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ANOPHELISM AND EPIDEMIOLOGICAL PATTERNS OF MALARIA IN THE SOUTH-WEST INDIAN OCEAN ARCHIPELAGOES

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SUMMARY: Anophelines of the south-western part of the Indian Ocean belong to the Afro-tropical fauna. Their presence in the archipelagoes of this region result from human settlements. However, the process of introduction of malaria vectors and the conditions of a successful establishment in each island vary, mainly according to different ecological situations. Indeed, the malaria epidemiological situation, especially in a small island biotope, is directly related to environmental modifications resulting from human activities. After an initial epidemic period, transmission became permanent in coastal areas with stable malaria. Lately, as has been observed in Mauritius and Reunion, spraying campaigns associated with socio-economic development, urbanization and pollution, favoured species selection, setting up unstable malaria and anophelism without malaria transmission.

KEY WORDS: Malaria, epidemiology, anopheline species, transmission, South-west Indian Ocean archipelagoes.

INTRODUCTION

In the south-western Indian Ocean, between the equator to the north, the East African coast to the west and the 70° east meridian, lie 3 archipelagoes around Madagascar: the Seychelles (with some 110 islands), the Comoros (Great Comoro, Anjouan, Mohéli, Mayotte) and the Mascareignes (Mauritius, Réunion, Rodrigues). Isolated islands are also scattered in this area (Fig. 1).

The main feature of all these islands is their ancient isolation. Madagascar was separated from Africa before the emergence of apes around 100 million years ago; all the other islands are volcanic, appearing at the end of the tertiary period. The advent of man is more recent, occuring at the beginning of the historic period, perhaps 2000 years ago. All these areas are part of the Ethiopian zoogeographical region.

An important link among these islands is their common human history: initially contacts with the European nations competing for the spice trade, followed by the slave trade and finally the Anglo-French wars. The outcome was the division of the area between the French and the British.

Analysis of historical data about malaria shows:

- Malaria has been present in Madagascar since early human history. Ancient legends report high mortality among the Merina on the coast, which probably was the reason for their withdrawal to the High Plateau. Mortality due to fevers amongst Portuguese sailors who reached Madagascar in 1500 suggests high endemicity at the start of written records (JULVEZ, 1993);
- The introduction of malaria by Malagasy invaders at the end of the 18th century (JULVEZ & BLANCHY, 1988) in Mayotte, Anjouan and Mohéli (Comoros Archipelago) has yet to be confirmed; however, records show the occurence of epidemic malaria in Great Comoro in 1920 and 1924 (RAYNAL, 1928);
- Small epidemic outbreaks occured on Seychelles' outer islands (Aldabra and Assumption Islands) in 1908 and 1930 (MATHEW & BRADLEY,1932); the vector was still present in 1975 (L.S.H.T.M., 1980);
- Epidemics in Mauritius in 1867 (REGNAUD, SMALL & NAZ, 1868), and in Réunion in 1869 (BARAT, 1869) are reported in many documents. The African origin of the disease has been pointed out by JULVEZ, MOUCHET & RAGAVOODOO (1990).

The comparison between available assessment of entomofaunas is difficult because of qualitative variations according to each island's accessibility. Otherwise it may be incorrect to gather various results collected in different times when the state of the art was not the same. The spread of vectors between continents and neighbouring islands is permanent; the situation in each island is no more than a temporary result of a long progressive evolution.

ANOPHELES SPECIES IN THIS AREA

Geographical distribution

With the exception of *Anopheles mascarensis*, an endemic species from Madagascar, anophelines of the south-western Indian Ocean are undoubtedly of African origin. All the others species found in the region belong to the Afro-tropical mainland fauna, and are also present in Madagascar (GRJEBINE, 1956a). Only Socotra Island, off the coast of Somalia, north of the equator, has been colonized by an oriental species of the *A. culicifacies* complex (ZAHAR, 1985).

Most of these species are anthropophilic or anthropozoophilic; their presence in the archipelagoes is related to human settlements. Only *A. pretoriensis*, present in Madagascar, is almost entirely zoophilic. It has spread

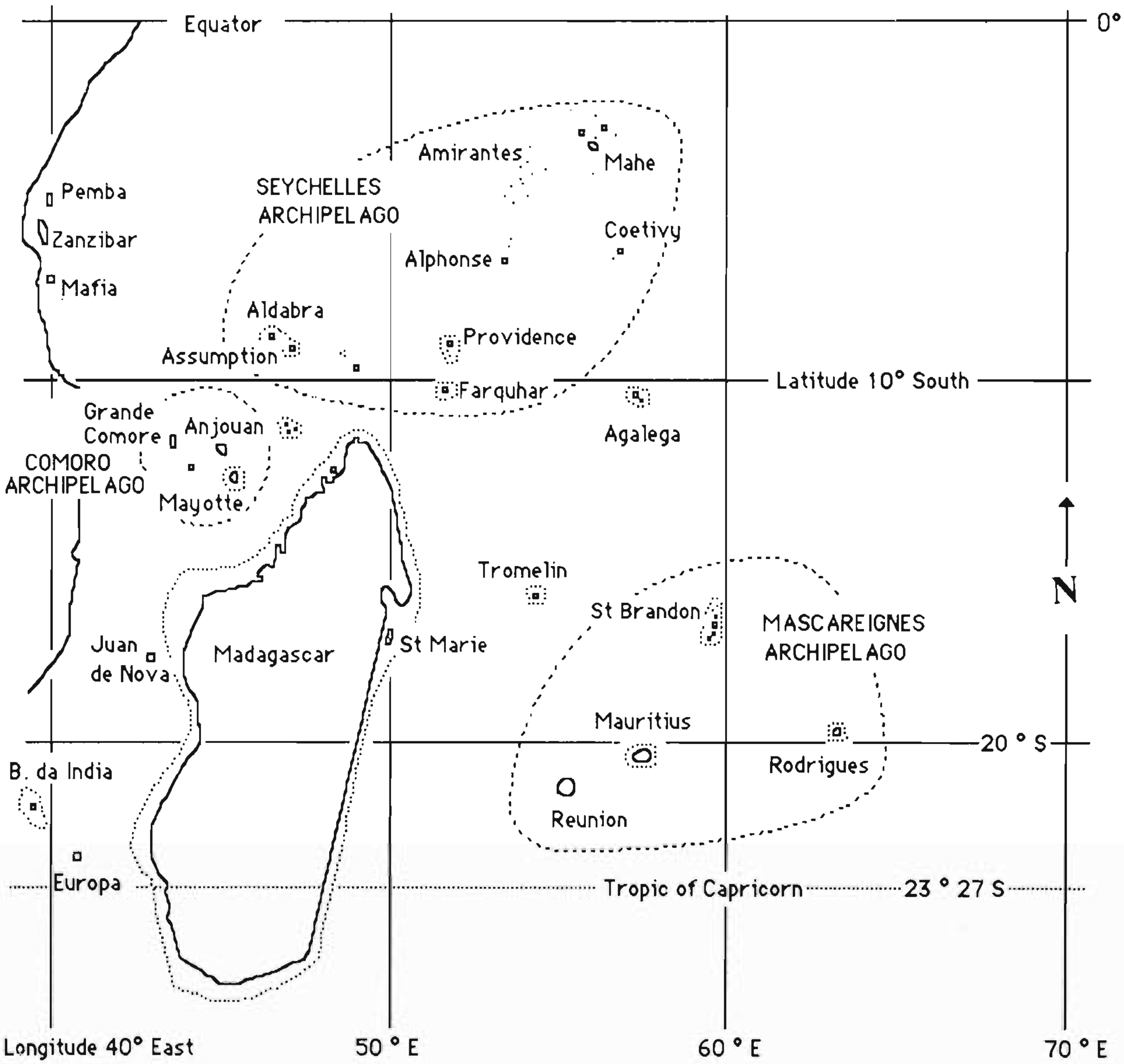

Fig. 1.– Geographical location of the South-west Indian Ocean archipelagoes.

only up to the nearest islands of the Comoros archipelago.

The main African vectors of human malaria, *A. gambiae s.l.* and *A. funestus*, are found in this area and throughout the East African coast and Madagascar. Two other species, *A. coustani* and *A. mascarensis*, are incidental vectors and their public health importance is still doubtful (GILLIES & DE MEILLON, 1968).

A. funestus, present in three of the Comoros (Mayotte, Mohéli and Anjouan), also reached Mauritius but disappeared after the first round of house-spraying during the malaria eradication programme (DOWLING, 1953). It was probably present in Réunion prior to the first malaria campaign.

A. gambiae s.l. is widespread, although limited to the Comoros and the Mascareignes, with temporary sporadic introductions in the southern-most islands of the Seychelles archipelago (Aldabra and Assumption Islands). However, it has never reached Mahe and Praslin, the main islands of this archipelago (BRUCE-CHWATT, 1976), located far away in the north.

Various species of the *Anopheles gambiae* complex

In the Comoros, HUNT & COETZEE (1986) described *A. gambiae s.s.* in Great Comoro, which was later confirmed by SABATINELLI (1988) and PETRARCA (1990). They found the same species in Anjouan and Moheli by polytenic chromosome analysis. In Mayotte, no cytotopic identification has yet been made.

Since larvae have frequently been found in brackish water (GRJEBINE, 1956b; BRUNHES, 1978), especially in Mayotte, the presence of *A. merus* is supposed.

In Mauritius, after VINSON's first description (1916) and other works (GEBERT, 1936; JEPSON, MOUTIA & COURTOIS, 1947), HALCROW (1957) isolated a brackish water variety, described as *A. gambiae litoralis*, which was *A. merus* Dönitz, 1902. PATERSON (1964) described two fresh water species, *A. gambiae s.s.* and *A. arabiensis*. Early observations made in Mauritius were of great interest for the study of the *A. gambiae* complex (BRUCE-CHWATT, 1974). After reintroduction of malaria in 1975, cytogenetic studies revealed the presence of *A. arabiensis* (BRYAN & GEBERT, 1976). From 1976 to 1987 (GOPAUL & KONFORTION, 1988) only *A. arabiensis* and *A. merus* were encountered. Mauritius is actually the eastern limit of *A. arabiensis*.

Before house-spraying in Réunion, the presence of *A. gambiae s.s.* was possible. However, the only cytogenetic determination (LONDON SCHOOL OF HYGIENE AND TROPICAL MEDICINE, 1980) showed *A. arabiensis*. The evidence of brackish water species (HAMON, 1956) indicate the presence of *A. merus*.

In the Seychelles, the species of the *A. gambiae* complex recorded have not been identified. However, according to its bad vectorial capacity, this does not sufficiently explain the epidemic outbreaks.

The distribution of anopheline species in the south-western islands of the Indian Ocean is summarized in Table 1.

Origin of anopheline species

A. merus from Mauritius are similar to those of East Africa (PATERSON, 1964). Chromosomal polymorphism found in *A. gambiae s.s.* from Great Comoro and Mohéli, is similar to those from East Africa (SABATINELLI, 1988).

PETRARCA *et al.* (1990) showed chromosomal evidence that *A. gambiae s.s.* from Great Comoro, Anjouan and Mohéli apparently belongs to the same forest forms (COLUZZI *et al.*, 1985) as specimens from the northern coast of Mozambique (PETRARCA *et al.*, 1984). Both have monomorphic standard 2R and the same frequency of polymorphic inversion 2La.

Cytogenetic studies also revealed that *A. arabiensis* from Madagascar is closely related to the East African type (RANDRIANSOLO & COLUZZI, 1987) and that it can be the same in the archipelagoes.

VECTOR BEHAVIOUR AND ECOLOGY

Comoros Archipelago

A. funestus larvae have never been found in Mayotte and Mohéli (BRUNHES, 1978) but was recently discovered in Anjouan (BLANCHY, BENTHEIN & SABATINELLI, 1987). Due to an habitual low density, its responsibility in malaria transmission was presumed to be small, although it became a problem during the dry season in Mayotte and Mohéli (SUBRA & HEBRARD, 1974). Despite the systematic house-spraying in Mayotte starting in 1976, and according to a strict anthropo-endophily (BRUNHES, 1978), *A. funestus* was still collected in houses of some coastal marshy areas (JULVEZ *et al.*, 1987) but it has now disappeared (unpublished personal observation, 1996).

A. gambiae s.l. is anthropophilic and endophilic (BRUNHES, 1978). Its biting reaches its peak during the middle of the night. It leaves the houses only at dawn.

In Gret Comoro, due to the lack of surface water, the only breeding places are the rain water tanks or the wash basins in private homes and mosques. They retain water throughout the year and anophelines can be found in houses at all times. These breeding sites allow a continuous presence at low density.

In Anjouan, Mohéli and Mayotte, seasonal variations occur. The rainy season provides multiple breeding sites, related or not to human activities. However, very heavy rain may wash off breeding places, leading to a decrease in vector density (SUBRA & HEBRARD, 1974). During the dry season, estuaries blocked by sand constitute the main breeding places in Mohéli and Anjouan. On the

Species	Madagascar (1)	Mauritius (2)	Réunion (3)	Great Comoro (4)	Mohéli (4)	Mayotte (4)	Anjouan (4)	Aldabra Assumption
A. gambiae s.s.	+	(+)	(+)	+	+	[+]	+	[-]
A. arabiensis	+	+	+	?	?	?	?	?
A. merus	+	+	[+]	–	[+]	+	[+]	?
A. funestus	+	(+)	(+)	–	+	+	+	–
A. coustani	+	+	+	–	+	+	+	–
A. mascarensis	+	–	–	–	+	+	+	–
A. maculipalpis	+	+	–	–	+	+	–	–
A. pretoriensis	+	–	–	+	+	+	+	–

Table 1. – Anopheles spp. distribution in the south-western islands of the Indian Ocean. (+) = species may be initially present but actually absent; [+]/[-] = likely present/absent. (1) GRJEBINE (1956); (2) HALCROW (1954); (3) HAMON (1953); (4) BRUNHES (1978).

northern coast of Anjouan, where the coastal plain is narrow with a few estuaries, the vector density is low in the dry season (BLANCHY, BENTHEIN & SABATINELLI, 1987).

In Mayotte, in villages without streams, the density is low at the beginning of the rainy season, increases gradually during the rains, and drops again during the dry season. In contrast, villages crossed by a river have higher vector densities at the beginning of the rainy season. Stagnant estuaries in the dry season were previously responsible for a high vector swarm (SUBRA & HEBRARD, 1974; GALTIER & BLANCHY, 1982). Increasing population and economic development have led to environmental pollution, particularly with detergents in estuaries, and *Culex* species have replaced the *Anopheles* species (JULVEZ *et al.*, 1987).

Mauritius

A. funestus was considered as the main vector (DOWLING, 1951) on the coastal plain, below 150 m altitude (MAC GREGOR, 1923). Due to its anthropophily and endophily, it may have been eliminated by the first spraying campaign and has not been observed since 1952 (DOWLING, 1953; GOPAUL & KONFORTION, 1988).

DARUTY DE GRANDPRE & D'EMMEREZ DE CHARMOY (1900) described *A. gambiae s.l.* behaviour as exophilic. Absent during the dry season, its proliferation during the rainy season reinforces transmission.

Its activity reaches its peak during the early evening, while people are still outside their houses; after this period, it feeds on animals (goats and dogs) which sleep on the verandahs (HALCROW, 1954). *A. gambiae s.l.* replaced *A. funestus* when urbanization developed, and after antimalarial measures (JEPSON, MOUTIA & COURTOIS, 1947).

Malaria transmission was briefly interrupted in 1952, despite the persistence of *A. gambiae s.l.* populations during the dry season (DOWLING, 1951); this suggests a marked zoophilic evolution. During the period from 1956 to 1966, MAMET (1976) confirmed its opportunistic behaviour according to the availability of man or cattle as hosts.

By 1972, the roof-top pools of houses made of concrete blocks seemed to have become the best breeding places for *A. arabiensis*, which was probably the only vector involved in the spread of malaria in 1975 (GOPAUL & KONFORTION, 1988); these sun-exposed breeding sites appear to maintain this species in the highlands during the dry season.

Réunion

Before the antimalaria campaign, *A. gambiae s.l.* was anthropophilic and endophilic; it colonized the coastal area, reaching an altitude of 250 m in the East and 350 m in the west (HAMON, 1953). Its density decreased at the end of the dry season, because breeding places dried up and the remaining waters were too polluted (HAMON & DUFOUR, 1954).

A. gambiae s.l. prefers clean water and sunny breeding places, although when necessary, it adapts to polluted water (HAMON, 1953). In summer it colonizes highlands such as Cilaos (1200 m). This was possible by climbing along the rivers banks, and by road transport (HAMON & DUFOUR, 1954); however, this species seems unable to survive a long time above an altitude of 500 m.

Although it feeds for a considerable extent at twilight, when people are still outside the houses (HAMON, 1956), its biting reaches its peak during the middle of the night.

After house spraying, *A. gambiae s.l.* became more exophilic than endophilic, but more anthropophilic than zoophilic (HAMON, 1956). Nevertheless, in Réunion Island, traditional animal shelters did not provide a good refuge against the wind since they did not have proper walls (HAMON, 1954). Wherever house-spraying stopped 20 years ago, *A. gambiae s.l.* remained exophilic. This may mean that it has also become zoophilic (JULVEZ, ISAUTIER & PICHON, 1982) due to the development of animal housing which provides a good shelter.

DISCUSSION

Introduction of anopheline vectors

Anophelines do not have long-lasting eggs, which makes their long distance spread by man more difficult than culicines, e.g., *Aedes aegypti*. It is, therefore, of particular interest to discuss how they have invaded and more or less successfully colonized the Indian Ocean islands.

In Mauritius the first malaria outbreak was in 1867 near Port-Louis (the main harbour at that time). It was explosive because the population was not immune, which strongly indicates the absence of a prior contact.

In Réunion, an epidemic outbreak occurred in 1869, in the north-eastern coast area, far away from traditional anchorages. The population's vulnerability seemed to have been extremely high.

The theory of the vector introduction in Mauritius brought about by the new steamer line from Madagascar was suggested. This new route had a shorter travel time, making it more compatible with the biological requirements of adult anopheles, both *A. gambiae* and *A. funestus* (JULVEZ, MOUCHET & RAGAVOODOO, 1990).

Similarly, for Réunion island, the same faster steamer might have produced the same effect, although one cannot exclude the theory of wind transport during the trade wind season, since Réunion is located «leeward» of Mauritius. The transport of the vector from Mauritius to Réunion during the 1868 typhoon was evoked in early litterature (BARAT, 1869). This is supported by the fact that the malaria epidemic started in the North-West of the island facing Mauritius and not near the anchorages.

The contemporary spread of *A. gambiae s.s.* in Great

Comoro seems to be the result of the building of rain water tanks during the vanilla boom (RAYNAL, 1928). Their successful implantation, after a major anthropic modification of the environment, indicate the occurence of numerous occasions for contact, prior to the introduction of *A. gambiae* from other islands of the archipelago. In addition, *A. gambiae s.s.* adapted to peri-domestic conditions, such as indoor basins or outdoor water tanks, which are not classic breedings sites for this species.

Major changes in the environment of Mauritius and Réunion Islands should be stressed: the large-scale felling of forest trees, for the extensive sugar cane plantations, and the subsequent human immigration. All of these factors coincided with the malaria epidemic (JULVEZ, MOUCHET & RAGAVOODOO, 1990).

In Mauritius, the internal drainage system through subterranean caverns left stagnant water and marshes, providing breeding sites for *A. gambiae*.

In Réunion, the ecological situation is different: the landscape is hilly with high mountains. Water surface flows and drainage is easy: such conditions do not provide adequate breeding sites other than the flat but narrow coastal plain.

Eradication and post-eradication period

The antimalaria campaign, in the two islands, aimed at adult stages of the vectors, began with DDT house spraying in 1949. Important differences between the two islands should be noted. While in Réunion one adulticidal and larvicidal campaign (1949-1952) was enough to break transmission, two campaigns, adulticidal and partly larvicidal, were needed in Mauritius (1949-1952 then 1960-1962) to obtain the same result. In spite of some differences between vector behaviour in the two islands, the same process seemed to have occured: the anthropophilic fraction of the population disappeared. Only exophagic and zoophilic species sub-populations, such as *A. arabiensis* survived.

Despite the growing importance of trading and the recent development of communications, the situation has remained unchanged in Mauritius and Réunion. After more than 20 years, only larvicidal control measures are carried out, without total coverage.

A. arabiensis is the only residual vector. Its exophily probably considerably reduced its life expectancy, thus preventing transmission; this may be the main argument for the *Anophelism without malaria* (BRUCE-CHWATT, 1974) still observed, even if some «introduced cases» occured both in Mauritius (RAGAVOODOO, 1988) and Réunion (DENYS & ISAUTIER, 1991).

The last outbreak of malaria in Mauritius was in 1975. It was closely related to a combination of events of strictly human origin. A vector became peri-domestic by adaptating to roof-top breeding (GOPAUL & KONFORTION, 1988) along with a sudden supply of numerous *Plasmodium vivax* from Indian soldiers coming to assist after a typhoon (RAGAVOODOO, 1984). Anopheles natural barriers seem to be plainless, since *P. vivax* requires a shorter vector longevity for transmission.

Analysis of cases showed predominence among male adults and teenagers; this is related to their habits of sitting outside houses and walking during twilight, which is compatible with the exophily of the vector.

EPIDEMIOLOGIC PATTERNS AND CONCLUSION

A great paradox exists between the difficulty for introduction in a new biotope for an anopheles species, its later establishment and its settlement, and the complexity of the measures needed to eradicate or control this vector.

Environmental modifications, resulting from human activities, are closely related to malaria epidemiology (CARNEVALE & MOUCHET, 1980). This seems particularly true in the case of the south-west Indian Ocean Islands. According to species distribution and biology, the malaria situation of the Comoros and Mascareignes Archipelagoes is now very different.

In the Comoros, especially in Mayotte and Moheli, ecological and climatic conditions lead to a permanent transmission with seasonal variations. Stable malaria (MAC DONALD, 1957) prevails on the four islands, despite differences in the vector density.

In Mascareignes Archipelago, appraisal is more complicated, as a result of the historic evolution of the anopheline fauna:

- After the preliminary epidemic period, in Mauritius and in Réunion, while transmission became continuous in the coastal areas, with some variation during the short dry season, it was seasonal above an altitude of 200 or 300 m due to temperature decrease. Therefore, malaria was stable on the coast and unstable in the highlands.
- Lately after the spraying campaigns and the eradication of some species, associated with an important socio-economic development and widespread urbanization, the theory of unstable malaria setting up corresponds more closely to the actual situation.

Human impacts on the environment are the main factor in vector introduction and/or multiplication (MOUCHET & BRENGUES, 1990), particularly in the South-West Indian Ocean archipelagoes (JULVEZ & MOUCHET, 1994); however, continuous development and economic pressures very often produce irreversible alterations. This may constitute the main cause for the present situation of an anophelism without (transmission of) malaria.

REFERENCES

BARAT, 1869.– Etude sur la fièvre épidémique qui a régné en 1869 à l'île de la Réunion. *Archives de Médecine Navale*, 12: 422-440.

BLANCHY (S.), BENTHEIN (F.) & SABATINELLI (G.), 1987.– Epidémiologie du paludisme en République Fédérale Islamique des Comores. Données actuelles. *Cahiers de l'O.R.S.T.O.M., série Entomologie médicale et Parasitologie*, No. spec. (1989): 45-52.

BRUCE-CHWATT (L.J.), 1974.– *Anopheles gambiae* complex in Mauritius. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 68: 497-498.

BRUCE-CHWATT (L.J.), 1976.– Malaria threat to the Seychelles. *British Medical Journal*, 2: 754-755.

BRUNHES (J.), 1978.– Les insectes hématophages de l'archipel des Comores. *Mémoires du Muséum d'Histoire Naturelle de Paris*, 109 (A, Zool.): 193-246.

BRYAN (J.H.) & GEBERT (F.), 1976.– Identifications of members of the *Anopheles gambiae* complex from Mauritius. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 70: 339.

CARNEVALE (P.) & MOUCHET (J.),1980.– Le paludisme en zone de transmission continue en région afro-tropicale. *Cahiers de l'O.R.S.T.O.M., série Entomologie médicale et Parasitologie*, 18: 162-171.

COLUZZI (M.), PETRARCA (V.) & DI DECO (M.A.), 1985.– Chromosomal inversion intergradation and incipient speciation in *Anopheles gambiae*. *Bolletin Zoologica*, 52: 45-63.

DARUTY DE GRANDPRE (A.) & D'EMMEREZ DE CHARMOY (D.), 1900.– *Les Moustiques*. Planters & Commercial Gazette, Port Louis, 59 pp.

DENYS (J.C.) & ISAUTIER (H.), 1991.– Le maintien de l'éradication du paludisme dans l'île de la Réunion (1979-1990). *Annales de la Société Belge de Médecine Tropicale*, 71: 209-219.

DOWLING (M.A.C.), 1951.– An experiment on the eradication of malaria in Mauritius. *Bulletin of the World Health Organization*, 4: 443-461.

DOWLING (M.A.C.), 1953.– Control of malaria in Mauritius. Eradication of *Anopheles funestus* and *Aedes aegypti*. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 47: 177-198.

GALTIER (J.) & BLANCHY (S.), 1982.– Le paludisme à Mayotte et son évolution de 1976 à 1981. *Cahiers de l'O.R.S.T.O.M. série Entomologie Médicale et Parasitologie*, 20: 145-151.

GEBERT (S.), 1936.– The breading of *Anopheles costalis* in sea water, in Mauritius. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 30: 255-257.

GILLIES, (M.T.) & DE MEILLON (B.), 1968.–*The Anophelinae of Africa south of the Sahara*. 2nd Edition. South African Institute for Medical Research, Johannesburg, 343 pp.

GOPAUL (A.R.) & KONFORTION (P.), 1988.– Roof-top breeding of *Anopheles arabiensis* (Patton, 1905) and the spread of malaria in Mauritius. *Mauritius Institute Bulletin*, 10: 136-174.

GRJEBINE (A.), 1956a.– Apperçu sommaire du peuplement anophélien de Madagascar. *Bulletin de l'Organisation Mondiale de la Santé*, 15: 593-611.

GRJEBINE (A.), 1956b.– Moustiques récoltés par E. Brygoo aux Iles Comores (Mohéli et Mayotte). *Le Naturaliste Malgache*, 8: 160-162.

HALCROW (J.G.), 1954.– Catalogue of the mosquitoes of Mauritius and Rodriguez. *Bulletin of the Mauritius Institute*, 3: 234-248.

HALCROW (J.G.), 1957.– A new sub-species of *Anopheles gambiae* Giles from Mauritius. *East African Medical Journal*, 34: 133-135.

HAMON (J.), 1953.– Etude biologique et systématique des culicidés de l'Ile de la Réunion. *Mémoire de l'Institut Scientifique de Madagascar*, 4 (E): 521-554.

HAMON (J.), 1956.– Seconde note sur la biologie des moustiques de l'île de la Réunion. *Annales de Parasitologie Humaine et Comparée*, 31: 598-606.

HAMON (J.) & DUFOUR (G.), 1954.– La lutte antipaludique à la Réunion. *Bulletin de l'Organisation Mondiale de la Santé*, 11: 525-556.

HUNT (R.H.) & COETZEE (M.), 1986.– Chromosomal and electrophoretic identification of a sample of *Anopheles gambiae* group (Diptera: Culicidae) from the island of Grand Comoros, Indian Ocean. *Journal of Medical Entomology*, 23: 655-660.

JEPSON (W.F.), MOUTIA (A.) & COURTOIS (C.), 1947.– The malaria problem in Mauritius: the bionomics of Mauritian anophelines. *Bulletin of Entomological Research*, 38: 177-208.

JULVEZ (J.), 1993.– *Anthropisation et paludisme. Eco-épidémiologie du paludisme dans les archipels du sud-ouest de l'Océan Indien*. Thèse Sciences, Université de Toulouse, Toulouse, 350 pp.

JULVEZ (J.) & BLANCHY (S.), 1988.– Le paludisme dans les îles de l'archipel des Comores. Eléments historiques et géophysiques, considérations épidémiologiques. *Bulletin de la Société de Pathologie Exotique*, 81: 847-853.

JULVEZ (J.) & MOUCHET (J.), 1994.– Le peuplement culicidien des îles du Sud-Ouest de l'Océan Indien. L'action de l'homme dans l'importation des espèces d'intérêt médical. *Annales de la Société Entomologique de France*, 30 (4): 391-401.

JULVEZ (J.), ISAUTIER (H.) & PICHON (G.), 1982.– Aspects épidémiologiques du paludisme dans l'Ile de la Réunion. Evaluation de certains paramètres constituant le potentiel paludogène. *Cahiers de l'O.R.S.T.O.M., série Entomologie Médicale et Parasitologie*, 20: 161-167.

JULVEZ (J.), MOUCHET (J.) & RAGAVOODOO (C.), 1990.– Epidémiologie historique du paludisme dans l'archipel des Mascareignes. *Annales de la Société Belge de Médecine Tropicale*, 70: 249-261.

JULVEZ (J.), GALTIER (J.), ALI HALIDI (M.A.), HENRY (M.) & MOUCHET (J.), 1987.– Epidémiologie du Paludisme et lutte antipaludique à Mayotte (Archipel des Comores, Océan Indien). Evolution de la situation de 1976 à 1986, perspectives. *Bulletin de la Société de Pathologie Exotique*, 80: 505-519.

LONDON SCHOOL OF HYGIENE & TROPICAL MEDICINE, 1980.– Progress Report No. 20.

MAC DONALD (G.), 1957.– *The epidemiology and control of malaria*. Oxford University Press, London.

MAC GREGOR (M.E.), 1923.– *Report on the Anophelinae of Mauritius and on certain aspects of malaria in the colony, with recommendations for a new anti-malaria campaign*. Waterloo & Sons, Colonial Office, London, 48 pp.

MAMET (J.R.), 1976.– Some observations on the *A. gambiae* (Giles) complex in Mauritius. *Proceedings of the Royal Society of Arts and Sciences Mauritius*, 3: 241-326.

MATHEW (K.C.) & BRADLEY (J.T.), 1932.– *Research work on an outbreak of malaria at Assumption and Aldabra Islands in 1930*. Govt Printing Office, Victoria, 14 pp.

MOUCHET (J.) & BRENGUES (J.), 1990.– Les interfaces agriculture-santé dans les domaines de l'épidémiologie des maladies à vecteurs et de la lutte antivectorielle. *Bulletin de la Société de Pathologie Exotique*, 83: 376-393.

PATERSON (H.E.), 1964.– «Saltwater *Anopheles gambiae*» on Mauritius. *Bulletin of the World Health Organization*, 31: 635-644.

PETRARCA (V.), CARRARA (G.C.), DI DECO (M.A.) & PETRANGELI (G.), 1984.– Osservazioni citogenetiche e biometriche sui membri del complesso *Anopheles gambiae* in Mozambico. *Parassitologia*, 26: 247-259.

PETRARCA (V.), SABATINELLI (G.), DI DECO (M.A.) & PAPAKAY (M.), 1990.– The *Anopheles gambiae* complex in the Federal Islamic Republic of Comoros (Indian Ocean): some cytogenetic and biometric data. *Parassitologia*, 32: 371-380.

RAGAVOODOO (C.), 1984.– La résurgence du paludisme à Maurice. In: *IIème Séminaire O.M.S. inter-îles sur le paludisme* (Maurice), paper communication, unpublished document.

RAGAVOODOO (C.), 1988.– Situation épidémiologique du paludisme à Maurice. In: *IVème Séminaire O.M.S. inter-iles de l'O-*

céan Indien sur le Paludisme (La Réunion), paper communication, unpublished document.

RANDRIANSOLO (R.) & COLUZZI (M.), 1987.– Genetical investigations on zoophilic and anthropophilic *Anopheles arabiensis* from Antananarivo area (Madagascar). *Parassitologia*, 29: 93-97.

RAYNAL (J.), 1928.– Enquête sanitaire à la Grande Comore en 1925. Observation de paludisme à forme épidémique. *Bulletin de la Société de Pathologie Exotique*, 21: 35-54 & 132-141.

REGNAUD (C.), SMALL (J.) & NAZ (V.), 1868.– *Rapport sur la fièvre épidémique de l'Ile Maurice*. Adopté par la Commission d'enquête nommée par S.E. le Gouverneur Sir H. Barkly, Imprimerie du Cernéen, Port Louis, 56 pp.

SABATINELLI (G.), PETRARCA (V.) & PETRANGELI (G.), 1988.– Données préliminaires sur le complexe *Anopheles gambiae* dans la République Fédérale Islamique des Comores. *Parassitologia*, 30: 178-179.

SUBRA (R.) & HEBRARD (G.), 1974.– *Etude entomologique des moustiques de Mayotte vecteurs du Paludisme et de la Filariose de Bancroft en vue de leur contrôle*. Rapport O.R.S.T.O.M.–S.S.B.G.E., unpublished document, 32 pp.

VINSON (L.), 1916.– Note sur le développement des anophèles dans l'eau salée. *Bulletin de la Société Medicale de l'Ile Maurice*, 34: 20-22.

ZAHAR (A.R.), 1985.– *Vector bionomics in the epidemiology and control of malaria*. Part I. The W.H.O. African region & the Southern W.H.O. Eastern Mediterranean region. Section III : East Africa, Eastern Outer Islands, Southwestern Arabia, Geneva, W.H.O., 244 pp.