Observations on the biology and behaviour of Anophelines in the Suriname rainforest with special reference to *Anopheles darlingi* Root

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Summary

As part of a research programme on transmission of malaria in the rainforest of Suriname a study was made of man-biting anophelines along the Upper-Suriname and Upper-Marowijne river, from March 1983 to May 1984. At seven sampling stations in the Upper-Marowijne River area human bait collections were made on four successive nights each month simultaneously at peridomestic sites within a few meters from an inhabited house in an open space in the center of a village and at sites in the adjacent forest. Catching periods from 18.30-20.30 hours, 23.30-01.30 hours and 04.30-06.30 hours revealed higher biting rates of Anopheles darlingi *in the peridomestic environment than in the forest, with a peak of activity around midnight. The other species collected, mainly* A. nuneztovari *and* A. oswaldoi, *were more abundant in the forest captures and exhibited maximum biting activity around dusk.*

Seasonal fluctuations in abundance of A. darlingi *varied between sampling stations and probably reflect local differences in availability of breeding places, which included creeks, strips of flooded forest, the river's edge and pools in the river bed.* A. nuneztovari *showed a well-defined seasonal peak of activity during the dry season, from October to January, which may be due to this species' apparent preference for breeding in pools in the river bed.*

In the Upper-Suriname River area, where there was a very low incidence of malaria, sampling stations were limited to peridomestic sites. A. darlingi *was present in very low densities, whilst* A. nuneztovari *was the most common species captured.*

Key words : Anophelinae — *Anopheles darlingi* — Behaviour — Ecology — Rainforest — Suriname.

Résumé

OBSERVATIONS SUR LA BIOLOGIE ET LE COMPORTEMENT DES ANOPHÈLES, EN PARTICULIER D'*ANOPHELES DARLINGI* ROOT, DANS LA FORÊT TROPICALE DU SURINAM. *Nous avons étudié les anophèles piquant l'homme le long des rivières haut-Surinam et haut-Maroni au cours de la période mars 1983-mai 1984, dans le cadre d'un programme de recherche sur la transmission du paludisme dans la forêt équatoriale du Surinam. Dans sept stations de capture sur le haut-Maroni les moustiques ont été capturés sur appât humain, chaque mois, pendant quatre nuits consécutives. Les récoltes avaient lieu*

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simultanément à différents endroits, au centre du village à quelques mètres d'une maison habitée et dans la forêt voisine. Les captures étaient effectuées de 18 h 30 à 20 h 30, de 23 h 30 à 1 h 30 et de 4 h 30 à 6 h 30. 85,2 % des moustiques péridomestiques étaient des Anopheles darlingi *qui ne formaient seulement que 19,8 % des moustiques capturés en forêt. Parmi ces derniers,* A. nuneztovari *était l'espèce la plus abondante (63,9 %). 72,6 % du nombre total des* A. darlingi *ont été pris dans le village, de même que 6,8 % des* A. nuneztovari *et 11,6 % des* A. oswaldoi. A. darlingi *était le plus actif de 23 h 30 à 1 h 30, tandis que* A. nuneztovari *et* A. oswaldoi *étaient plus agressifs entre 18 h 30 et 20 h 30.*

Dans la région du haut-Surinam, où l'incidence du paludisme est très basse, les sept stations de capture ont été sélectionnées de façon aléatoire. Les captures n'eurent lieu que dans les villages. A. darlingi *n'a été présent qu'en petit nombre, l'espèce la plus fréquente étant* A. nuneztovari.

*Les fluctuations saisonnières de la densité de population d'*A. darlingi *étaient variables d'une station à l'autre. Il est possible que cela est dû aux variations locales du nombre des gîtes larvaires disponibles, comme celui des criques, des plantes flottantes le long des rives, des petites mares et des inondations locales.* A. nuneztovari *a atteint sa densité maximale en saison sèche d'octobre à janvier, ce qui peut s'expliquer par sa préférence pour les petites mares du lit des rivières.*

A. oswaldoi *était présent en petit nombre pendant toute l'année avec une légère augmentation en saison des pluies.*

Mots-clés : Anophelinae — *Anopheles darlingi* — Comportement — Écologie — Forêt humide — Surinam.

Introduction

DDT residual house spraying was introduced as an antimalaria measure in Suriname in 1958 following spectacular results with this control method in other countries. However, the programme was of limited success, possibly due to the low coverage (between 15 % and 60 % of houses were sprayed per cycle) caused by the poor cooperation of the bushnegro population and by organizational problems (Barnes and Jenkins, 1972). In addition there was a poor understanding of the behaviour of the most likely vector in the Suriname interior, *Anopheles darlingi* Root, which made difficult the predictable impact of DDT house spraying on malaria incidence.

Previous entomological studies of anophelines include the work of Hudson (1984) on *A. darlingi*. He also reviewed the evidence for *A. darlingi* being the primary vector of malaria in Suriname. Collections on human bait in rainforest settlements showed *A. darlingi* to be the most common species. Parasitological evidence of the vectorial role of this species was earlier provided by Bonne and Bonne-Wepster (1925) and Bruyning (Verslag van de medische expeditie Tapanahony-Paloemeu, unpublished report, Bureau of Public Health, Paramaribo, 1952). Larvae were often found in semipermanent open swamps (Bonne and Bonne-Wepster, 1925 ; Van der Kuyp, 1950 ; Bruyning, *op. cit*) in floating vegetation or debris near river banks (G. A. Fleming, PAHO-entomologist, in an unpublished report in 1962 to the head of the malaria campaign ; Panday, 1980 ; Hudson, 1984). Fleming (*op. cit.*) and Hudson (1984) studied the seasonal fluctuations in biting density at Pokigron (Suriname River) and Aselikamp (Lawa River) respectively. According to Fleming the peak biting density is during the dry season in October and November. Highest monthly Mean Biting Rate (MBR) was 0.34 per manhour, when the stable and low water level of the Suriname River allowed favourable breeding places to form. By contrast, Hudson recorded the highest monthly MBR, 83.2 per manhour, during the rainy season from April to June. During this period the Lawa River flooded a strip of forest in which larvae were found in sunny places. However, malaria incidence in the Upper-Marowijne River area was at its minimum this time. Like Fleming, Hudson also found larvae between protrusions from the river bank in the period August to March when the water level was low.

The data reported here are part of an in-depth study of the behaviour of *A. darlingi* in relation to man-vector contact. Data about biting-cycle, indoor resting period, effect of DDT residual house spraying and mosquito nets impregnated with Permethrin on *A. darlingi* will be presented elsewhere. This paper reports on the occurrence, seasonal fluctuations and biting behaviour of man biting anophelines in or near bushnegro settlements in the Suriname interior.

Area of study and methods

THE STUDY AREA

Malaria transmission and *A. darlingi* occur mainly in the tropical rainforest area south of the limit of the tidal influence (fig. 1). This area is divided by many rivers of which the Upper-Marowijne and Upper-Suri-

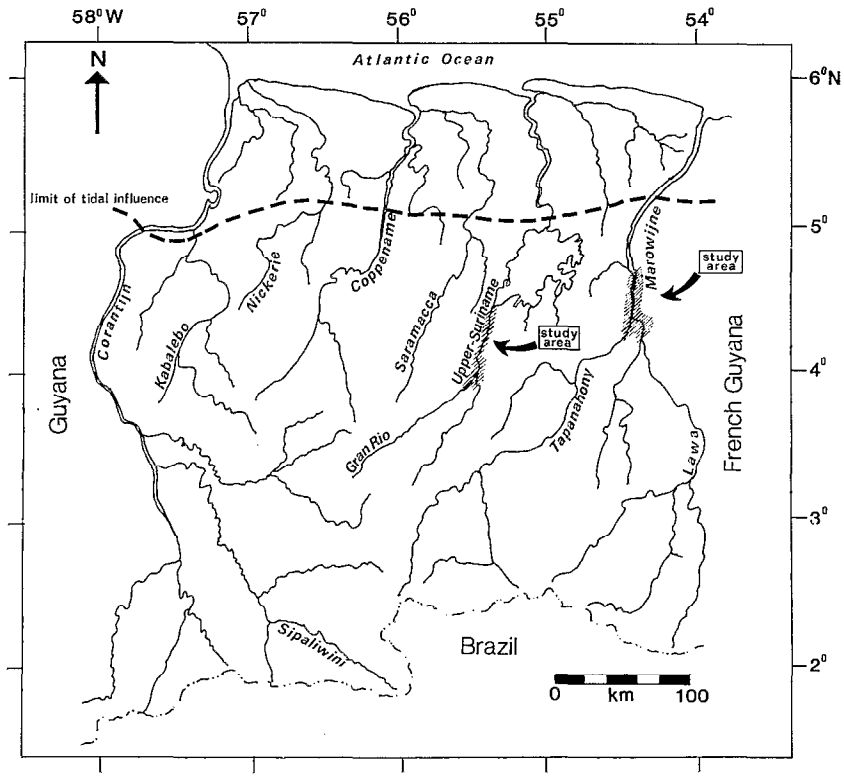


FIG. 1. — Map of Suriname indicating the limit of the tidal influence and the study areas in the Upper-Marowijne River and Upper-Suriname River areas.

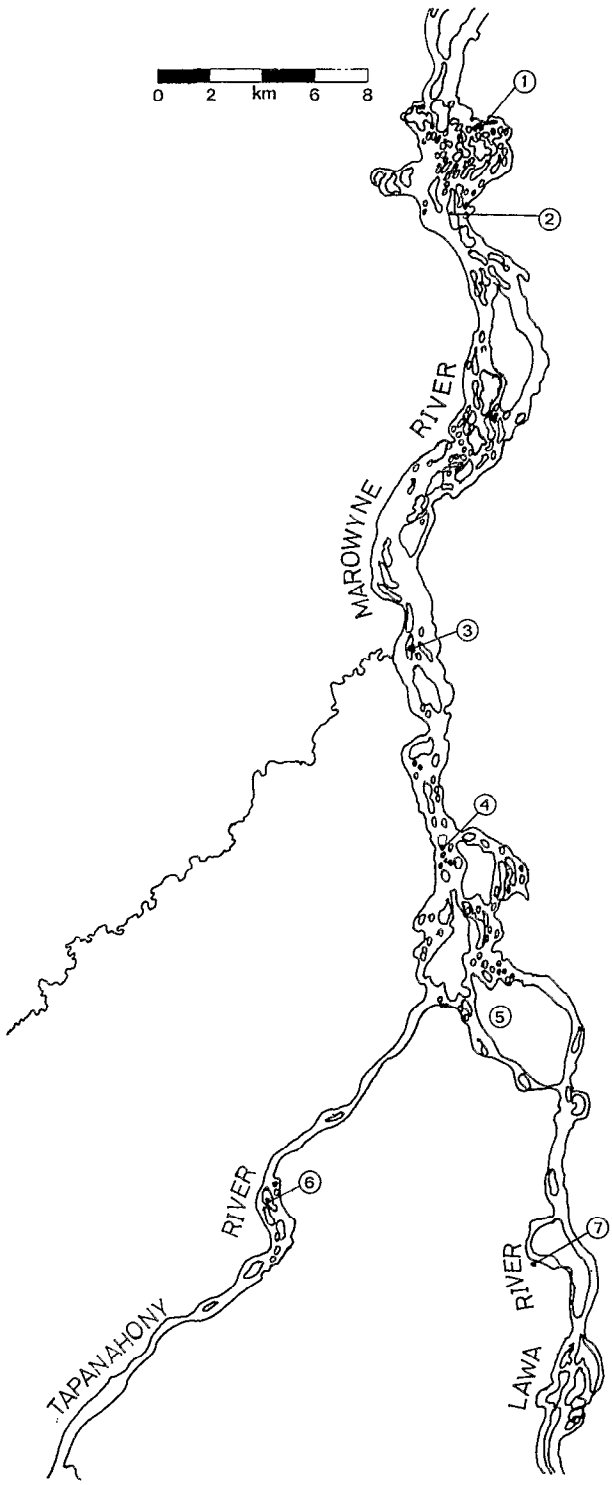
name Rivers are most important. Geomorphologically the Upper-Marowijne differs from the Upper-Suriname River. The river basin of the Upper-Marowijne consists of river floodplains and the river has a width of 3.5-4 km with many islands. The Upper-Suriname has almost no river floodplains and is much smaller, with a width of about 100-200 m.

THE PEOPLE

Out of Suriname's total population of about 400.000 only an estimated 33.000 people live in the rainforest area. Of these 31.000 are bushnegroes and 2.000 are amerindians. The latter live in small isolated villages in the southern part of Suriname. The bushnegroes mostly live along the Marowijne River (33 %), Suriname River (63 %) and Saramacca River (4 %). They are descendants of escaped slaves and are organized in several tribes, each with their own territories. The women practise slash-and-burn cultivation. Men often work in the coastal region. Along the Upper-Marowijne and its tributaries, the Tapanahony and Lawa Rivers, members of the Djuka tribe spend most of the year in very small settlements, called " camps ", far from their main villages. The camps are always sited on islands in the river basin (fig. 2) close to their cultivations. During periods of tribal ceremonies or festivities they return to their main villages. By contrast, in the Upper-Suriname River, the people of the Saramaccan tribe live in large villages on the banks of the river. Their planting grounds are many hours walking distance from the river.

THE CLIMATE

The climate is a tropical rainforest climate usually with a major rainy season from Mid-March to Mid-August, a major dry season from August to November, a minor dry season from February to Mid-March and a minor rainy season from December to January (Van der Kuyp, 1950). Rainfall data for Stoelmanseiland and river height near Abetredjoeka in the Upper-Marowijne



River are presented in figure 3 c, d for the years 1982, 1983 and 1984.

THE PARASITE

As part of the primary health care programme a system of case detection was introduced in 1982 in the interior in which bloodsmears were collected from 10 % of the population in all villages each month (Schaapveld, 1984). Most of the *Plasmodium falciparum* cases were detected in the Upper-Marowijne River area (table I). In the Upper-Suriname River area malaria incidence has been low in recent years but epidemic outbreaks have been reported previously. The latest epidemic, in 1979/1980, resulted in hundreds of cases. *Plasmodium vivax* occurs only among the amerindians in the southern part of Suriname.

SELECTION OF SAMPLING SITES

Between March 1983 and May 1984 surveys were made at a number of sampling stations in the Upper-Marowijne and Upper-Suriname River areas. In the Upper-Suriname River area only a few malaria cases were reported during the study period, from the Gran Rio tributary (fig. 1). In the Upper-Marowijne River area, with a higher malaria incidence, it was impossible to determine the exact place of transmission due to the extensive travelling between villages and camps by the local people. Therefore sampling stations could not be selected at foci of malaria transmission but were selected at regular intervals over the whole area. The same procedure was followed in the Upper-Suriname River area.

COLLECTION OF MATERIAL

Adults

In the Marowijne River area the sampling stations were visited four days each month (except during holiday periods) by an entomological team of five men. Catches were made simultaneously at peridomestic sites within each settlement and in the forest adjacent to the settlement. Collection periods were evening (18.30-20.30), midnight (23.30-01.30) and morning (04.30-06.30 hours). Mosquitoes were collected from bare legs using an aspirator and flashlight. To

FIG. 2. — The study area in the Upper-Marowijne river area. Indicated are the seven sampling stations : 1. Semisamsonkamp ; 2. Davediekamp ; 3. Dabalangakamp ; 4. Abetredjoeka ; 5. Stoelmanseiland ; 6. Tabiki ; 7. Aselikamp.

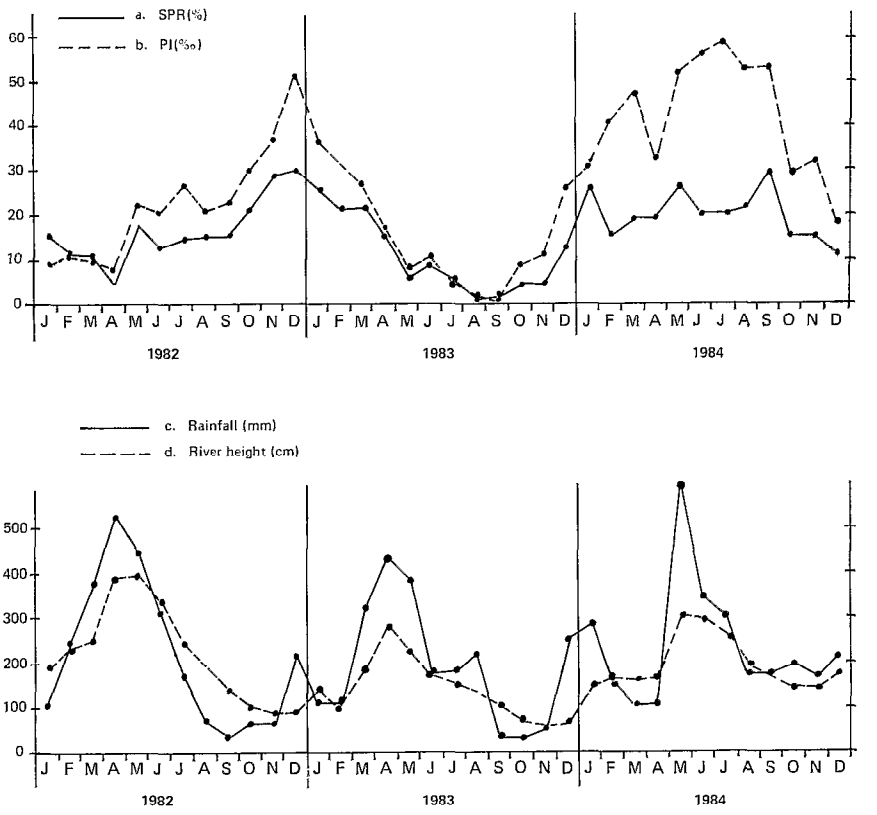


FIG. 3. — (a) Monthly Slide Positivity Rate (SPR) and (b) monthly Parasite Incidence (PI) for the Medical Mission district " Stoelmanseiland " in 1982, 1983, 1984. (c) Rainfall at Stoelmanseiland and (d) river height at Manbari (near Abetredjoeka) in 1982, 1983, 1984.

prevent a bias of data due to personal differences in skill and attraction catchers were rotated between shifts. In the Upper-Suriname River area a four-man team applied the same method but captures were only made at peridomestic sites.

Immatures

In both areas searches for anopheline larvae were every month conducted in the vicinity of each sampling station. Dippers were used to sample forest creeks, river banks, strips of flooded forest (swamps), ponds and pools in the river bed. Habitat details were recorded.

For subsequent identification in the laboratory mosquitoes were preserved dry on naphthaline paper, larvae were preserved in alcohol (70 %). The key of Faran and Linthicum (1981) was used for identification.

TABLE I

Results of bloodsmear examination by the Medical Mission

Year	slides examined	positive P. falc.	positive P. vivax	Number and percentage of total of P. falciparum from Upper-Marowijne	Upper-Suriname	Other areas
1982	37.866	2171	261	1209 (55.7 %)	85 (3.9 %)	877 (40.4 %)
1983	36.300	1012	328	820 (81.0 %)	42 (4.2 %)	150 (14.8 %)
1984	42.355	2477	164	2281 (92.1 %)	30 (1.2 %)	166 (6.7 %)

TABLE II

Total numbers of anophelines collected on human bait at seven stations in the Upper-Marowijne River area from March 1983 to May 1984 (283 nights, 3 396 manhours). Collections were made simultaneously from 18.30-20.30 hr. ; 23.30-01.30 hr. ; 04.30-06.30 hr. at peridomestic sites within human settlements and in adjacent forest areas. The mean number per manhour is shown in brackets

Species of *Anopheles*	Site and hours of collection 18.30-20.30		23.30-01.30		04.30-06.30		total peridomestic	total forest	grand total	perc. of total collected	
	per.	for.	per.	for.	per.	for.				per.	for.
A. darlingi	555	248	1326	451	856	335	2737 (1.61)	1034 (0.61)	3771	72.6	27.4
A. nuneztovari	377	2966	34	241	29	140	440 (0.26)	3347 (1.97)	3787	11.6	88.4
A. oswaldoi	28	319	2	63	2	53	32 (0.02)	435 (0.26)	467	6.8	93.2
A. punctimacula	2	204	0	113	0	54	2 (0.01)	371 (0.22)	373	0.5	99.5
A. mediopunctatus	0	24	1	11	0	2	1 (0.01)	37 (0.02)	38	2.6	97.4
A. nelvai	1	1	0	0	0	0	1 (0.01)	1 (0.01)	2	( )*	( )*
A. triannulatus	0	1	0	0	0	0	0 (0.00)	1 (0.01)	1	( )*	( )*
A. peryassui	0	6	0	0	0	1	0 (0.00)	7 (0.01)	7	( )*	( )*

* ( ) numbers to small

Results

RELATIVE ABUNDANCE

Collections were made on a total of 283 nights in the Marowijne River area. *A. darlingi* was the anopheline species most represented in the peridomestic catch. Out of a total of 3 213 anophelines 85.2 % were *A. darlingi* (table II). In the nearby forest 5 233 anophelines were collected but only 19.8 % were *A. darlingi*, whereas *A. nuneztovari* comprised 63.9 % of the catch. Of the total number of *A. darlingi* caught, 72.6 % were collected at the peridomestic site. In table III the stability of this trend among the several stations is shown. Only Stoelmanseiland is an exception but this might be an artefact due to the very low local biting density of *A. darlingi*. Of *A. nuneztovari* and *A. oswaldoi* only 11.6 % and 6.8 % respectively were collected peridomestically (fig. 4, table II). Highest biting densities of *A. darlingi* were observed during the period 23.30-01.30 hours whereas *A. nuneztovari* and *A. oswaldoi* were most numerous during the catching period 18.30-20.30 hours.

In the Upper-Suriname River area *A. darlingi* was only collected along the Gran Rio tributary (table IV) where very low densities were recorded ; most were collected from 18.30-20.30 hrs. *A. nuneztovari* was the predominant man-biting species in this area comprising over 80 % of the total catch.

TABLE III

Total numbers of *Anopheles darlingi* collected on human bait per sampling station and per collection site in the Upper-Marowijne River area from March 1983 to May 1984 (283 nights, 3 396 manhours). Collections were made simultaneously from 18.30-20.30 hr. ; 23.30-01.30 hr. ; 04.30-06.30 hr. at peridomestic sites within human settlements and in adjacent forest areas. The percentage of the total is shown in brackets

sampling station	peridomestic	forest	total
Semisamsonkamp	1062 (75.1)	352 (24.9)	1414
Davediekamp	413 (72.8)	154 (27.2)	567
Dabalangakamp	101 (75.9)	32 (24.1)	133
Abetradjoeka	439 (70.1)	187 (29.9)	626
Stoelmanseiland	6 (31.6)	13 (68.4)	19
Tabiki	302 (56.4)	233 (43.6)	535
Aselikamp	414 (86.8)	63 (13.2)	477
Total	2737 (72.6)	1034 (27.4)	3771

SEASONAL FLUCTUATIONS IN BITING DENSITY

In figure 5 the monthly mean biting densities of *A. darlingi* in the Upper-Marowijne River area are presented for six sampling stations separately. Because of the low biting densities per manhour no data for Stoelmanseiland have been presented. Seasonal variations differed between the several sampling stations. At Tabiki and Abetedjoeka fluctuations were not marked. On Davediekamp and Dabalangakamp peak

TABLE IV

Total numbers of anophelines collected on human bait in the Upper-Suriname River area from March 1983 to April 1984 (1 434 manhours, Upper-Suriname River 107 nights and Gran Rio 132 nights). Collections were made at peridomestic sites in villages from 18.30-20.30 hr. ; 23.30-01.30 hr. and 04.30-06.30 hr. The mean number per manhour is shown in brackets

Species	hours of collection			total		Grand total
	18.30-20.30	23.30-01.30	04.30-06.30	Upper-Suriname	Gran Rio	
A. darlingi	84 (0.18)	21 (0.04)	10 (0.02)	0	115	115 (0.08)
A. nuneztovari	808 (1.69)	12 (0.03)	21 (0.04)	171	670	841 (0.59)
A. oswaldoi	84 (0.18)		4 (0.01)	39	49	88 (0.06)
A. apicimacula	2 (0.01)			2	0	2 (0.01)
A. punctimacula	2 (0.01)			0	2	2 (0.01)
A. mediopunctatus	1 (0.01)			1	0	1 (0.01)

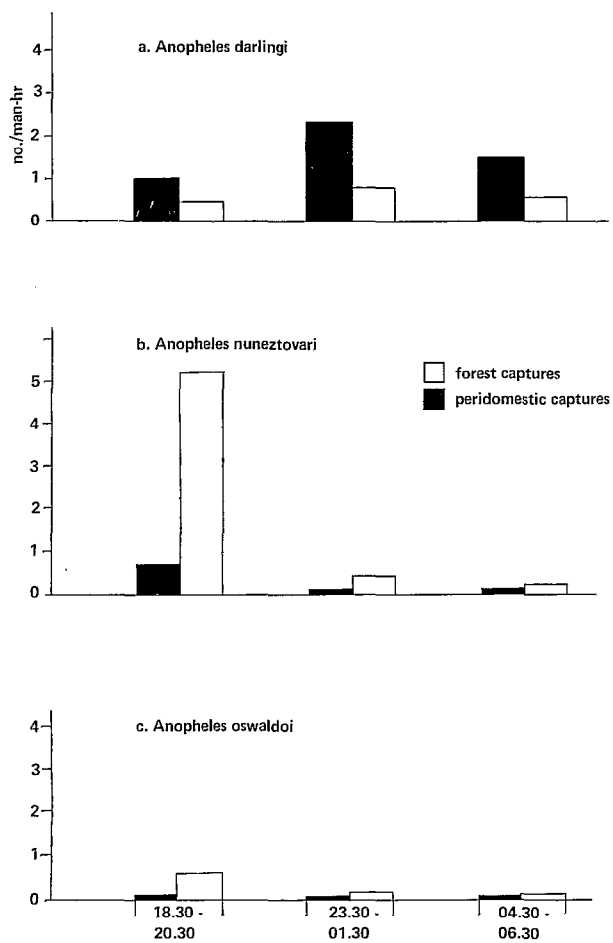


FIG. 4. — Comparison of captures of (a) *A. darlingi* (b) *A. nuneztovari* and (c) *A. oswaldoi* at peridomestic and forest sites. Data are calculated from table 2.

densities were evident during the long dry season. Semisamsonkamp had high densities during the long and short dry periods and low densities during the long and short rainy season. In Aselikamp biting densities reached a peak during the long rainy season.

Seasonal fluctuations in biting density of *A. nuneztovari* and *A. oswaldoi* followed the same pattern at all sampling stations. Therefore monthly biting densities of all sampling stations are presented together in figure 6. *A. nuneztovari* exhibited a well defined dry season peak. *A. oswaldoi* occurred in low densities throughout the year but with a slight increase during the long rainy season.

ECOLOGY OF LARVAE

Habitats where larvae were found could be divided into four categories as follows :

— *creeks* : small forest streams almost completely shaded by the forest canopy ; roots, fallen trunks and other obstacles provided suitable breeding places ;
— *river edge* : deep water mats of water hyacinth (*Eichhornia*) and water fern (*Salvinia*) or floating debris protected from the river bank ; usually this habitat was partly shaded by the forest near river bank ;
— *flooded forest* : in the rainy season the river sometimes overflows its banks and floods part of the forest behind it ; in open, sunny places between emergent plants or grass stems and floating debris larvae were to be found ;
— *pools* : when the water level dropped during the dry season, pools formed in or near the river bed ; pools near the river bank were partly shaded whilst these in the river bed were unprotected.

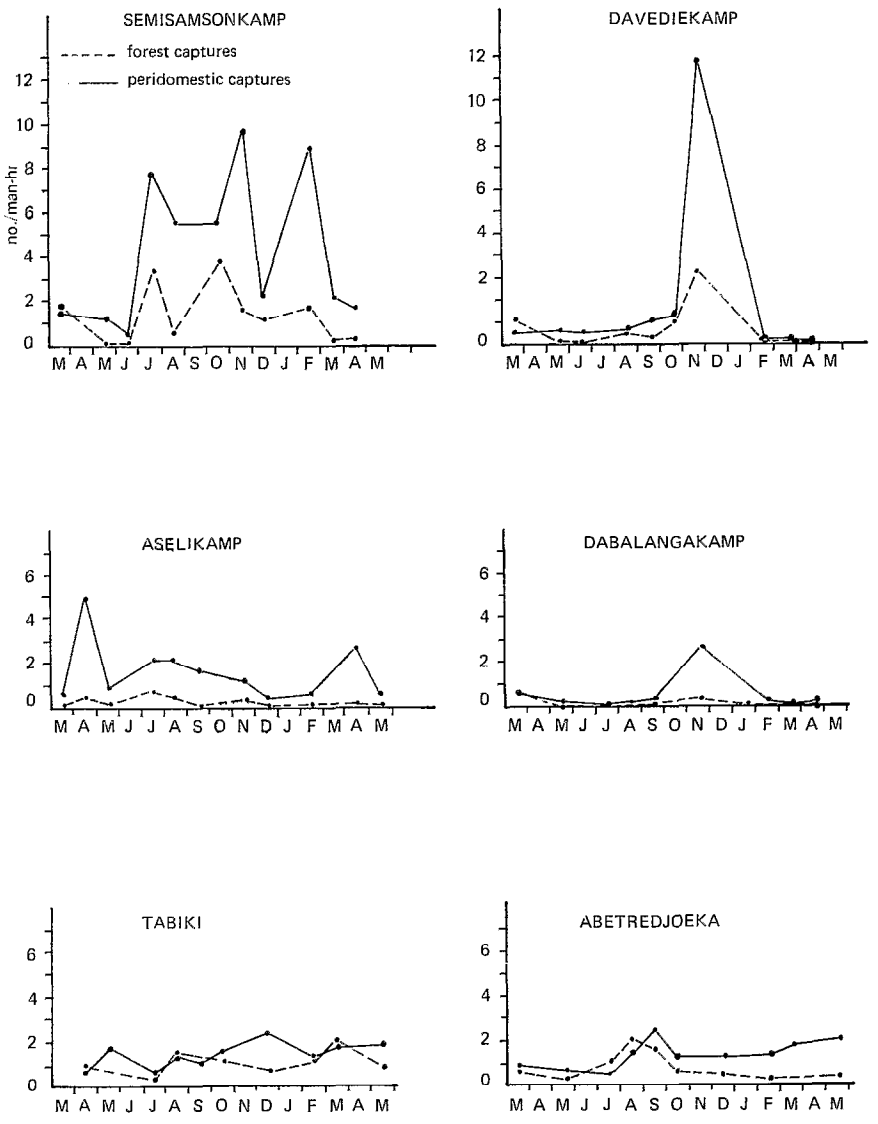


FIG. 5. — Monthly Mean Biting Rate of *A. darlingi* for six sampling stations in the Upper-Marowijne river area from March 1983 to May 1984. Collections are made four nights a month simultaneously peridomestic, in a village and in the adjacent forest. Collection hours : 8.30-20.30 hr. ; 23.30-01.30 hr. and 04.30-06.30 hr.

In all four habitats pH was between 6 and 7. The average water temperature was ± 26° C with a maximum of 40° C and a minimum of 22° C. The highest temperatures were recorded in sunlit pools in the river bed. Measurements were made during the larval collections at daytime between 10.00 and 15.00 hours.

Larvae of *A. darlingi*, *A. oswaldoi* and *A. nuneztovari* were collected from all four habitat types. The most numerous species are *A. nuneztovari* and *A. oswaldoi*. *A nuneztovari* was found breeding extensively in sunlit pools in the river bed during the dry season. *A. oswaldoi*, however, was more commonly found in shaded breeding places. Most larvae were collected in the dry period between August and March. In this period pools in the river bed and sheltered places near the river bank became avai-

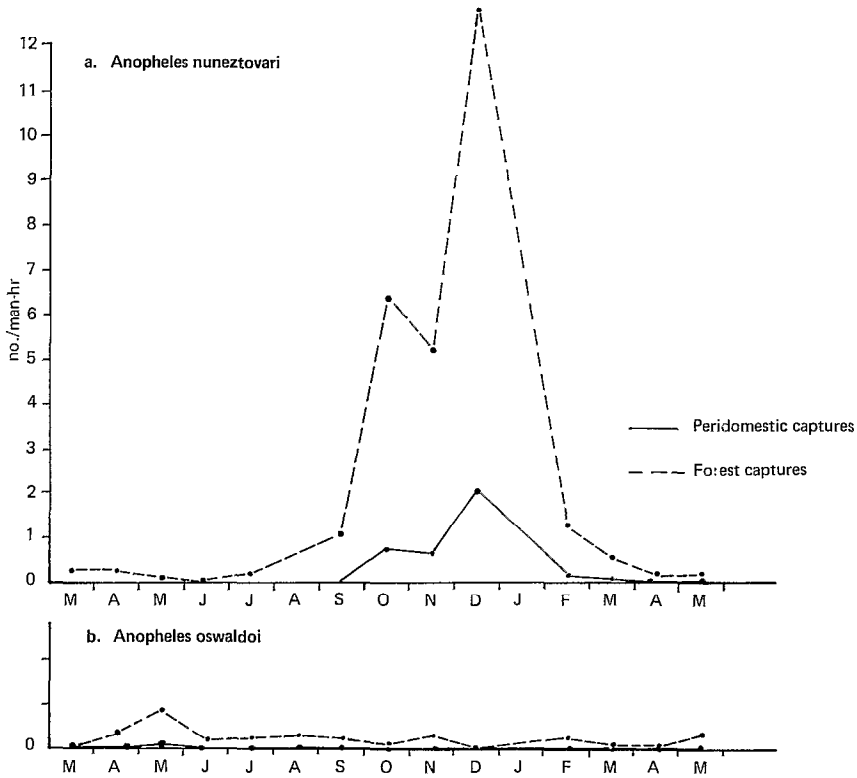


FIG. 6. — Monthly Mean Biting Rate of (a) A. *nuneztovari* and (b) A. *oswaldoi* for seven sampling stations in the Upper-Marowijne river area together. Collections are made on human bait from March 1983 to May 1984 simultaneously peridomestic and in the adjacent forest. Collection hours : 18.30-20.30 hr. ; 23.30-01.30 hr. and 04.30-06.30 hr.

lable. Throughout the year creeks were found to be suitable habitats for most anophelines. In the rainy season strips of forest became flooded, some providing breeding sites for several months before drying out.

Discussion and conclusions

THE ROLE OF A. *DARLINGI* AS A VECTOR OF MALARIA.

In figure 3 a, b monthly parasite incidence (P.I.) and monthly slide positivity rate (SPR) of *P. falciparum* are for 1982-1984 presented for the medical district Stoelmanseiland. This area includes the study area in figure 2. Fluctuations occurred but did not follow a fixed seasonal pattern, with transmission occurring throughout the year. The only anopheline species biting man at night in villages throughout the year was A. *darlingi* but seasonal densities of this species varied between catching stations. A. *darlingi* was also the only anopheline which was more prevalent at peridomestic sites than in the forest. In Brazil de Bustamente (*in* Giglioli, 1956) found similar results ; 65 % of A. *darlingi* were captured in a village and 35 % in the forested environment. Of all anophelines collected outside of the village A. *darlingi* constituted only 12 % while inside of the village 91 % appeared to be A. *darlingi*. This preference for biting in human settlements might indicate some degree of adaptation to men (Giglioli, 1956).

Biting activity of A. *darlingi* was higher from 23.30-01.30 hours than in the early evening and early morning and is in agreement with the observations of Hudson (1984) in the same region, by Elliott (1972) in Colombia and Charlwood and Hayes (1978) in Amazonas.

However, in French Guyana, Pajot *et al.* (1977) found a biting activity with peaks not only in the middle of the night, but also at dusk and dawn.

In the Upper-Suriname River area during the study period malaria transmission was negligible. The apparent absence of A. *darlingi* along the Upper-Suriname River and the very low densities along the Gran Rio

TABLE V

Anopheline larval habitats during dry and wet season in Upper-Marowijne river area (a) and Upper-Suriname river area (b) from March 1983 to April 1984

a. Upper-Marowijne river area

habitat	creek		river edge		flooded forest		pool	
season	wet	dry	wet	dry	wet	dry	wet	dry
no° of sites investigated	62	78	2	31	11	4	7	84
percentage (%) of sites pos. for :	%	%	%	%	%	%	%	%
A. darlingi	11.3	14.1	0.0	35.5	9.1	25.0	0.0	7.1
A. nuneztovari	8.1	11.5	0.0	67.7	9.1	50.0	0.0	72.6
A. oswaldoi	87.1	51.3	100.0	61.3	90.9	100.0	85.7	71.4
A. punctimacula	3.2	12.8	0.0	3.2	9.1	0.0	0.0	1.2
A. mediopunctatus	17.7	21.8	0.0	0.0	9.1	25.0	28.6	0.0
A. nimbus	0.0	1.3	0.0	3.2	0.0	0.0	0.0	0.0

b. Upper-Suriname river area

habitat	creek		river edge		flooded forest		pool	
season	wet	dry	wet	dry	wet	dry	wet	dry
no° of sites investigated	25	48	3	20	4	1	1	34
percentage (%) of sites pos. for :	%	%	%	%	%	%	%	%
A. darlingi	8.0	4.2	0.0	5.0	0.0	0.0	0.0	0.0
A. nuneztovari	12.0	14.6	0.0	65.0	50.0	0.0	0.0	97.1
A. oswaldoi	48.0	58.3	0.0	70.0	75.0	0.0	0.0	88.2
A. punctimacula	16.0	27.1	0.0	5.0	25.0	0.0	0.0	5.8
A. mediopunctatus	48.0	35.4	0.0	0.0	50.0	0.0	0.0	5.8
A. apicimacula	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0

presumably account for this situation. In the Gran Rio area the catching period 18.30-20.30 hr. did yield more *A. darlingi* females than did the other two catching periods but this apparent contrast with the results from the Upper-Marowijne River area may be attributable to the small catch size. Alternatively geographical variations in biting cycles as observed by Charlwood and Hayes (1978) in Brazil provide an explanation for this observation.

In the Upper-Marowijne River area *A. nuneztovari* was the second most common species biting man at peridomestic sites but was seasonally abundant only from October to January and was more active in the forest. The activity peak just after sunset has also been described for the Amazon region by Elliott (1972) and for the Brokopondo Lake in Suriname by Panday (1977). The possible role of *A. nuneztovari* as a secondary vector of malaria in Suriname was reviewed by Panday (1977) but remains unconfirmed.

SEASONAL ABUNDANCE IN RELATION TO LARVAL ECOLOGY

The low biting density of *A. nuneztovari* during the long rainy season may be explained by the disappearance, due to high water levels, of suitable, sunny breeding places in the river bed and near the river bank. *A. oswaldoi* was found breeding in all habitats except sunny places in the river bed. An increase in

flooded forest areas may account for the rise in biting density observed during April and May 1983.

Seasonal fluctuations in biting density of *A. darlingi* differed between catching station. These differences are presumably due to variations in availability of larval habitats. Higher biting densities at Aselikamp during the rainy season were, according to Hudson (1984), probably due to an increase in larval habitats in the flooded forest. In areas with a higher biting density in the dry season river banks may constitute productive breeding places. Along the Gran Rio *A. darlingi* was only captured in the dry season. In Pokigron along the Upper-Suriname River Fleming, in 1962, found a peak in biting density near the end of the rainy season. Differences in seasonal fluctuations were also observed in Brazil by Charlwood (1980). In Amazonas he found a peak in biting activity at the end of the long dry season and in Mato Grosso he found a peak at the end of the long rainy season.

Differences in geomorphology of the Upper-Marowijne River and the Upper-Suriname River may account for the comparatively high or low densities in the two areas. The Upper-Suriname River is a narrow, eroding river with banks which seldom overflow. In the Upper-Marowijne River area the river basin consists of river flood plains which readily flood. In some places the river attains a width of 3.5-4 km, with many islands between its banks and which provide extensive breeding places.

SEASONAL ABUNDANCE IN RELATION TO MALARIA TRANSMISSION

Because of the frequent travelling of the Djuka people it is difficult to determine the exact sites of transmission. With localized seasonal fluctuations in biting density of *A. darlingi* meaningful comparison between vector densities and malaria incidence for the whole area is not possible. In the Upper-Marowijne River area suitable breeding places for *A. darlingi* are available throughout the year. Travelling Djuka's will introduce parasites into these areas, where the transmission potential appears to be high.

ACKNOWLEDGEMENTS

I wish to thank Prof. Dr. B. F. J. Oostburg, Dr. L. E. M. Jozefzoon and Mr. R. Dompig of the Bureau of Public Health, Paramaribo, for support in organizational and logistical matters ; Prof. Dr. H. J. van der Kaay, Prof. Dr. J. J. Laarman, Dr. J. E. Hudson and Dr. M. Nathan for their advices ; Mr. A. Baboeram of the Medisch Wetenschappelijk Instituut for his technical assistance and P. Poetisie and his entomological field team for their help with collecting data.

Manuscrit accepté par le Comité de Rédaction le 10 février 1987.

REFERENCES

BARNES (S. T.) and JENKINS (C. D.), 1972. — Changing personal and social behaviour : experiences of health workers in a tribal society. *Soc. Sci. Med.*, 6 : 1-15.

BONNE (C.) and BONNE-WEPSTER (J.), 1925. — Mosquitoes of Surinam. Meded. K. Vereen. indisch. Inst. Amst. n° 21, 558 p. (Afd. Trop. Hyg. n° 13).

CHARLWOOD (J. D.), 1980. — Observations on the bionomics of *Anopheles darlingi* Root (Diptera : Culicidae) from Brazil. *Bull. ent. Res.*, 70 : 685-692.

CHARLWOOD (J. D.) and HAYES (J.), 1978. — Variações geográficas no ciclo de picado do *Anopheles darlingi* Root no Brazil. *Acta Amazon.*, 8 : 601-603.

ELLIOTT (R.), 1972. — The influence of vector behavior on malaria transmission. *Am. J. Trop. Med. Hyg.*, 21 : 755-763.

FARAN (E. M.) and LINTHICUM (K. J.), 1981. — A handbook of the Amazonian species of *Anopheles* (*Nyssorhynchus*) (Diptera : Culicidae). *Mosq. Syst.*, 13, 1 : 1-81.

GIGLIOLI (G.), 1956. — Biological variations in *Anopheles darlingi* and *Anopheles gambiae* : their effect on practical malaria control in the neotropical region. *Bull. Wld. Hlth. Org.*, 15 : 461-471.

HUDSON (J. E.), 1984. — *Anopheles darlingi* Root (Diptera : Culicidae) in the Suriname rainforest. *Bull. ent. Res.*, 75 : 129-142.

PAJOT (F. X.), LE PONT (F.), MOLEZ (J. F.) and DEGALLIER (N.), 1977. — Agressivité d'*Anopheles* (*Nyssorhynchus*) *darlingi* Root, 1926 (Diptera, Culicidae) en Guyane française. *Cah. ORSTOM, Sér. Ent. méd. et Parasitol.*, 15, 1 : 15-22.

PANDAY (R. S.), 1977. — *Anopheles nuneztovari* and malaria transmission in Surinam. *Mosq. News*, 37 : 728-737.

PANDAY (R. S.), 1980. — A medical entomological survey in West-Surinam. *Sur. Med. Bull.*, 3 : 61-68.

SCHAAPVELD (K.), 1984. — Integration of antimalaria activities into basic health services in Suriname. Thesis, Leiden.

VAN DER KUYP (E.), 1950. — Contribution to the study of the malarial epidemiology in Surinam. Meded. K. Vereen. indisch. Inst. Amst. n° 89, 146 p. (Afd. Trop. Hyg. n° 18).