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ANOPHELES NUNEZTOVARI AND MALARIA TRANSMISSION IN SURINAM

ROY S. PANDAY

Medisch Wetenschappelijk Instituut, Biology Division, P.O. Box 537, Paramaribo, Surinam

ABSTRACT. During recent entomological surveys a tremendous increase in numbers of *Anopheles nuneztovari* Gabaldon has been observed in the interior of Surinam. The construction of the Afobaka dam, which gave rise to the Brokopondo storage lake, was the main factor responsible for this increase. The scarcity of *An. darlingi*, the principal vector of *Plasmodium falciparum* in Surinam, and the failure to capture this species during recent epidemics of malignant malaria in certain areas where *An. nuneztovari* abound, indicate that the latter might be involved in active transmission of the parasite. Breeding experiments with *An. nuneztovari* showed a duration of 1 day for the egg stage, 7 days for the larval stages and 1 day for the pupal stage. The gonotrophic cycles may last 4 days each, except the 1st which takes 5 days. The daily biting activity pattern of this species shows a unimodal pattern with a sharp peak at 6:00–7:00 pm. The maximum and minimum parous rates which may be reached over a longer period of time are 0.69 and 0.14 respectively, the mean being 0.34. This rather high parous rate indicates that this species may well act as a good vector of pathogens, because it feeds readily on man and occurs in large numbers during certain periods of the year. It appears that the population of *An. nuneztovari* at Brownsweg is fully susceptible to DDT, dieldrin and malathion.

INTRODUCTION

Anopheles nuneztovari Gabaldon was initially reported from Surinam in 1949 (Van der Kuyp 1949). Until now this species was considered to be relatively unimportant because of its limited geographical distribution and abundance. Its role as a potential vector of *Plasmodium falciparum* was totally neglected. This paper presents the results of recent entomological surveys which show that this species now occupies vast areas in the interior of Surinam, where it occurs in great numbers. It appears that in a large part of the interior *An. nuneztovari* is at present the dominant anthropophilic mosquito, outnumbering other species by far, and there are indications that it might have been involved in recent malaria outbreaks. It became clear that more ecological information on this species was badly needed, and therefore a field station was established near Brownsweg at the border of the Brokopondo storage lake. Here observations on abundance, diel activity, physiological age, susceptibility of adults to insecticides and life cycle characteristics were made.

MATERIAL AND METHODS

THE STUDY AREA. According to Bruyning (1952b) Surinam may be divided into 4 zones:

1. The marshy coastal region in which shell and sand ridges lie more or less parallel with the coast.
2. The sandy savanna zone which touches the coast in the eastern part and from there takes a west-south-westerly direction. Sandy plains in this zone alternate with swamps and forests. The part between the Saramacca and Upper Commewyne Rivers (west and east of Surinam River) is the driest, consisting mainly of sandy plains with thin scrub. West of the Saramacca River and east of the Upper Commewyne River there are only a few small and open sandy plains.
3. The hilly and mountainous forest region which gradually merges into the savanna and swamp regions of the south.

During 1975 and 1976 several entomological surveys were made in the coastal region, the savanna zone and the hilly and mountainous forest region to determine the geographical distribution of *An. nuneztovari*. From July through December 1976 observations on biting activity patterns, abundance, physiological age, susceptibility of adult mosquitoes to insecticides and life cycle characteristics were made near Brownsweg, a Bushnegro village situated at the northwestern border of the Brokopondo storage lake in the hilly and mountainous forest region. Adult mosquitoes were captured some 15 m inside the forest near the lake, and larvae were sampled from both the edge of the lake and temporary grassy sunlit swamps.

MAINTAINING A LABORATORY COLONY. Adult females caught on human bait were given human blood meals. They were held in metal cages sized 45x45x45 cm. and were supplied with a sugar solution, raisins and fresh water; the relative humidity was kept between 80 and 100%. Eggs were laid in a plastic container partially filled with water and grassy vegetation. The grassy vegetation seems a requisite for oviposition to occur. Larvae and pupae were reared in enamel laboratory containers filled with water and grassy vegetation. They were fed a mixture of dog chow and brewer's yeast. The emerged adults were transferred to the metal cages mentioned above, given a blood meal and given time for development. Infertile eggs were laid, and dissectious showed spermathecae without spermatozoa.

BITING ACTIVITY PATTERN. In October 1976 a series of three 72-hr catches on human bait was carried out by a team of 4 pairs of collectors. Each pair worked during periods of 3 hr, so that they were "on" 3 hours and "off" 9 hours. The composition of the pairs was changed every other 24-hr session. Collecting was done on a 15-minute basis; after each 15-minute period a new tube was used. Between 6:00–7:00 pm collecting was done on a 5-minute basis.

ABUNDANCE. From July through December 1976 catches on human bait were made near Brownsweg from 6:00–7:00 pm. The actual local time was converted, so that sunset was fixed at 6:00 pm. Thus the catches in various parts of the year were adjusted to sunset and hence comparable. When possible, 5 catches a week were carried out with 3 collectors. Sometimes the number of catches per week was reduced to 4 or even 3. For each species the total number per catch was converted to the number of specimens per man hour.

AGE DETERMINATION. The captured mosquitoes were first identified and separated according to species. Dissections of a representative sample (about 100 females) of *An. nuneztovari* were made daily in a drop of distilled water only when the catch was large enough. The ovaries were carefully transferred to a separate drop of distilled water, where they dried out, after which time the parous rate was determined (Detinova 1962). Less than 1% of the dissected mosquitoes had ovaries in the 3rd Christophers' stage or beyond, and these were excluded from examination.

SUSCEPTIBILITY OF ADULT MOSQUITOES TO INSECTICIDES. Baselines for DDT, dieldrin and malathion susceptibility were established by the standard WHO test for insecticide resistance in adult mosquitoes. Tests were conducted on June 2, and October 11, 1976 for DDT susceptibility, on June 2 and October 13 for dieldrin susceptibility and on June 3 and October 8 for malathion susceptibility. The mosquitoes were blood-fed from human source and maximum and minimum temperatures during the 24 hr holding period were about 38°C and 22°C, respectively, whereas relative humidity was 80–100%.

RESULTS AND DISCUSSION

After Van der Kuyp (1949) mentioned the occurrence of *An. nuneztovari* in Surinam, this species has been captured on several other occasions. Before the

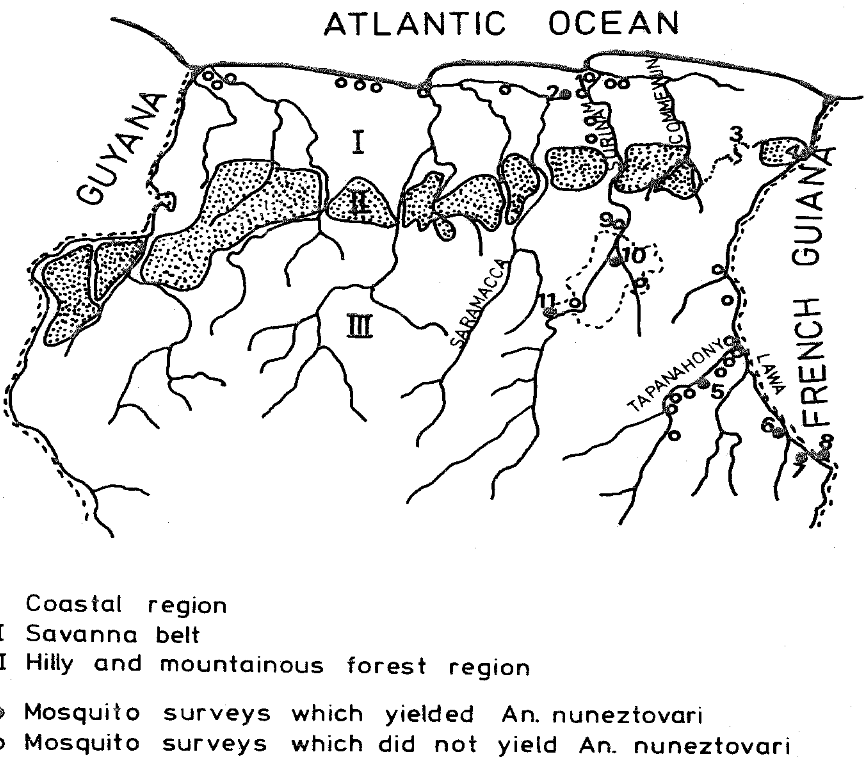

Fig. 1. Geographical records of *An. nuneztovari* before 1964. 1= Paramaribo, 2= Leiding XIa, 3= Moengo, 4= Albina, 5=Sajé, 6= Cottica, 7= Benzdorp, 8= Wacapoe, 9= Afobaka, 10= Ganzee, 11= Pokigron.

completion of the Afobaka dam in 1964, however, this mosquito was considered to be a rarity. In 1971 the lake was filled, and the spillway was used for the first time. Fig. 1 shows the geographical records of *An. nuneztovari* before 1964 (Van der Kuyp 1950, Bruyning 1952a, Van Thiel 1962, and Fleming 1963). In June 1946 Van der Kuyp collected some larvae from Leiding XIa near Paramaribo in the coastal area. Until now this is the only record from the coastal area and is therefore considered to be an anomalous finding. On June 13, 14 and 15, 1952 Bruyning captured 30 females on human bait and collected a number of larvae in Sajé, a village situated on the Tapanahony River in the interior. Van Thiel, who made entomological surveys only in the future lake area, captured 5 females on human bait on June 7 and 8, 1960 in the village of Ganzee. In discussing the chances of eradication of malaria and *An. darlingi* Root in the future lake area he considered it possible that *An. nuneztovari*, which is not affected by house spraying, may take the place of *An. darlingi*, something that has really happened. In the last 2 weeks of January 1963 Fleming captured 13 females on human bait in Cottica and Benzdorp, whereas he col-

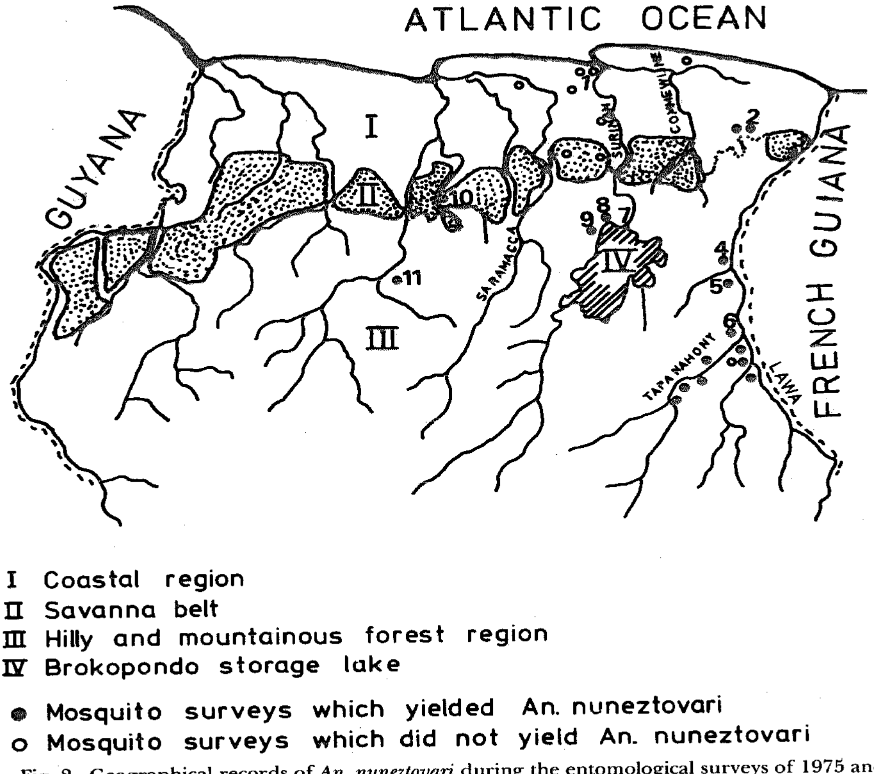

Fig. 2. Geographical records of *An. nuneztovari* during the entomological surveys of 1975 and 1976. 1= Paramaribo, 2= Moengo, 3= Albina, 4= Nason, 5= Bergi, 6= Stoelmanseiland, 7= Afobaka, 8= Brownsweg, 9= Brownsberg, 10= Tibiti bridge, 11= Voltzberg.

lected 68 specimens, which were resting in a stable where they were feeding on cattle and sheep at Wacapoe. From June 1962 to May 1963 only 7 specimens were caught on human bait at Pokigron, a village situated in the future lake area. Fig. 2 represents the findings of *An. nuneztovari* during the entomological surveys of 1975 and 1976. It appears that this species has occupied a much larger area than before, and what is more important, has increased its numbers considerably, so that at this moment *An. nuneztovari* seems to be the dominant anthropophilic *Anopheles* species of the hilly and mountainous forest region, outnumbering the others by far (Table 1).

The figures 1 and 2 suggest that in general *An. nuneztovari* is restricted to the hilly and mountainous forest region. The enormous numbers of females caught at Brownsweg, and the observed extensive breeding of larvae in the lake during certain periods of the year led to the assumption that the construction of the Afobaka dam, which gave rise to the Brokopondo storage lake, was the main factor responsible for the further spreading and tremendous increase in numbers of this species. The scarcity of *An. darlingi*, a mosquito which nowadays appears to occur only in the deep interior far south of the savanna belt and which is considered to be the principal vector of *Plasmodium falciparum*,

Table 1. Summary of the *Anopheles* species caught during the entomological surveys of 1975 and 1976 in the hilly and mountainous forest region. H = catch on human bait, T.T. = catch with the Trinidad trap. The figures represent the number of specimens captured.

Locality	Species	H	TT
Moengo area	*An. aquasalis* Curry	74	12
	An. apicimacula Dyar & Knab	6	13
	An. braziliensis (Chagas)	13	1
	An. nuneztovari Gabaldon	17	0
	An. mediopunctatus (Theobald)	12	3
	An. oswaldoi (Peryassu)	13	10
	An. peryassui Dyar & Knab	11	4
	An. punctimacula Dyar & Knab	1	15
Albina	*An. aquasalis* Curry	1	0
	An. nuneztovari Gabaldon	2	0
	An. oswaldoi (Peryassu)	0	2
Tapanahony river area	*An. darlingi* Root	61	0
	An. nuneztovari Gabaldon	354	27
	An oswaldoi (Peryassu)	0	1
	An. punctimacula Dyar & Knab	1	1
Lawa river area	*An. nuneztovari* Gabaldon	6	0
	An. oswaldoi (Peryassu)	0	10
Bergi	*An. nuneztovari* Gabaldon	3	0
	An. oswaldoi (Peryassu)	0	5
	An. punctimacula Dyar & Knab	0	1
Nason	*An. nuneztovari* Gabaldon	7	0
Brownsberg	*An. nuneztovari* Gabaldon	16	0
Brownsweg	*An. nuneztovari* Gabaldon	16,455	749
	An. punctimacula Dyar & Knab	0	1
Tibiti bridge	*An. nuneztovari* Gabaldon	92	41
	An. oswaldoi (Peryassu)	3	0
Voltzberg	*An. nuneztovari* Gabaldon	3	0

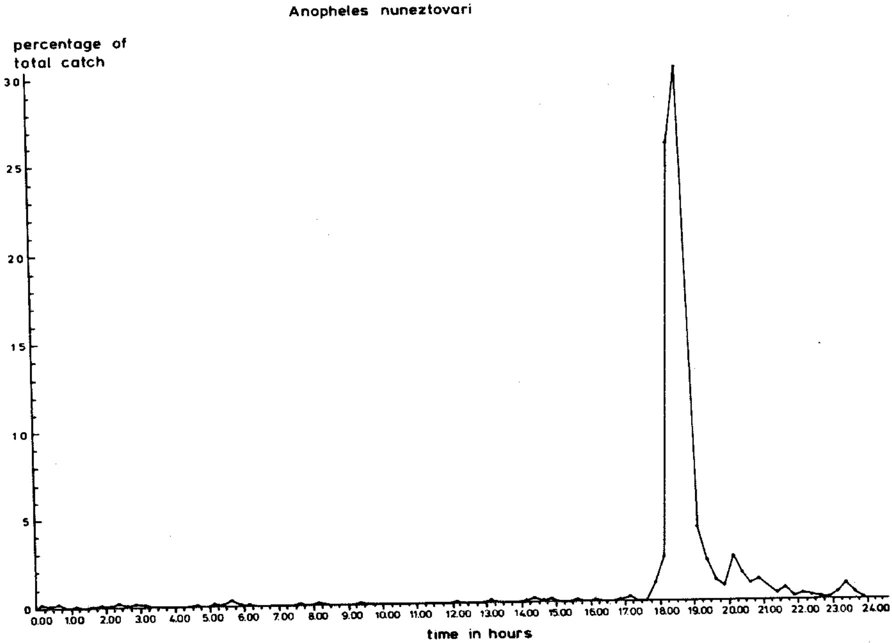

Fig. 3. Daily biting activity pattern of *An. nuneztovari.*

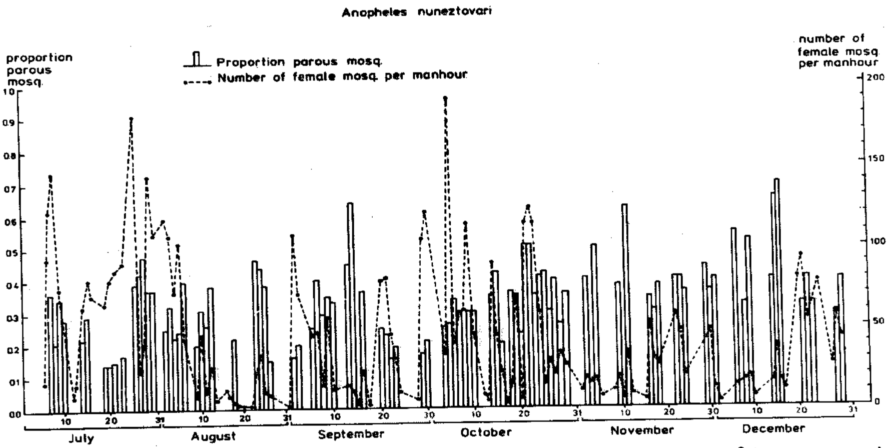

Fig. 5. Daily distribution of adult female population density and parous rate of *An. nuneztovari,* July–December 1976.

and the failure to capture this species during recent epidemics of malignant malaria in certain areas may indicate the presence of at least a 2nd vector in Surinam.

In 1974 after many decades of eradication *falciparum* malaria reappeared in the coastal area. During June and July local transmission of *P. falciparum* took place in the Moengo area, resulting in 49 cases. This malaria outbreak was controlled by emergency operations and no additional cases have been found. Catches on human bait during the epidemic revealed the presence of the following anophelines in the Moengo area: *An. nuneztovari, An. aquasalis, An. oswaldoi, An. braziliensis* and *An. apicimacula*. Both *An. aquasalis* and *An. nuneztovari* occurred in fairly large numbers. In April 1976 an epidemic of malignant malaria raged in the Tibiti bridge area, situated in the southern part of the savanna belt. During this period *An. nuneztovari* was caught in large numbers both on human bait and with the Trinidad No. 10 trap, baited with adult white mice. *An. oswaldoi* was the only other anopheline species caught. The latter was captured on human bait in very low number. The findings mentioned above indicate that *An. nuneztovari* might be involved in active transmission of *P. falciparum* in Surinam, although the possibility of temporary extensions of the breeding area of *An. darlingi*, due to suitable weather conditions during the principal rainy season as mentioned by Bruyning (1952 b), must be kept in mind. Therefore it was decided to establish a field station at Brownsweg to study certain aspects of the biology and behavior of *An. nuneztovari*.

LIFE CYCLE CHARACTERISTICS; Breeding experiments showed a duration of 10 days for all immature stages and young adult life until the 1st blood meal. The length of the 1st gonotrophic cycle was 5 days, whereas subsequent gonotrophic cycles lasted 4 days each.

BITING ACTIVITY PATTERN. The biting activity pattern in 24 hr is shown in Fig. 3. *An. nuneztovari* shows a unimodal pattern with a sharp peak at 6:00–7:00 pm. Sunset was fixed on 6:00 pm and the duration of twilight in Surinam is 22 min. Fig. 4, which gives a more detailed account of the peak period, shows that the peak begins in fact at the end of twilight and lasts until ca. 7:00 pm. Bruyning (1952a) also observed a distinct peak in biting activity just after nightfall. Elliott (1972) summarized the evidence for at least 2 sibling populations of *An. nuneztovari*. He mentioned that in Brazil and Surinam, in Ecuador and almost certainly in Bolivia and Peru, there is a species that bites at sunset, and preferentially on animals. In northern Colombia and western Venezuela, a closely similar but slightly smaller species bites later in the night, and therefore mainly inside houses. It is a primary vector of malaria, as it forms up to 99% of the anophelines biting man in highly malarious areas well outside the range of *An. darlingi*, and where the ecology is unsuitable for the other Colombia vectors. Kitzmiller et al. (1973), who studied the chromosomes of some Brazilian, Venezuelan and Colombian populations, found that the Venezuelan and Colombian populations, responsible for malaria transmission in certain areas of these countries, differ in an X-chromosome arrangement from the Brazilian specimens, the difference apparently being due to the fixation of an inversion in the homozygous state in one population.

ABUNDANCE. From July through December 1976, 13,824 females of *An. nuneztovari* were caught on human bait, indicating that the Surinam population of this species is readily attracted to man. Fig. 5, which represents the daily variation in adult female population density and parous rate, shows that the number of female mosquitoes per man-hour may be as high as 192 and as low as 1, the mean being 44.75. Catches were made daily during the peak period from 6:00–7:00 pm. Research on seasonal distribution and population dynamics is still in progress and will be extensively dealt with in a subsequent paper.

AGE DETERMINATION. Fig. 5 also shows that the maximum and minimum parous rates which may be reached are 0.69 and

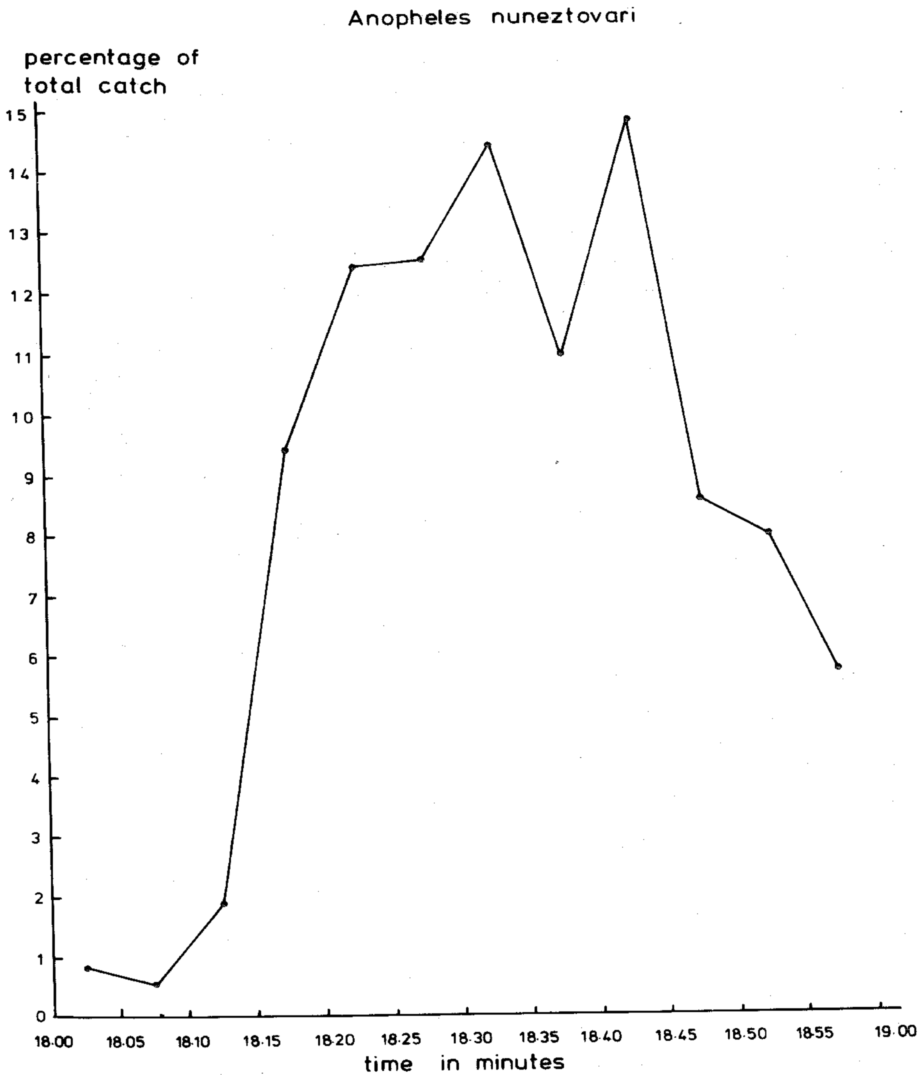

Fig. 4. Detail of biting activity pattern, 6:00–7:00 pm.

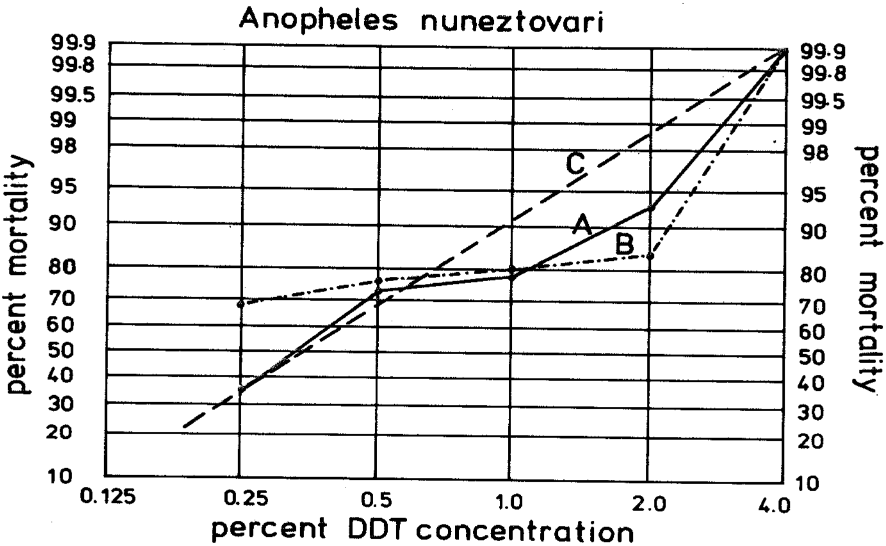

Fig. 6. Sample regression lines for DDT susceptibility. Line A represents the baseline of June 2 and line B that of October 11. Line C is a hypothetical line, designed to fit the observations of both dates.

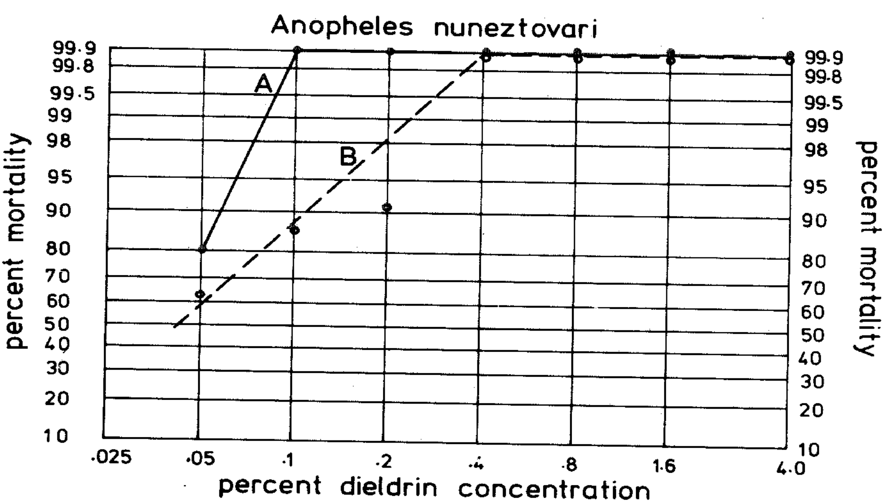

Fig. 7. Sample regression lines for dieldrin susceptibility. Line A represents the baseline of June 2 and line B that of October 13.

0.14, respectively, the mean being 0.34. This rather high parous rate indicates that *An. nuneztovari*, in the Brownsweg area, may well act as a good vector of pathogens because it feeds readily on man and occurs in large numbers during certain periods of the year.

SUSCEPTIBILITY OF ADULT MOSQUITOES TO INSECTICIDES. Fig. 6 shows the sample regression lines for DDT susceptibility. Line A represents the baseline of June 2, line B that of October 11 and line C is a hypothetical line, designed to fit the observations of both dates. It appears that the population is fully susceptible to DDT, a 4.0% concentration causing 100% mortality. The LC_{50} value is estimated to be 0.34%. Fig. 7 shows the sample regression lines for dieldrin susceptibility. Line A represents the baseline of June 2, line B that of October 13. It appears that the populations of both dates were fully susceptible to dieldrin. Concentrations of 0.1% and higher caused 100% mortality on June 2, whereas concentrations of 0.4% and higher were responsible for 100% mortality on October 13. The population of *An. nuneztovari* at Brownsweg also proved to be fully susceptible to malathion, which was applied in the concentrations of 0.5%, 3.2% and 5.0%. All three concentrations gave 100% mortality on both dates, June 3 and October 8.

ACKNOWLEDGMENTS

I am much indebted to Mr. A. Baboeram, Mrs. J. Tjon A Joe-Vervuurt and Mr. D. Kanhai for their technical assistance.

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