution of symptomatic malaria cases in Vila Candelária, Rondônia, Brazil in 2001

Age group (years)	Population			Pf cases			Pv cases			Malaria cases			API in the age group
	M	F	T	M	F	T	M	F	T	M	F	T	
0-5	17	16	33	1	1	2	1	6	7	2	7	9	272
6-10	10	16	26	3	3	6	3	4	7	6	7	13	500
11-15	13	16	29	1	1	2	7	6	13	8	7	15	517
16-40	64	63	127	7	7	14	13	15	28	20	22	42	330
>40	28	27	55	1	1	2	0	5	5	1	6	7	127
Total	132	138	270	13	13	26	24	36	60	37	49	86	318

Pf: *Plasmodium falciparum*; *Pv*: *P. vivax*. API: Annual Parasite Index; M: male; F: female; T: total. Number of malaria cases in adult age groups are significantly lower in relation to children from 6 to 10 years of age and young adolescents with 11 to 15 years of age ($\chi^2 = 18.9$; p = 0.0008).

tomatic infection was between 14.3 and 19% of the samples examined (Table II). No significant differences in sex distribution were observed (data not shown). The lower prevalence in the second, third, and fourth cross sectional analysis, represent a clear under-estimation of the prevalence, since many male adults (more than 50% of the age/sex group) refused to participate due to their professional activities, or other reasons such as stating that "I've never suffered from malaria".

Symptomatic malaria infections in Vila Candelária in the 2001 to 2003 period - Data from the Funasa had showed the Annual Parasite Index (API) higher than 100/1000 inhabitants in Vila Candelária in 1999 and 2000. From 2001 onwards, the presence of a Clinic and Laboratory Unit in Vila Candelária and clear identification of inhabitants, following the demographic survey, permitted a more precise identification of malaria cases, and their seasonal distribution. Fig. 1 summarizes the

monthly distribution of *P. vivax* and *P. falciparum* malaria cases in 2001, 2002, and 2003 concerning to the variation in rain fall. The total number of cases was 86 in 2001, 85 in 2002, and 57 in 2003, which gives APIs values of 310/1000 for 2001/2002, and 132 for 2003, with *P. vixax/P. falciparum* ratios of 31, 31, and 30. As shown in Fig. 1, malaria transmission seems to occur throughout the year with a peak in April and May, after the peak of the rainy season. In 2002 and 2003 the highest incidence observed in April and May continued throughout June followed by a net decrease at the beginning of the dry season, however an unexpected outbreak was observed from September to November, just when the new rainy season started. The November outbreak of 2002 was investigated and identified as a localized epidemy of *P. falciparum* malaria affecting young adults (16 cases) living in a limited area.

Age and sex distribution of malaria incidence in Vila Candelária - As shown in Table III the age distribu-

tion of malaria cases in 2001 indicates that the risk groups are children between 6 to15 years of age (χ^2 = 18.9, P = 0.0008). While only 27% of children of less than 5 years of age suffered from malaria episodes in 2001. Symptomatic malaria infections occurred among more than 50% of children from 6 to 10 years of age, and among young adolescents from 11 to 15 years of age (annual parasite index APIs values over 500). The decrease in incidence in adults of 16 to 40 years of age (API = 330) is noteworthy and particularly a low incidence in subjects over 40 years (API = 127), indicating the acquisition of immunity. No difference was seen in sex distribution. The profile of incidence of malaria cases in Vila Candelária according to age and sex is similar to that observed in other rural riverside localities. Data from 2002 and 2003 followed a similar age and sex distribution (data not shown), with some change in 2002 due to the exceptional *P. falciparum* outbreak that affected mainly young male adults (Fig. 1B).

Asymptomatic malaria carriers seems to be immune resistant to homologous species infections - As shown in Table IV, the follow up in 2001 of asymptomatic carriers (20 cases of *P. vivax* and mixed infection) in the 4 months following diagnosis revealed only 1 case of symptomatic *P. vivax* infection, in a 3 year old child. The other 20 individuals did not present clinical malaria infections, while among the 164 PCR-negative subjects 18 *P. vivax* infections occurred in the same period. Statistic analysis of data shows that these differences are not significant (χ^2 =0.18, P = 0.34), however the results can be interpreted as indicating some degree of clinical immunity in the asymptomatic carriers against species homologous infection, particularly if we consider that the single asymptomatic infection in the 3-year-old child might have be due to a non-immune mechanism. A similar tendency occurred in *P. falciparum* carriers, after the second survey, but the small number of samples did not reach any statistical significance.

DISCUSSION

Urban malaria is frequently described as related to poverty, absence of water supply and sanitation, and is associated with mosquito invasion of housing. An outline contrast, the Vila Candelária neighborhood at the periphery of Porto Velho on the right bank of the Madeira River, is an attractive local tourist center, with historical sites, good modest restaurants, but adequate housing conditions, with electricity, basic water supply, and sanitation.

Nevertheless, as shown in the Results, the incidence of malaria in the Vila Candelária neighborhood in the last years has shown APIs values of the order of 100 to 300, while in the poor peripheral outskirts of Porto Velho, located in dry land areas, autochthonous malaria occurs with APIs values usually bellow 10, or exceptionally between 10-50 (Sesau 2002, Semusa 2004).

An entomological survey performed in Vila Candelária, simultaneously with the clinical-parasitological survey showed variations in the *Anopheles* densities, with increases in the rainy season that explained
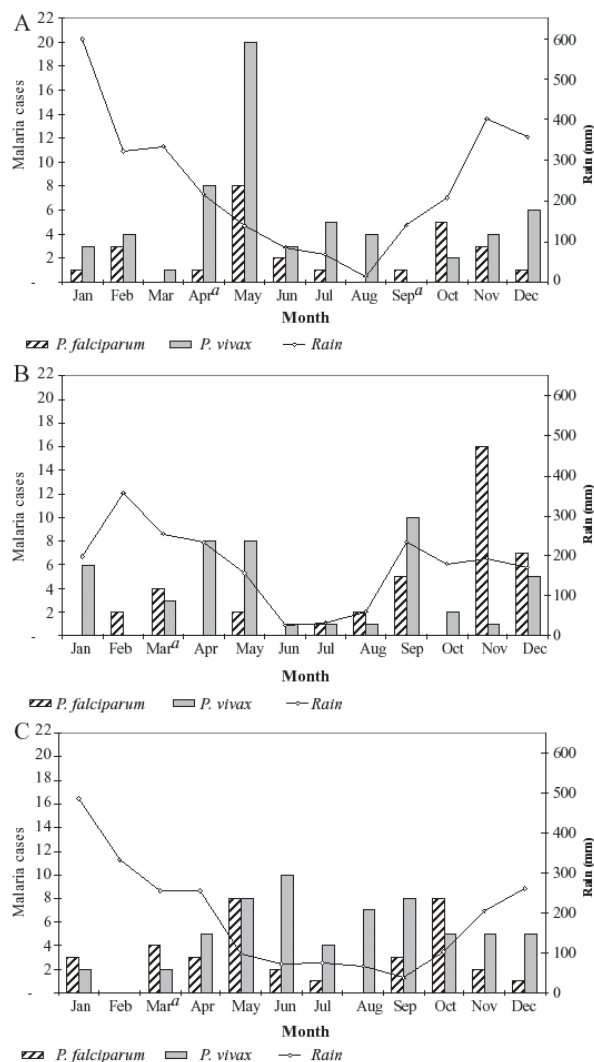

Fig. 1: monthly distribution of vivax and falciparum malaria cases in 2001 (A), 2002 (B), and 2003 (C) in relation to rain precipitation (in mm) in Vila Candelária; *a*: cross-sectional.

TABLE IV

Incidence of symptomatic infections in malaria parasite carriers

Age group (years)	Examined sample	Result of PCR analysis in April 2001		Malaria cases from May to August 2001 in PCR (+) and PCR(–) subjects	
	n	PCR(+)	PCR(–)	PCR(+)	PCR(–)
-5	21	2	19	1	1
6-10	16	0	16	0	1
11-15	22	1	21	0	2
16-40	89	13	76	0	10
>40	37	5	32	0	4
Total	185	21	164	1	18

PCR: polymerase chain reaction. Differences in number of malaria cases in previously PCR(+) subjects (1) in relation to PCR(–) subjects (18) are not statistic significant ($c^2 = 0.18$) but suggest that asymptomatic infections provide protection against acute infections. From 187 subjects examined in the cross sectional study (Table I) 2 adults moved out from Vila Candelária and were excluded from the follow up (Table IV) with 185 subjects.

the seasonal malaria transmission profile in the locality (Gil et al. this issue). However, it was necessary to identify the source of malaria parasites responsible for the high transmission observed. In communities of rural riverside areas the incidence of new malaria's cases is quite low in the dry season and increases sharply at the end of the rainy season, after the increase of the *Anopheles* density (Alves 2003, Gil et al. 2003). It had been suggested that the source of infection responsible for the malaria outburst were parasites present in asymptomatic carriers. Our development studies in Vila Can-delária provide direct support to this hypothesis. Nowadays based on the classic observations of malariologists in Africa (Molyneaux 1988) we have the knowlegment that humans can only infect mosquitoes about one week after the appearance of asexual blood stages, when gametocytes appear in the blood circulation. In contrast *P. vivax* gametocytes appear nearly simultaneously with asexual blood parasites (Tauil 1992, Pereira-da-Silva & Oliveira 2002). After the clinical ambulatory was set up in Vila Candelária in 2000, the delay between malaria diagnosis and treatment became usually less than 24 h, never more than 48 h. Considering the relative isolation of the Vila Candelária population, a striking reduction in *P. falciparum* transmission was expected, and also some in *P. vivax* transmission.

The maintenance of high APIs and the same falciparum/vivax ratios during the three years of follow-up, despite of the introduction of strict diagnostic and treatment measures during this period, strongly suggests that asymptomatic carriers are the source of mosquito infection. We also demonstrated under laboratory conditions that asymptomatic carriers could infect mosquitoes (Alves et al. 2005). In addition, analysis of the genetic make-up of *P. falciparum* parasites obtained from asymptomatic individuals and clinical *P. falciparum* malaria cases examined in 2001 and 2002 showed a similar haplotype composition with regard basis of microsatellite markers (Dalla-Martha pers. commun.).

In conclusion, several important similarities were observed by comparing epidemiological malaria profiles of the urban district of Vila Candelária and rural river-side localities: (1) high prevalence of asymptomatic carriers, in adults of both sex; (2) high incidence of both *P. falciparum* and *P. vivax* malaria, with no gender differences and with risk groups represented by children and young adolescents; (3) an unstable mesoendemic profile with epidemic outbreaks at the peak of the rainy season. These aspects were associated with a relative absence of reduction of timing between onset of infection, diagnosis, and treatment. Taken together with the demographic stability and long-lasting residency of the local population, these data strongly suggest that asymptomatic malaria carriers are important sources for sustaining malaria transmission in peripheral urban localities. This seems not only true for Vila Candelária, but for other urban riverside localities in the northern area of Porto Velho (data not shown). It seems also that a similar situation was responsible for the recent malaria epidemic in urban riverside areas of Manaus, registered in 2003-2004 (Ministério da Saúde 2004).

However, a marked difference was observed in the seasonal malaria incidence in Vila Candelária in comparison to rural riverside areas; namely, the perennial transmission together with episodes of epidemic outbreaks at the beginning of the rainy season. As sown by Gil et al. (this issue), this is due to important environmental degradation brought about by the human presence including artificial barriers and changes in flow of natural small streams, as well as road construction, fish and shrimp breeding and other activities. Gil et al. (this issue) emphasize these aspects as being responsible for important increases in vector densities highlighting the complexity of factors involved in urban malaria epidemiology and the need to add additional measures of malaria control in urban riverside communities in the Amazon Region, including identification of the epidemiologic importance of asymptomatic infections and urban sanitation.

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