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MALARIA VECTORS IN BRAZIL

LEONIDAS M. DEANE

There are no indications of the presence of malaria in Brazil during the first decades after the Portuguese settled in the country in 1500. Apparently the first reference is in Gabriel Soares de Souza's (1587) "Noticia do Brazil", in which the existence of "tertian and quartan fevers" among the Tupinambá indians is mentioned. No record of epidemics is found during the colonial times. In the late 1870s, attention was brought to malaria when thousands of migrants, fleeing from the drought-stricken Northeast, particularly from the almost malaria-free State of Ceará, came into the Amazon Region to collect latex from the native rubber trees during the rubber boom that enriched that region for the next forty years. Nearly all those "nordestinos" suffered from malaria acquired in the Amazon and very many died of it.

Soon after the slaves were freed in 1888, some of the most important farms and plantations in Eastern Brazil -- like the coastal plains of Rio de Janeiro State, the "Baixada Fluminense" and similar areas of São Paulo State, became highly malarious for decades, due to the deterioration of the irrigation and drainage systems as a consequence of the abandonment of the plantations by the former slaves.

Another extensive epidemic occurred, in the Amazon Region again, during the construction of the Madeira-Mamoré Railroad in the beginning of this century as described by Oswaldo Cruz (1910, 1913) and Carlos Chagas (1913), who visited the area and suggested control measures. At that time, not only "nordestinos", but immigrants from other Brazilian states and many foreigners, mostly imported Caribbees, were victims of the disease.

In the late 1930s a violent epidemic broke out in the Northeastern States of Rio Grande do Norte and Ceará, due to the invasion of this zone by the African *Anopheles gambiae*, a sad episode with a happy ending, since this species was eradicated from the country, in 1940.

During the II World War, the Allies needed an incrementation of the natural rubber production, as the plantations in the Orient had been taken over by the Japanese. This led to another mass migration, this time of more than 50 thousand "nordestinos" to the rubber areas of the Amazon and, consequently, a sharp increase in malaria prevalence. Meanwhile, malaria endemicity was being kept high in the valleys of non-Amazonian large rivers, like the São Francisco and the Paraná and in the Baixada Fluminense and other areas in such a way that, by the mid 1940s, before the National Anti-Malaria Campaign started, an estimated 4 to 5 million cases were said to occur annualy in Brazil, when the population was around 55 million. At that time more than one-half of the malaria cases in Brazil came from outside the Amazon. Then, as a consequence of a well planned and efficiently conducted campaign, started under the leadership of Brazil's outstanding public health executive Mario Pinotti, the incidence of the disease lowered to 52 thousand confirmed cases in 1970, the great majority from the Amazon Region. From then on malaria started to increase again in this Region, as new waves of immigrants, this time chiefly from the Southern States were lured by the promises of "development" programme. In 1985 about 400 thousand cases occurred in Brazil, nearly all from the Amazon Region, which, comprizing 51% of the 8.5 million square km of the country's territory and harboring only 9% of its inhabitants, was responsible for more than 99% of the autochtonous malaria recorded. Therefore, we wish to emphasize that, at present, malaria, once prevalent in vast areas of the country, has been almost eradicated from non-Amazonian Brazil.

THE BRAZILIAN ANOPHELINES AND THEIR RELATION TO MALARIA

Until the end of last century the knowledge on Brazilian mosquitoes was very scarce, limited to the few species studied by foreign scientists or collectors from Europe or the United States.

The discoveries on the role of mosquitoes in the transmission of malaria and yellow fever soon aroused in Brazil, especially among the research team of the Instituto Soroterápico Federal – now the Instituto Oswaldo Cruz – a great interest for the study of these insects, which was not surprising in a country where the two diseases were recognized as major national problems.

Due to their work and that of Brazilians from other institutions and of foreign scientists, more than fifty species of Anophelines are known to be present in this country, as named in the list below.

Instituto Oswaldo Cruz, Departamento de Entomologia, Caixa Postal 926, 20001 Rio de Janeiro, RJ, Brasil.

LIST OF ANOPHELINES FOUND IN BRAZIL

Genus *Anopheles* Meigen, 1818
Subgenus *Nyssorhynchus* Blanchard, 1902
An. darlingi Root, 1926
An. argyritarsis argyritarsis Robineau-Desvoidy, 1827
An. argyritarsis sawyeri Causey, Deane, Deane & Sampaio, 1943
An. albitarsis Lynch-Arribalzaga, 1878
An. braziliensis (Chagas, 1907)
An. lanei Galvão & Amaral, 1938
An. aquasalis Curry, 1932
An. oswaldoi (Peryassu, 1922)
An. ininii Sevenet & Abonnenc, 1938
An. dunhami Causey, 1945
An. evansae (Brethes, 1926)
An. rangeli Gabaldon, Cova-Garcia & Lopez, 1940
An. nuneztovari Gabaldon, 1940
An. benarrochi Gabaldon, Cova-Garcia & Lopez, 1941
An. galvãoi Causey, Deane & Deane, 1943
An. strodei Root, 1926
An. triannulatus triannulatus (Neiva & Pinto, 1922)
An. triannulatus davisi Paterson & Shannon, 1927
An. rondoni (Neiva & Pinto, 1922)
An. lutzi Cruz, 1901
An. parvus (Chagas, 1907)
An. antunesi Galvão & Amaral, 1940
An. nigritarsis (Chagas, 1912)
Subgenus *Kerteszia* Theobald, 1905
An. cruzi cruzi Dyar & Knab, 1909
An. cruzi laneanus Corrêa & Cerqueira, 1944
An. homunculus Komp, 1937
An. bellator Dyar & Knab, 1903
An. bambusicolus Komp, 1937
An. neivai Howard, Dyar & Knab, 1912
Subgenus *Anopheles* Meigen, 1818
An. eiseni Coquillet, 1902
An. peryassui Dyar & Knab, 1908
An. mattogrossensis Lutz & Neiva, 1911
An. tibiamaculatus (Neiva, 1906)
An. maculipes (Theobald, 1903)
An. mediopunctatus (Theobald, 1903)
An. punctimacula Dyar & Knab, 1906
An. intermedius (Chagas, 1908)
An. fluminensis Root, 1927
An. minor Costa Lima, 1929
An. shannoni Davis, 1931
An. neomaculipalpus Curry, 1933
An. evandroi Costa Lima, 1937
An. bustamantei Bello Galvão, 1951
An. rachoui Bello Galvão, 1951
An. anchietai Corrêa & Ramalho, 1968
Subgenus *Lophopodomyia* Antunes, 1937
An. squamifemur Antunes, 1937
An. gilesi (Neiva, 1908)
An. pseudotibiamaculatus Galvão & Barretto, 1941
Subgenus *Stethomyia* Theobald, 1902
An. nimbus (Theobald, 1903)
An. kompi Edwards, 1930
An. thomasi Shannon, 1933
Genus *Chagasia* Cruz, 1906
Ch. fajardoi (Lutz, 1904)
Ch. bonneae Root, 1927
Ch. rozeboomi Causey, Deane & Deane, 1945

But, already in 1898, the same year Ronald Ross showed the transmission of a plasmodium by mosquitoes, and even before Grassi, Bastianelli and Bignami demonstrated, in 1899, that Anophelines are the vectors of human malaria, Adolfo Lutz regarded the anopheline presently known as *Anopheles cruzi*, as responsible for a malaria epidemic occurring during the construction of the Santos-São Paulo railroad. Lutz also discovered that this mosquito bred in bromeliad plants, a very original observation at the time. His findings were published in 1903. This was the first incrimination of a species of Anopheline as a vector of malaria in Brazil, a presumption confirmed in a nearby area some forty years after. Lutz was so engaged in mosquito studies that the first Anopheline to be described in Brazil, by Oswaldo Cruz, in 1901, was named *Anopheles lutzi*. He was responsible for one of the first classifications of the Anophelines and assisted Celestino Bourroul in his 1904 Thesis on Brazilian mosquitoes. Emílio Goeldi's report on mosquitoes from Pará State appeared in 1905.

Through the following three decades appreciable work was done on Brazilian Anophelines by Brazilian workers: Oswaldo Cruz created a new genus, *Chagasia*, proper of the Neotropical Region; Carlos Chagas, Lutz, Arthur Neiva, Cesar Pinto, Antonio Peryassu, and Angelo da Costa Lima described a dozen new species; the first monograph on Brazilian mosquitoes, by Peryassu, a book of 408 pages, appeared in 1908 and, in 1922 the first Anopheline dissections for sporozoites were made, by Alcides Godoy and Pinto, who found oocysts and sporozoites in a species that they called *An. albitarsis* and that was possibly, *An. darlingi* in Campos, State of Rio de Janeiro; the systematics of Brazilian Anophelines was discussed by Costa Lima (1928, 1929).

Still in the 1920s, extensive malaria surveys were performed by a team of the Rockefeller Foundation, led by Mark Boyd, on the coastal lowlands of Rio de Janeiro State, the "Baixada Fluminense", aiming to find the vectors and establish practical control measures. Some of the chief conclusions of Boyd's (1926) work were that the most important vector in the area would be *An. argyritarsis* (he was probably dealing with *An. darlingi*), because of its marked preference for human blood and its high natural infection rate, and that *An. tarsimaculatus* (now known as *An. aquasalis*) would be of less importance because of its zoophily and lower infection rate. To clarify the systematics of the local Anophelines Boyd brought an entomologist, Francis Metcalf Root, who wrote a very valuable monograph on the Brazilian *Nyssorhynchus* in which one of the most important points was the description of a new species in the *argyritarsis* group that, at Boyd's suggestion, he called *An. darlingi* (Root, 1926), and that was later proved to be the chief malaria vector in most of Brazil. In the same paper Root described another new species, *An. strodei*.

In March 1930 Raymond Shannon made the outstanding discovery of the presence of the African *Anopheles gambiae* in Natal, Rio Grande do Norte State. Malaria was starting to show up in this previously non-malarious area and when Nelson Davis visited it in May, 100% of the humans in the district were sick and of 172 *gambiae* examined 52, or 30.2%, had sporozoites in the salivary glands. It should be pointed out that Adolfo Lutz, in 1928, while doing a mosquito survey in an area in Natal where a leprosarium was to be built (he believed in leprosy transmission by mosquitoes), had warned Brazilian authorities of the risk of invasion of that region by African insects due to the establishment of ever faster transportation between the two Continents.

In 1931, examining the salivary glands of 181 *An. darlingi* caught in Belém, Pará State, during a severe malaria epidemic, Davis found 5% infected with sporozoites, and this was the first time that this Anopheline under its proper name of *An. darlingi*, was proved to be a vector. This finding and the local habits of this mosquito, led Davis to regard it as the chief vector in the Amazon Region. Still in the 1930s, Davis and Henry Kumm (1932) in França, Bahia State, re-encountered *An. darlingi* with infected salivary glands and in the next year, an important article on the Anophelines of the Amazon Valley appeared, in which Shannon (1933) incriminates *An. darlingi* as probably the most dangerous vector in the region; he regarded *An. aquasalis* as of little importance because, except for the gland infection detected by Boyd (1926) in Rio de Janeiro, specimens examined by other workers were negative and in his experience this mosquito would be very zoophilic and exophilic, contrary to what had been observed with *An. darlingi*.

In 1930 Godoy, Lobo and Oswaldo Cruz Jr. confirmed the role of *An. albitarsis* as a vector in the "Baixada Fluminense" by finding 1 out of 200 specimens with sporozoites in the salivary glands.

It should be mentioned that salivary glands dissection was considered a delicate and laborious technique and Anopheline infection rates were based on small numbers and chiefly on the finding of oocysts. After the adoption, in the late 1930s, of Marshall Barber's technique – of squeezing out the glands by compressing the anterior part of the thorax of decapitated mosquitoes with the aid of a small coverslip, the numbers of examined salivary glands by the various investigators raised to the hundreds and thousands.

Throughout the early 1940s, the investigations on malaria vectors by Brazilian workers, which until then had been performed by scientists from the Oswaldo Cruz Institute, in Rio de Janeiro, were taken over by a group led by Samuel Pessôa, at the Faculty of Medicine, University of São Paulo. This group was very active and along with colleagues from the State of São Paulo Anti-Malaria Service, performed a comprehensive study on the local Anophelines, in the field and in the laboratory, concerning their systematics, biology, ecology and relation to malaria. New Anopheline species were described by Augusto Ayroza Galvão, Dacio Amaral and Mauro Barretto, extensive up-to-date monographs by Ayroza Galvão dealt with the *Nyssorhynchus* (1940) and the *Myzorhynchella* (1941) from São Paulo State and neighbouring areas, besides a large series of papers by the latter Author and Barretto, John Lane, José Coutinho, Alberto Ramos, Paulo Antunes, Ovidio Unti and others, which, along with Renato Corrêa (1943a), very much enriched our knowledge on the local Anophelines. In 1942, Ayroza Galvão, Reinaldo Damasceno and Artur Marques performed a detailed study on the malaria vectors of Belém, Pará, confirming the role already conferred to *An. darlingi*, but regarding *An. aquasalis* as an also important vector, because of its high density and in spite of its relative exophily and zoophily; they found natural salivary gland infection in both species.

By that time another group of workers were also dealing with Anophelines and malaria transmission in Brazil. Ottis Causey, Leonidas Deane and Maria Deane, during the anti-*An. gambiae* Campaign in Northeast Brazil, studied the ecology of this mosquito in its New World environment, as well as that of the indigenous species and their relation to malaria, confirming the role of *An. aquasalis* because of its endophily and anthropophily in that semi-arid region and by the finding of specimens with sporozoites in Ceará State (Fortaleza, Beirada and Cumbe). These workers extended their Anopheline survey to the Amazon Region, studying the geographical distribution, the habits of adults and larvae and the relation to malaria of the local species. They found an sporozoite index of 1.8% among 1,600 *An. darlingi* examined in the States of Pará, Amazonas, Rondônia and Amapá and of 0.9% among 1,360 *An. aquasalis*, in Pará and Amapá; they also detected one *An. braziliensis* with sporozoites out of 122 examined from Lake Tamacuri, State of Pará, and one *An. albitarsis* of 1,508 with oocysts only, from Monte Alegre, in the same State. Mosquitoes of eleven other species dissected were negative, and no correlation was found between their presence and that of malaria, on that occasion, in Amazônia. In the Author's opinion, in that region, *An. darlingi* was the only important vector in the interior and *An. aquasalis* along the coast; other species, like *An. albitarsis* and *An. braziliensis* were secondary or local vectors (Causey, Deane & Deane, 1946; Deane, Causey & Deane, 1948). The group described three new species and one subspecies from the Northeast or the Amazon Region.

In the late 1940s and early 1950s, the bulk of malaria research shifted to the National Malaria Service, in Rio de Janeiro, being conducted in the whole country, but with emphasis in the so-called "bromeliad malaria", i.e., malaria transmitted by the bromeliad-breeding *Kerteszia*, these investigations being conducted chiefly by René Rachou and José Coutinho. The bromeliad plants are described and superbly illustrated in a treatize by Father Raulino Reitz (1983).

In 1943, some forty years after Lutz's suggestion on the role of the bromeliad-breeder *An. cruzi* as a malaria carrier, this was confirmed by Renato Corrêa, from the São Paulo Anti-Malaria Service, who found the first sporozoite infected specimen during an outbreak of the disease in Serra do Cubatão, State of São Paulo, when a road, the "via Anchieta", was being constructed. Before and after that, several findings of oocysts since Galli-Valerio (1904) were recorded and, later, sporozoite infections with indices of up to 16.8% were found for *An. cruzi* in Santa Catarina and São Paulo States (Rachou, 1946; Deane et al., 1971).

Two other bromeliad breeders of subgenus *Kerteszia* were proved to be involved in malaria transmission in Southern Brazil: *An. bellator*, which tends to proliferate on coastal areas and was found several times with oocysts, or with oocysts and sporozoites, in Angra dos Reis, Paranaguá and Florianópolis, in Rio de Janeiro, Paraná and Santa Catarina States, by Davis (1926), J. Amaral (1942), Coutinho, Rachou & Ricciardi (1943) and Rachou (1946); and *An. homunculus*, found only in Santa Catarina State, being the most numerous species in the city of Blumenau where malaria was highly prevalent in the 1940s and where it was found with sporozoite infections (Rachou, 1946). Part of the studies on the *Kerteszia* in Southern Brazil were summarized by Coutinho (1946, 1947) and Rachou (1958), who headed a group of very industrious investigators including Mario Aragão (1964), Ivan Ricciardi, Joaquim Ferreira Neto, Milton Moura Lima, and others.

In 1953 John Lane published his authoritative 1112 pages book on Neotropical mosquitoes.

During the last three decades three rare new species of Anophelines were described by Bello Galvão and by Correa and Ramalho, the relation of Anophelines to malaria in Brazil was

treated in detail in Oswaldo Forattini's (1962) Medical Entomology, and a few studies appeared on karyotypes (Schreiber & Memória, 1957; Kreutzer, Kitzmiller & Ferreira, 1972; Kitzmiller, Kreutzer & Tallaferro, 1973; Kreutzer, Kitzmiller & Rabbani, 1976; Steiner et al., 1980; Tadei & Santos, 1982), on the isozymes of some species of *Nyssorhynchus* (Norang et al., 1979) and on the biology of *An. darlingi, An. nuneztovari* and *An. triannulatus* (Charlwood & Hayes, 1978; Charlwood & Wilkes, 1981). However, studies on Anophelines and malaria transmission sharply decreased, the impression being that the principal vectors of human malaria in Brazil had been identified and their habits were fairly well known, and after all, malaria had been practically eradicated or was being kept under control in most of the country.

It was then generally accepted that the Brazilian Anopheline species responsible for the human malarias were:

An. darlingi, the most important primary vector throughout the inland malarious areas, from the Northern part down to North of Paraná State;

An. aquasalis, less important and transmitting the disease along the coast down from the North to São Paulo;

An. cruzi, An. bellator and *An. homunculus* responsible for the so-called "bromeliad-malaria", and the only vectors in the Southern States, South of parallel 25ºS.

An. albitarsis, a rather poor vector with some importance in restricted areas.

At this point we wish to make two remarks about the value of sporozoite indices as a basis to incriminate an Anopheline species as vector of human malaria:

1. In our own experience with thousands of dissections of *An. gambiae, An. darlingi, An. aquasalis, An. albitarsis, An. cruzi* and other species of less importance, all caught in malarious areas, we had local variations from less than one to 50% in sporozoite indices. The higher values were seen when both malaria and mosquitoes had passed the highest point in their incidence curve, i.e., at a time when the proportion of gametocyte carriers is high and that of infected mosquitoes is not diluted in a large population of newborn imagos. Also, species that are not usual vectors of human malaria can be infected when local environmental conditions bring them to an abundant source of gametocytes. Such a situation we have seen, for instance, at Lake Tamacuri, State of Pará, where the whole human population was passing through an epidemic wave for which *An. darlingi* was, undoubtedly, the responsible vector, but where one specimen (out of 200) of *An. braziliensis* was found to harbour sporozoites (Deane, Causey & Deane, 1948).

2. The second comment is about the identification of the species of *Plasmodium* in the mosquito. Anophelines are the only natural vectors of mammalian plasmodia and, in the New World, humans and monkeys are the only mammals known to harbour plasmodia. As it happens, at least one species of Anopheline of the sub-genus *Kerteszia, An. cruzi* is the natural vector of both human and monkey malarias in some areas in Brazil, as demonstrated by Deane and co-workers in 1971.

In the Horto Florestal da Cantareira, State of São Paulo, where *An. cruzi* is extremely acrodendrophilic, i.e., resting mostly at the canopy level, 60% of the howler monkeys harboured simian plasmodia but human malaria did not occur, the dissection of 1,134 *An. cruzi* revealed eight sporozoite infections (0.7%); in this case we may assume that all infections might have been of simian origin. On the other hand, in Santa Catarina, where the proportions of *An. cruzi* caught at the canopy and at ground level were, respectively, 52% and 48%, and monkey and human malarias coexisted, 24 *An. cruzi* of 1,230 dissected (2%) harboured sporozoites; how many of them were of human plasmodia? This raises the problem that wherever human and simian malarias are present, the sporozoites found in the Anophelines are not necessarily of human origin (Deane et al., 1971). One experiment in a coastal forest of Santa Catarina has shown that specimens of *An. cruzi* caught while attacking a bait in the canopy, painted and released, could be later caught while biting at ground level (Deane, Ferreira Neto & Lima, 1984), a fact suggesting the possibility of transmission of simian malaria to man in such areas, since man is known to be susceptible to both local species of monkey plasmodia (Contacos et al., 1963; Deane, Deane & Ferreira Neto, 1966).

Another species of *Kerteszia, An. neivai*, was found infected with sporozoites, in nature, in Brazil: one specimen of the 72 dissected in the Manaus-Itacoatiara Road, Amazonas State. Since this species is very acrodendrophilic and 15.8% of the local monkeys had malaria (due to *Plasmodium brasilianum*) while human malaria was uncommon, we are prone to regard this infection as of simian origin (Deane et al., 1971).

The above remarks seem quite relevant in view of the entirely new techniques very recently developed for the detection of mosquito infection and the identification of the *Plasmo-*

dium species involved, findings of the utmost importance for the malaria epidemiologist. Until then, all mosquito infections were detected by dissecting individual Anophelines, examining their guts and salivary glands in fresh preparations. Since the morphological differences of both stages of the various species of the human and animal plasmodia are slight and not always reliable, the species of parasite could not be identified. In 1982 and 1983, Zavala et al., working at Prof. Ruth Nussenzweig's laboratories at the Department of Medical and Molecular Parasitology, New York University School of Medicine, developed a immunoradiometric assay (IRMA) and Burkot et al., standardized a enzyme-linked immunosorbent assay (ELISA), both based on the use of species-specific antisporozoite monoclonal antibodies. The mosquitoes collected in an endemic area can be killed and sent dried to a distant laboratory, where many can be examined simultaneously. Both the IRMA and the ELISA were used to detect the malaria vectors in endemic areas of the State of Pará, in the Amazon Region in 1983 to 1985, some forty years after the last large scale surveys were performed there. During this period, a dramatic change occurred in the landscape of the Amazon, due to desforestation consequent to the huge unorganized immigration of nearly one million people from other regions of Brazil, to work in agricultural or mining projects or the building of hydro-electric plants. The survey was performed by a team from the New York University, the Oswaldo Cruz Institute (Rio de Janeiro), and the Institute of Tropical Medicine (São Paulo) and published by Arruda et al. (1986). In six districts in the State of Pará, inhabited by unstable migrant farmers and miners from non endemic areas the IRMA revealed sporozoite infections in four species of Anophelines: *An. darlingi*, with both *vivax* and *falciparum*; *An. albitarsis*, *An. triannulatus* and *An. nuneztovari*, with only *vivax*. In the ELISA the same species plus *An. oswaldoi* harboured sporozoites, *An. darlingi* and *An. oswaldoi* with both *vivax* and *falciparum*, the others again with *vivax* only. Three of these species had never been found infected before in this country, *An. nuneztovari, An. oswaldoi* and *An. triannulatus* – which therefore are to be included in the list of possible malaria carriers in Brazil. Their importance in the country as a whole needs to be measured, because, from other areas, all had been examined before for malaria parasites with negative results and, in previous surveys, no correlation was ever found between their presence and malaria endemicity. It is quite possible that the above mentioned environmental changes in the area studied deprived potencial vector species of their traditional feeding sources among forest animals, the option being to get their blood meal on groups of human malaria carriers, often crowded into very precarious shelters.

ECOLOGY AND BEHAVIOUR OF THE VECTOR SPECIES

The preceeding historical outline shows that of over fifty species of Anophelines found in Brazil, all known vectors of human malaria belong to the subgenera *Nyssorhynchus* and *Kerteszia*, none to subgenera *Anopheles, Lophopodomyia, Stethomyia* or to genus *Chagasia.*

A very large amount of information is available on the distribution and ecology of the vectors and of other Brazilian Anophelines, obtained by a long list of workers, which includes Lutz, Chagas, Costa Lima, Neiva, Pinto, Boyd, Root, Shannon, Davis, Galvão, Lane, Barretto, Coutinho, Corrêa, Forattini, Causey, L. Deane, M. Deane, Bustamante, Rachou and others. However, time forces me to limit this report to the principal characteristics of each species of vector, concerning their geographical distribution, habits and re-emphasizing their relation to malaria. Among the *Nyssorhynchus, An. darlingi, An. aquasalis, An. albitarsis, An. nuneztovari, An. oswaldoi, An. triannulatus* and *An. strodei* and *An. evansae* are to be considered; among the *Kerteszia, An. cruzi, An. bellator* and *An. homunculus.*

An. darlingi is the principal vector in Brazil. It is present all over the interior of the country, except in the driest sections of the Northeast, the extreme South and the higher altitudes, being more frequent along the large rivers and near forests. It is the most endophilic of the Brazilian Anophelines, it is quite anthropophilic, biting man mostly at the late hours of the night and indoors, but there are definite variations on the biting cycle from one area to another. The residual breeding places in the dry season are large collections of fresh water, sunlit or partially shaded, but in the rainy season many distinct types of deposits harbour the immature stages. In the absence of control measures, wherever *An. darlingi* is present malaria is to be found and naturally infected specimens with sporozoites have been detected many times in numerous endemic localities, where it is the most important or the only vector (see Rachou, 1958). It transmits malaria indoors and outdoors, even when its density is low.

An. aquasalis breeds in brackish-water collections of various sizes and nature, being therefore limited to the coastal areas. In most of its territory it is exophilic, zoophilic and crepuscular, but in the drier Northeast it is endophilic and bites man frequently and at the late hours of the night. It is much less important than *An. darlingi*, but has also been found infected many times

and in many places, and transmits malaria only when abundant; it was the only indigenous vector in the drier zones of the Northeast.

An. albitarsis, if regarded as a single species, will be the most numerous and widespread Anopheline in Brazil, breeding in a great variety of water collections, mostly sunlit, grassy, fresh water marshes. In most endemic zones it may enter houses in large numbers and feed on man, but in the dry Northeast and in some inland areas of Southern and Central Brazil it is decidedly exophilic and zoophilic. Most natural infections found were with oocysts, but sporozoite infections have been detected in a few places, in some of which it is regarded as the only vector.

The other *Nyssorhynchus* regarded as vectors have a wide distribution in Brazil except *An. nuneztovari*, which is almost restricted to the Amazon. They are mainly exophilic, zoophilic and crepuscular, but may feed on man. *An. braziliensis* bites frequently during daytime and breeds in slowly-moving, sandy-bottomed, sunlit streams or ponds, while the breeding-places of *An. triannulatus* are usually rich in vegetation, such as *Pistia stratiotes*, *Eichornia*, and others, and those of the other species are very eclectic. *An. braziliensis*, *An. nuneztovari*, *An. triannulatus* and *An. oswaldoi* have been found infected with sporozoites but only in limited areas (all in the State of Pará), and their importance as autonomous vectors, i.e., in the absence of a primary vector, has yet to be measured. In *An. strodei* and *An. evansae* only oocysts have been detected, in both cases from a single locality.

The *Kerteszia*. Besides breeding in bromeliad plants, *An. cruzi*, *An. bellator* and *An. homunculus* have other characteristics in common. They are mostly exophilic and acrodendrophilic, but can enter houses in large numbers and they are very eclectic as to the source of blood meal, avidly biting man, but also other mammals and birds. The first two are found along the coast, from the Northeast to Rio Grande do Sul, but are only numerous in the Southern States, particularly Paraná and Santa Catarina; *An. homunculus* seems to be restricted to a small area in the latter State. All feed principally at sunset and at the first hours of the night: *An. cruzi* and *An. homunculus* also bite during the day, while *An. bellator* does so less frequently because it lives in more open spaces, subject to much sunlight; the latter species which is restricted to altitudes up to 200 meters, breeds in bromeliads attached to trees, to rocks and to the ground; the plants may be large so as to hold enough water to resist desiccation, while *An. cruzi* prefers epiphyte bromeliads, which can be smaller because rapid evaporation can be prevented by the shade provided by the forest canopy. All three *Kertesziae* have been found infected with sporozoites, *An. homunculus* only once, *An. cruzi* from São Paulo and Santa Catarina and *An. bellator* twice, from the latter State. Because they feed on many different animals besides man, the *Kertesziae* are only vectors where they are extremely abundant. Therefore, only where the density of bromeliads is very great – hundreds of these plants may be found attached to a single tree in Santa Catarina and Paraná States, and the ground and rocks may be litterally covered by them, in some places.

The relation of the *Kerteszia* with monkey malaria has been discussed.

THE FOREIGN, ONE-TIME VECTOR, *ANOPHELES GAMBIAE*

Although not an indigenous vector, the importance of this mosquito in the history of malariology in Brazil is such that it can not be let aside in this report.

Imported from Africa, *Anopheles gambiae* remained in Brazil at least from 1930, when it was found in Natal, to 1940, when it was eradicated. In 1930 and the next year it caused severe malaria outbreaks, which were locally controlled. From 1932 to 1937 it remained rather quiescent, although expanding, in a very dry area, with few appropriate water collections. In 1938, it reached the valleys of Rivers Assu and Apodi in Rio Grande do Norte State and River Jaguaribe, the largest in Ceará, jokingly mentioned as "the largest dry river in the world". At the peak of its expansion it covered an area of about 50 thousand square kilometers in those two States. By disembarking in a previously malaria-free area (or almost free), it caused one of the major epidemics ever registered in Brazil: over 150 thousand cases with 14 thousand deaths during the course of eight months in 1938 and 1939 and over 600 thousand cases during the whole epidemic. The mosquito, in the area, was very endophilic, the females were decidely anthropophilic and the breeding-places were rather small, shallow collection of seepage water with little vegetation, such as shallow wells, burrow pits and animal tracks, 90% being seepage pits dug by the people for water supply (the "cacimbas") on the bed or at the margins of partially dried rivers, one common charater for nearly all breeding-places being their fully exposure to the sun; for this reason, unlike most breeding places of the indigenous Anophelines, they were easy to find and to treat with Paris green larvicide. This fact, together with the endophily of the adults facilitating their elimination with indoor spraying with pyrethrum insecticides and – it should be emphasized – a well organized programme and a strictly disciplined force of 1,000 to 4,000 men, helped in the surprisingly rapid eradication of the

mosquito in less than two years work by the Brazilian Malaria Service of the Northeast and the Rockefeller Foundation (Pinto, 1939; Soper & Wilson, 1943).

The erradication of *An. gambiae* illustrates how helpful may be the previous knowledge of the ecology and behaviour of a vector species when control measures are contemplated. In the case in question no time, men and monkey were lost in paris-greening larger bodies of water or pyrethrum-spraying outdoor mosquito shelters.

Although with less spectacular results, much has been done in this country to control or eradicate malaria from large areas by using chiefly anti-vector measures, based on the same kind of knowledge. On the other hand such a knowledge may be discouraging. Can one expect to control malaria by destroying the myriads of *Kertesziae* breeding places in the "bromeliad-malaria" areas? Can we hope to eradicate malaria in the Amazon Region by spraying the unexistent walls of the huts or treating *darlingi* breeding places spread over the immense plains flooded by the largest river in the world?

"Bromeliad-malaria" has been practically eradicated from the Southern States in great part by the systematic use of chemotherapy. In the Amazon Region, where resistant *P. falciparum* strains have appeared, our major hope lies on the promises of our dear colleagues, Ruth and Victor Nussenzweig and Luís Hildebrando Pereira da Silva and their co-workers, to give us an efficient anti-malarial vaccine.

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