SEASONAL DISTRIBUTION AND BITING PATTERNS OF *ANOPHELES* MOSQUITOES IN COSTA MARQUES, RONDONIA, BRAZIL [1,2]

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ABSTRACT. Thirteen species of anopheline mosquitoes were collected in all-night human-bait indoor and outdoor collections at 5 houses from July 1986 through December 1987 in and near the town of Costa Marques, Rondonia, Brazil. *Anopheles darlingi* and *An. deaneorum* accounted for more than 92 and 6%, respectively, of all anophelines collected from human-bait outside houses and 90 and 9%, respectively, inside houses in the town. The diversity of anophelines was greater in human-bait collections in rural areas. However, *An. darlingi* still accounted for more than 90% of all the anophelines collected from human-bait inside and outside rural houses. Data on nocturnal and seasonal biting rhythms for the more common anophelines are given.

INTRODUCTION

The number of reported malaria cases in Brazil has increased from 86,437 in 1976 to 508,864 in 1987 (Fig. 1) (Ministry of Health 1984). The increased incidence of malaria has been linked to the continuous influx of nonimmune immigrant populations into areas with endemic malaria, combined with poor housing, inadequate mosquito control and drug resistant *Plasmodium falciparum* (Marques 1987, McGreevy et al. 1989). Over 99% of all malaria in Brazil is reported from the Amazon Basin, and in recent years almost half of these cases occurred in the state of Rondonia [Superintendencia das Campanhas (SUCAM), unpublished data, 1989].

The inside walls of houses are sprayed with DDT every 6 months as the principal activity of the national malaria control program. Program efficacy is difficult because of such factors as population mobility, poorly constructed houses and vector behavior. However, a first step in the assessment process is to identify the anopheline mosquitoes responsible for malaria transmission and develop a solid base of information on their vector biology.

We studied anopheline mosquitoes in the town of Costa Marques, Rondonia, from July 1986 through December 1987 (Fig. 2). Our objectives were to determine the species of adult *Anopheles*, their temporal and spatial distributions, and endophilic/exophilic preferences.

MATERIALS AND METHODS

Study site: Costa Marques is a small frontier town situated on the Guapore River, which serves as the border between Bolivia and Brazil (12°26'S, 64°14'W) (Fig. 2). The land is flat and covered with a tropical semi-evergreen seasonal forest (Beard 1944). Rainfall is seasonal with a dry season from May to September and a wet season from October to April (Fig. 3).

Two rivers and a stream border Costa Marques on 3 sides (Fig. 2). The São Domingos River joins the Guapore River on the south. A small temporary stream transects the NW part of Costa Marques and empties into the Guapore River. During periods of peak flow, the temporary stream and the 2 rivers flood much of the land on 3 sides of Costa Marques. On the Bolivian side of the Guapore River, the flood plains cover a large expanse of virgin forest. When the water recedes from these flooded areas, the natural water impoundments form oxbows and temporary and permanent marshes, ponds and pools that serve as important immature mosquito habitats. Along road BR 429 there were many natural low lying areas and manmade depressions that form permanent or temporary water impoundments with sparse to abundant vegetation.

Dogs and chickens were the most common animals in Costa Marques. Cattle were common on the periphery of the town and occasionally were observed inside the town. A small dairy farm was located at km 8. These cattle were pastured at km 7 and penned in a corral before dusk each night about 10 m from house 5.

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Mosquito collections: Adult mosquito collections were made from July 1986 to December 1987 at 3 houses in the town (houses 1, 2 and 3) and at 2 houses along BR 429 at km 2 and km 7 from the town (houses 4 and 5, respectively) (Fig. 2). Houses 1 and 2 were approximately 0.5 km apart, and both were near larval mosquito habitats along the margins of the Guapore River and associated flood plains. House 3 was located in the northwest sector of the town about 1 km from house 2. House 4 was near the base of a forested hill at km 2. Houses 2 and 4 were further from anopheline habitats during the late dry season than the other houses. House 5 was located in a cleared area about 0.5 km from a temporary stream that emptied into a swamp that dried to form a large stagnant pool at the end of the dry season. Houses 1, 2 and 4 were constructed with wood and had tin roofs and shuttered windows. The eaves were not screened and the windows were often left open. Houses 3 and 5 were single room houses constructed of scrap lumber. Anophelines could gain access through large cracks between the wall boards as well as open doors of these houses.

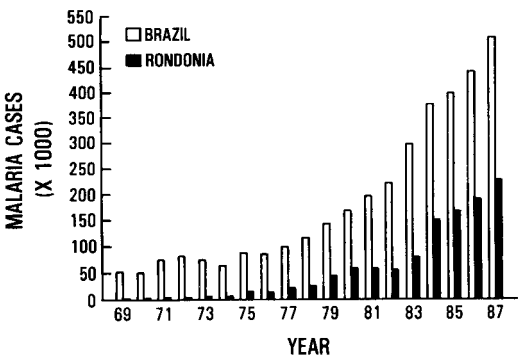

Fig. 1. Number of reported malaria cases in Brazil and for Rondonia State, Brazil. Data provided by SUCAM.

The study houses were sprayed biannually by SUCAM in January and July of each year. In Costa Marques, 98% of all houses were sprayed with DDT biannually (SUCAM, personal communication, 1988). Irregular cold fogging with malathion was conducted by SUCAM in July–August 1987 (arrows, Fig. 4).

Nocturnal activity patterns and seasonal distributions of mosquitoes were studied by using systematic human-bait collections inside and outside of house 1 (July 1986–December 1987) and house 5 (January–December 1987). Human-bait collections were conducted for 40 min of

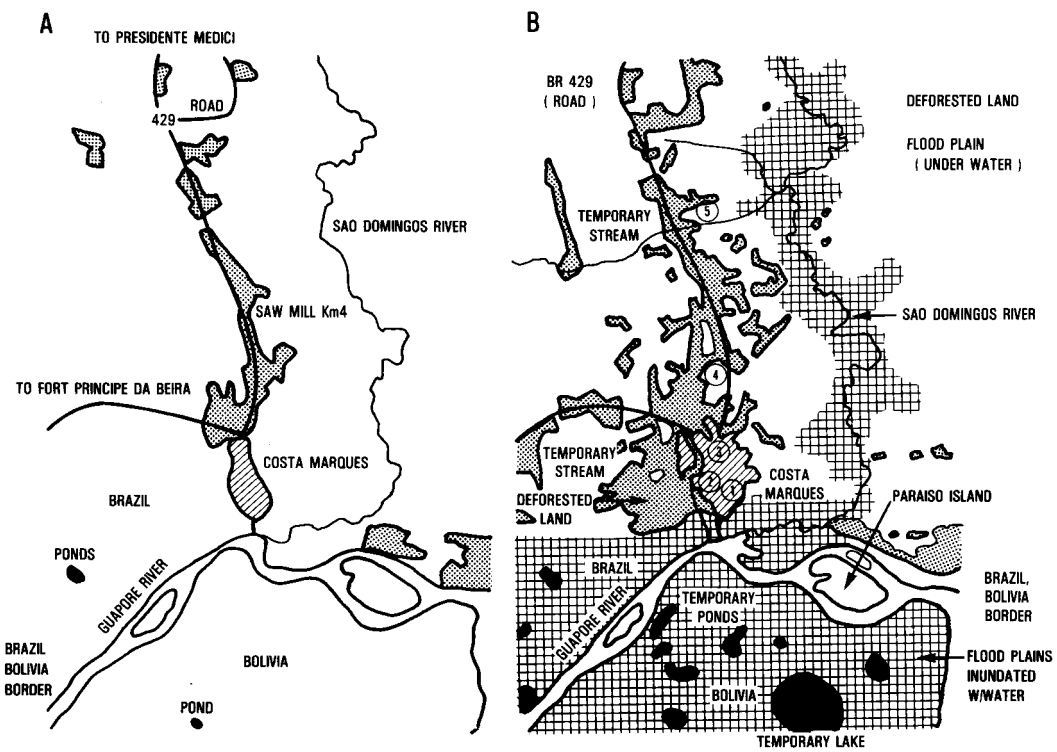

Fig. 2. Costa Marques and road BR-429 during the dry season (A) (Sept. 1983), and wet season (B) (March 1987). Maps were drawn from satellite photographs by the Instituto Brasileiro de Desenvolvimento Florestal.

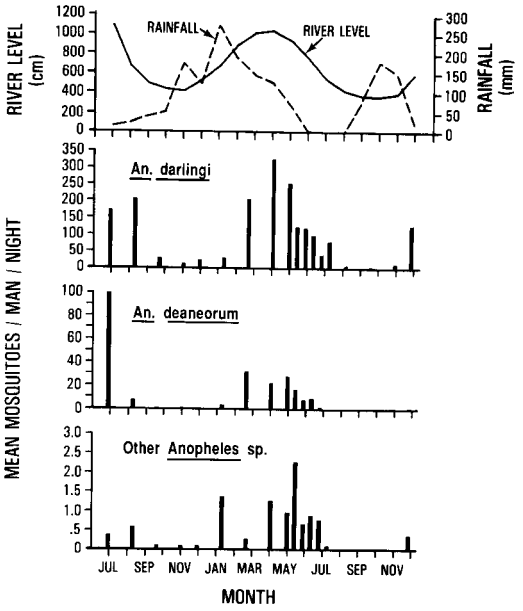

Fig. 3. Rainfall, Guapore River level and mean number of mosquitoes collected per man per night from human-bait outside 3 houses in Costa Marques from July 1986 to December 1987. "Other" *Anopheles* species include *An. oswaldoi*, *An. triannulatus*, *An. albitarsis*, *An. mattagrossensis*, *An. braziliensis*, *An. rondoni*, *An. minor*, *An. mediopunctatus*, *An. nunez-tovari*, *An. peryassui* and *An. benarrochi*. Meteormetric data provided by the Meteorological Military Unit, Fort Principe da Beira, located 26 km NW of Costa Marques.

each hour from 1800 to 0700 h by exposing the lower part of the legs of the collectors. Mosquitoes were collected with oral aspirators, transferred to screened pint cartons, killed by freezing and identified.

Identifications used in this paper follow Faran and Linthicum (1981), Lane (1953) and Rosa-Freitas (1989). The taxonomy of anophelines in Brazil is complicated by recent discoveries of species complexes and species designations in this paper will probably change with further study. Therefore, representatives of wild collected anophelines and reared progeny with larval and pupal exuviae were deposited in the Walter Reed Biosystematics Unit at the Smithsonian Institution, Washington, DC, where our field identifications were confirmed.

RESULTS

In the Costa Marques area, adults of 13 anopheline species were collected from human-bait (Table 1). *Anopheles darlingi* Root and *An. deaneorum* Rosa-Freitas were the most abundant anophelines in human-bait collections inside and outside houses. *Anopheles darlingi* and *An. deaneorum* accounted for 92 and 6%, respectively, of the anophelines collected outside all houses and 90 and 9%, respectively, collected inside house 1. The relative abundance of anophelines were similar for houses 1, 2 and 5 located near larval habitats and much lower at houses 3 and 4 that were located farther away from larval habitats.

The anopheline diversity at house 5 along road BR 429 was much greater than at houses in the town of Costa Marques, but *An. darlingi* still accounted for 90 and 91% of the anophelines collected indoors and outdoors, respectively (Table 1, Fig. 4). All 13 species of anophelines were collected at house 5 whereas only 2 species were collected at house 3 and 6 species at houses 1, 2 and 4. *Anopheles deaneorum* was less frequently collected at house 5 than in the town and accounted for 5 and 3% of the anophelines collected inside and outside house 5, respectively. *Anopheles albitarsis* Lynch Arribalzaga was rarely collected in town but was more frequently collected at house 5 and accounted for 3 and 4% of the anophelines collected indoors and outdoors, respectively. The remaining anophelines accounted for <3% of the total collected indoors or outdoors at house 5. Of these, *An. oswaldoi* (Peryassu) and *An. triannulatus* (Neiva and Pinto) were more abundant at houses 4 and 5, but still were only a small proportion when compared to the relative abundance of *An. darlingi*.

The abundance of adult *An. darlingi* was positively correlated with the level of the Guapore River by linear regression ($r = 0.84$) (Fig. 3). All *Anopheles* species were most abundant during the early dry season, but their densities subsequently declined as the natural water impoundments subsided. During the latter part of the dry season after natural and manmade temporary pools, swamps and ponds dried, the frequency of mosquitoes in biting collections was very low. However, *An. darlingi* and *An. triannulatus* were still collected throughout the year along the bank of the Guapore River 0.5 km from houses 1 and 2.

Host-seeking *An. darlingi* were active throughout the night with peak biting activities in the early evening (1800–2000 h) and morning (0500–0600 h) (Fig. 5). The peak biting activity is bimodal and varied throughout the year in association with the timing of sunset and sunrise. The nocturnal biting activity of *An. deaneorum* and *An. albitarsis* were similar to that of *An. darlingi*, but with less activity during the middle of the night (Figs. 5–7).

Of the total number of mosquitoes collected in human bait collections at house 1, 18% of *An. darlingi* and 16% of *An. deaneorum* were col-

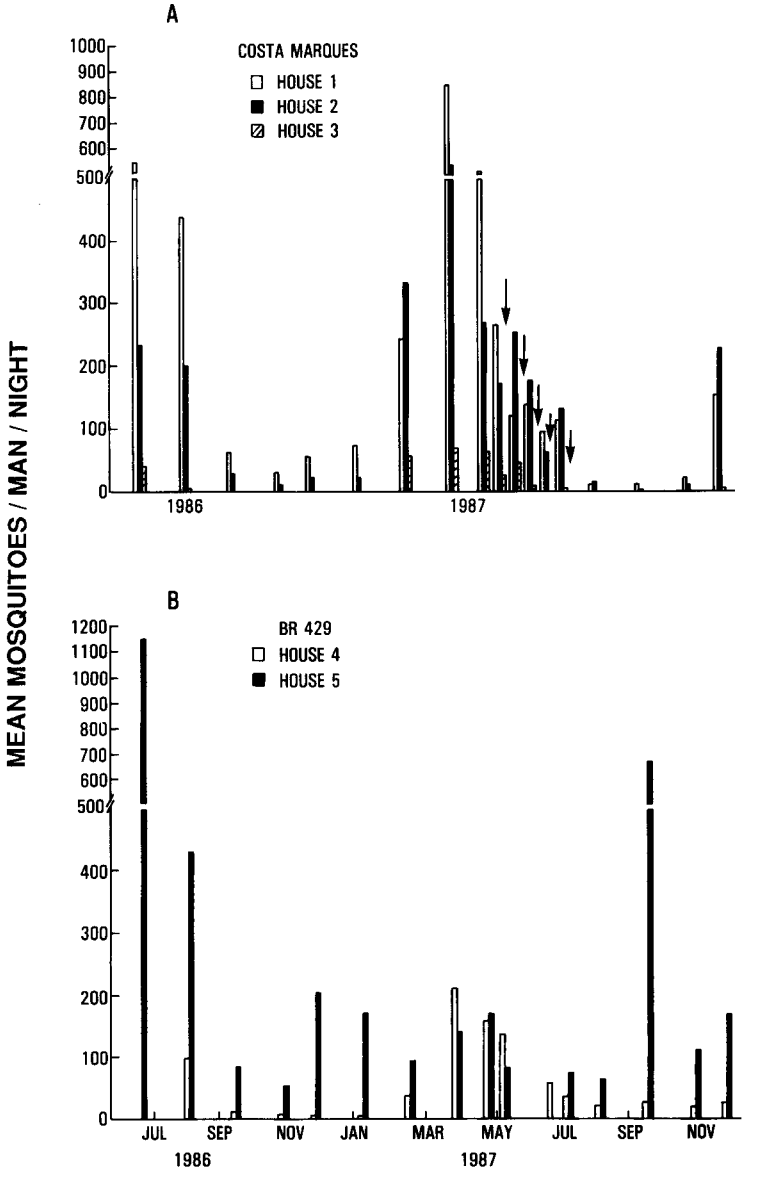

Fig. 4. Mean number of mosquitoes collected/man/night from human-bait at 3 houses in Costa Marques and 2 houses along road BR-429. Arrows indicate fogging with malathion.

lected indoors (Table 2). In contrast, the proportion of each anopheline species collected indoors at house 5 was much higher than at house 1, with 32% *An. darlingi*, 41% *An. deaneorum*, 31% *An. oswaldoi* and 30% *An. triannulatus* collected indoors.

DISCUSSION

Mosquito bionomics: The rise and fall of *An. darlingi* populations in Costa Marques were directly correlated with the rise and fall of water level in the Guapore River. Population densities were highest during the late wet season and early dry season when Costa Marques was flooded on 3 sides by water. The seasonal abundance of *An. darlingi* is known to vary throughout its distribution. In the states of Amazonas, Roraima and Matto Grosso, Brazil, *An. darlingi* populations peak during the dry season (Charlwood and Hayes 1978, Hayes and Charlwood 1979). In Suriname, populations were shown to peak dur-

Table 1. Anophelines collected inside and outside 5 houses from human-bait during the same period from January 1987 through December 1987 in the Costa Marques area. Each number represents the mosquitoes captured during 785 h of collecting for each collection site.

	Outside house					Inside house	
Anopheles	1	2	3	4	5	1	5
darlingi	11,164	10,359	1,302	4,230	9,197	2,417	4,411
deaneorum	1,358	508	109	65	323	252	224
albitarsis	6	1	0	2	380	1	151
triannulatus	25	10	0	68	47	2	20
oswaldoi	15	18	0	40	128	1	57
mattagrossensis	10	8	0	11	2	1	4
nuneztovari	0	0	0	0	7	0	0
benarrochi	0	0	0	0	6	0	0
mediopunctatus	0	0	0	0	3	0	0
peryassui	0	0	0	0	1	0	0
braziliensis	0	0	0	0	2	0	0
rondoni	0	0	0	0	2	0	0
minor	0	0	0	0	1	0	0
Total	12,578	10,904	1,411	4,416	10,099	2,674	4,867

ing the long dry and short dry season in some localities and in the long rainy season in others (Panday 1979, Hudson 1984, Rosendaal 1987). In the state of São Paulo, Forattini (1987) showed that populations peaked during the "hot season," but also peaked during periods of non-typical excessive rains. Some of these differences might be related to geographical variations in seasonal temperatures, rainfall and river levels and the combined effect on the abundance of natural water impoundments and quantity of aquatic vegetation.

The nocturnal periodicity of *An. darlingi* in Costa Marques and other areas of Rondonia corresponds to human activity (Lourenco-de-Oliveira et al. 1989). Peak biting activity occurs in the early evening and morning hours when people are active both outdoors and indoors. Houses are infrequently screened and doors and windows are frequently left open for ventilation during these hours. In other areas, the peak biting activity of *An. darlingi* varies from early evening to 2330–0200 h (Deane et al. 1948, Elliott 1972, Charlwood and Hayes 1978, Roberts et al. 1987, Rosendaal 1987). Although our data indicated no difference in indoor and outdoor biting rhythms, Deane et al. (1948) demonstrated a single indoor biting peak that did not correspond with the outside biting peak. The diversity of biting activity may be due to population variation throughout the wide range of *An. darlingi* (Deane 1988). However, *An. darlingi* could be a complex of sibling species, and these variations in biting rhythm may reflect the behavior of each species.

The nocturnal biting activity of *An. deaneorum* and *An. albitarsis* at the collection sites were similar to those of *An. darlingi* collected in Costa Marques. These results are similar to those obtained by Deane et al. (1948) and Forattini (1987) in other parts of Brazil. The parallel human activity with the diel periodicity of *An. deaneorum* and *An. darlingi* may be important factors in peridomestic malarial transmission.

Anopheles darlingi and *An. deaneorum* were more frequently collected indoors than the other species of anophelines at both houses 1 and 5. The proportion of *An. darlingi* and *An. deaneorum* collected indoors was 2.5-fold greater than for *An. oswaldoi* and *An. triannulatus* at house 1 (Table 2). However, there was very little difference in the proportion of these mosquitoes biting indoors in a poorly constructed house such as at house 5.

The larger percentage of *An. darlingi*, *An. deaneorum*, *An. triannulatus* and *An. oswaldoi* collected inside house 5 is believed to be due to "house effect," with the large gaps in the walls providing easy entry for mosquitoes. Poorly constructed houses are common in rural Rondonia, and this may result in ineffective insecticide residues since mosquitoes can easily exit houses and avoid DDT on the walls.

It appears that both *An. darlingi* and *An. deaneorum* are more endophilic than the other anopheline mosquitoes, but this difference is negligible for poorly constructed houses (Table 2). Lourenco-de-Oliveira et al. (1989) proposed that the continued use of DDT on inside wall surfaces has selected for exophilic *An. darlingi*. This, in addition to a large percentage of poorly constructed houses in rural areas, could account for the continued increase of malaria in the Amazon Basin in spite of continued DDT application.

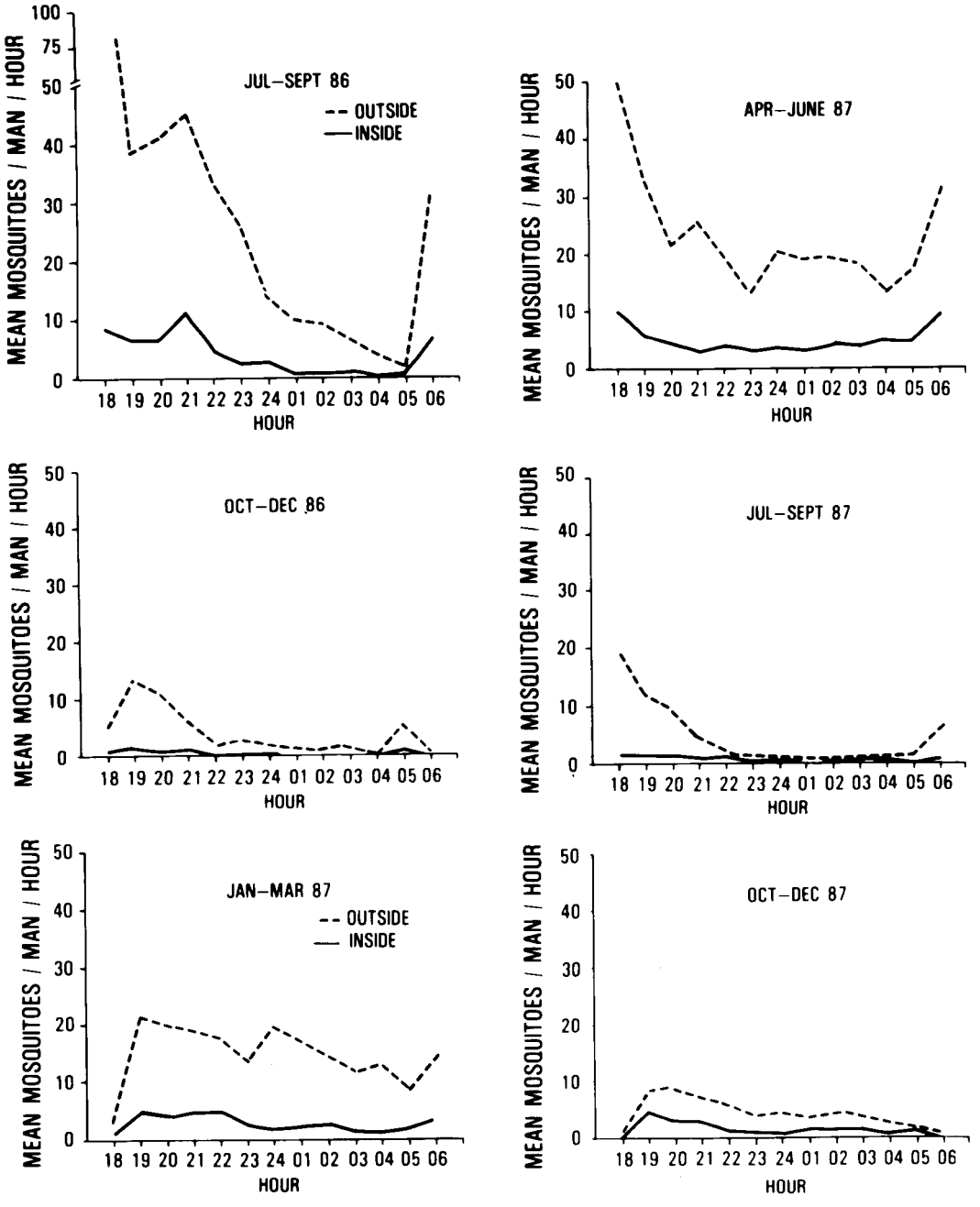

Fig. 5. Nocturnal biting behavior of *Anopheles darlingi* collected inside and outside house 1 in Costa Marques from July 1986 to December 1987.

Taxonomy: The taxonomy of *Anopheles* mosquitoes in the Amazon Basin is poorly understood, and many groups are undergoing study or revision. For example, it has recently been shown that the cuticular hydrocarbon pattern of *An. darlingi*, the primary malaria vector throughout most of Brazil, from Costa Marques is distinct from those collected at 2 other localities (Rosa-Freitas et al. 1990). In addition, *An. deaneorum*, a member of the *An. albitarsis* complex and a vector of both *P. falciparum* and *P. vivax*, has only recently been described from

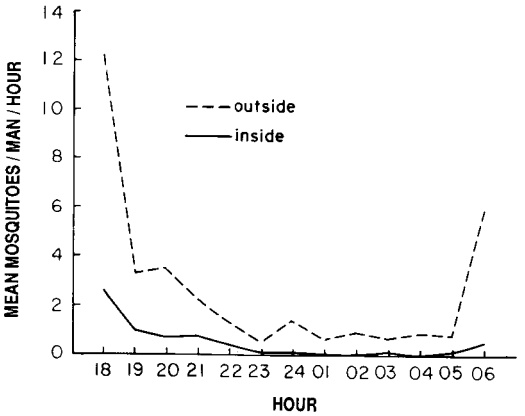

Fig. 6. Nocturnal biting behavior of *Anopheles deaneorum* collected from human bait inside and outside house 1 from April to September 1987 in Costa Marques.

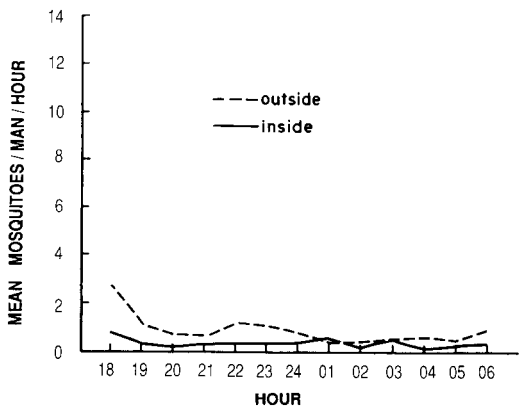

Fig. 7. Nocturnal biting behavior of *Anopheles albitarsis* collected inside and outside house 5 from human-bait from April through September 1987 along road BR 429.

Guajara Mirim, Rondonia. It is also unlikely that *An. albitarsis* from Costa Marques is either *An. albitarsis sensu stricto* or *An. marajoara* (Galvão and Damasceno) (R. Wilkerson, personal communication). *Anopheles mediopunctatus* Theobald is undergoing revision, and there are two forms of *An. mediopunctatus sensu lato* that are sympatric in forested areas near Costa Marques (R. Wilkerson, personal communication). It is also suspected that most *An. oswaldoi* from open clearings in Costa Marques is actually *An. konderi*, currently a synonym of *An. oswaldoi* and that *An. oswaldoi sensu stricto* is restricted to the forested areas (E. L. Peyton, personal communication). Other authors have indicated variations in other anopheline species groups throughout Brazil.

The taxonomy of anopheline mosquitoes and their vector potential is necessary to understand the epidemiology of malaria in the Amazon Basin. In addition, malaria control should be based on the local evaluation of anopheline biology and vector potential due to the diversity of anophelines throughout the Amazon Basin.

Table 2. Percent of anophelines biting indoors compared with the total number of each species collected indoors and outdoors at house 1 and house 5.

	House 1		House 5	
Anopheles	Inside and outside	Percent indoors	Inside and outside	Percent indoors
darlingi	13,581	18	13,608	32
deaneorum	1,610	16	547	41
albitarsis	7	14	531	28
triannulatus	27	8	67	30
oswaldoi	16	6	185	31
mattagrossensis	11	9	6	67
Total	15,252	18	14,944	33

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