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Ecology and behaviour of malaria vectors in the american region *

by

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INTRODUCTION

Compared with other regions, the literature on the ecology and habits of malaria vectors in the New World since eradication began is scanty. One reason for this is general acceptance of GABALDON's view (1949) that the effectiveness of insecticides should be measured only in terms of reduction of malaria, and not deduced from mosquito studies. More recently, this view has been modified by MACDONALD (1965), who, while admitting the need for further research, recommended that this should be limited to experimental processes in parallel to, and incorporated with, the mainstream activity of operational schemes, and geared to spotting and solving operational problems. Later, YOUNG (1966) pointed out that while progress to eradication had been encouraging, it had been hindered by premature reduction of research effort before solution of some important problems ; that new problems had appeared, and that it was now logical to re-introduce research.

While entirely agreeing with MACDONALD that investigations should always be fully relevant to the programmes they are designed to support, one must recognize the danger that over-emphasis on this point might slow the process of acquiring the necessary new knowledge by placing it under the control of programmes that may not welcome the addition of activities that appear to question the basis on which their organization, successes and prestige have been founded. MACDONALD also recommended that experimental processes should be backed by central regional or continental laboratories capable of taking on the main problems. It is likely that this approach may be more productive than the attempt to graft a new element on to existing programmes that were never designed to support it.

While the above considerations apply generally to vector studies in M.E., they apply with especial force to the American region, for the historical reasons mentioned.

HABITS OF MALARIA VECTORS

In a review of the literature of the period 1958-1968, one third of all references to western hemisphere vectors apply to *A. albimanus*, while another third refer to *A. pseudopunctipennis*, *A. darlingi* and *A. aquasalis* ; the order in which the species are dealt with here is that of frequency of appearance in the literature rather than of operational importance.

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A. albimanus.

A. albimanus is stated to be a main vector of malaria in Mexico, Puerto Rico, Ecuador and Venezuela (HECHT and CORZO, 1957, REHN *et al.*, 1950, MONTALVAN, 1953, GABALDON, 1957). In Venezuela it is described as partly zoophilic (GABALDON, 1949). It is said to be 98 per cent exophagic in its man-biting activity in the dry season in Jamaica (MUIRHEAD-THOMSON and MERCIER, 1952), but less so during the rains, while in El Salvador (MOUCHET, 1965) outdoor bites outnumbered indoor bites by five to one. In Haiti (TAYLOR, 1966), the main biting period was from 5 : 30 to 9 : 00 p.m. : in Mexico, early evening (HECHT and CORZO, 1957), and in Jamaica (MUIRHEAD-THOMSON and MERCIER, 1952) at sunset and dawn. Its indoor biting activity is said to have been reduced after each round of DDT spraying in Mexico (ZULUETA and GARRETT-JONES, 1965), Venezuela (GABALDON, 1949) and Panama (TRAPIDO, 1952) ; only after the first rounds but not after later ones in Panama (ZULUETA, 1964), and not at all in Venezuela (COVA-GARCIA, 1959).

In Mexico (HECHT and CORZO, 1957), doubt is expressed as to whether it is a house mosquito, and in Puerto Rico (REHN *et al.*, 1950), although outdoor searches were not very productive, it was found in small numbers resting in relatively exposed sites on cliffs and among rocks, with relative humidity between 85 and 90 per cent. Outdoor searches were negative in Jamaica (MUIRHEAD-THOMSON and MERCIER, 1952).

Its preferred indoor resting places in Mexico were dark (MUNIZ et BARRERA, 1960), very humid (FORATTINI *et al.*, 1961), but up to three or five meters high on walls and under roofs (HECHT and CORZO, 1957). In Jamaica (MUIRHEAD-THOMSON and MERCIER, 1952) only ten per cent of those biting indoors remained to rest ; in Haiti (TAYLOR, 1966) 50 per cent of those biting in sprayed houses, and all of those biting in unsprayed houses, did so. In Venezuela (GABALDON, 1949) it is considered that the main effect of DDT on this species is *interception ;* i.e. the reduction of human contact by diversion of the mosquito to outside and animal sources of food. However, in Mexico (MARTINEZ-PALACIOS and ZULUETA, 1964), particularly in the south (ROMERO ALVAREZ, 1964) its behaviour in presence of DDT is said to have led to persistence of transmission and the development of problem areas. It was also seen (DIAZ-NAJERA, 1964) to leave DDT-treated surfaces faster than surfaces treated with DDT-Malathion mixture, and to be knocked down sooner by the latter.

In Panama (TRAPIDO, 1952) observations made in experimental huts in 1944-1945, after the first use of DDT, had indicated that the insecticide reduced the percentage of females entering to feed, and not only reduced the fraction becoming engorged to about one-seventh of that in control huts, but also caused increased mortality in the engorged fraction. Repetition of the observations in the same huts in 1962 showed an increased entry into treated huts, almost equal to the pre-DDT density ; the percentage fed remained about equal, but the 24-hour survival of the fed fraction had increased ninefold. It was concluded that increased activity and heightened phototropism were responsible for the changed behaviour, but that decreased physiological susceptibility played no part (BROWN, 1958). Further experiments to clarify the situation (DURET, 1961), produced the result that, of three susceptible strains two recently brought in from the field left experimental sprayed huts more rapidly than a longer-established laboratory strain. Finally, producing an apparent contradiction of the reasonably logical situation so far observed, a comparison of strains from two areas where DDT had never been used and one from an area treated many times, showed the former two as the more irritable (DURET, 1964). The hypothesis that failure to interrupt malaria transmission is due to selection of a hyper-irritable strain is not proved by the evidence from Panama, therefore.

In El Salvador (RACHOU *et al.*, 1965) resting densities were found to be higher in sprayed than in unsprayed houses, and different intensities of malaria transmission were attributed in different areas to various combinations of susceptibility or resistance, of irritability and non-irritability, and of death or survival, the last two measured with the PAHO excito-repellency apparatus. High rates of transmission were caused by resistant populations with moderate to high rates of escape from the apparatus and high subsequent survival, also by susceptible ones with high escape rates and low to moderate survival. Moderate transmission rates were caused by moderately resistant populations with high escape and survival rates, while minimal transmission rates consonant with successful eradication were found in areas with both susceptible and resistant populations, with moderate to high escape rates, and survival according to their susceptibility. This complex situation was subject to seasonal changes in the variables, and observations made at the same time and place showed high variance.

A. pseudopunctipennis.

This species has been considered a main vector in Mexico (DIAZ-NAJERA, 1964) especially the Pacific Coast (ROMERO ALVAREZ, 1964), but to be unimportant in Venezuela (GABALDON, 1957) in the absence of other vectors. It is stated to be the only Mexican species uniting exophagous and endophilous habits (SENIOR-WHITE, 1954, ROMERO ALVAREZ, 1964), and in Morelos at 1500 m of altitude to rest in unsprayed houses after 5 years use of DDT, entering them more for shelter than for food (BORDAS and DOWNS, 1951). In spite of its exophagy, DDT was successful in interrupting transmission. On the Pacific Coast, the habits were different, being endo/exophagous and exophilic (BORDAS and DOWNS, 1951, ROMERO ALVAREZ, 1964). It rested in houses at heights of over 3 m. (ROMERO ALVAREZ, 1964). Slightly reduced indoor biting was observed ofter each spray-round of DDT (ROMERO ALVAREZ, 1964) ; after spraying, however, it exhibited evasion (MOUCHET, 1965), resting only for a short time on walls. It is behaviour is said to have led to persistent transmission, entry to houses having been much reduced by DDT in 1949-1950, but much less so in 1962-1963 (MARTINEZ-PALACIOS and ZULUETA, 1964), with no change in susceptibility to DDT.

In Ecuador (MONTALVAN, 1953) it was not considered highly domestic, but after use of DDT its entry of houses was much reduced.

A. darlingi.

This species is regarded as an important vector throughout its range. The centre of its distribution is regarded (GIGLIOLI, 1956), as central Brazil and there it is regarded as zoophilic and exophilous and also anthropophilic and endophilous ; anthropophilous and endophilous tendencies are thought to increase with distance from this centre. It has therefore been reduced in numbers (GABALDON, 1949) or eliminated (COVA-GARCIA, 1959) in Venezuela, and suppressed in the inhabited parts of French Guiana (FLOCH and FAURAN, 1958). The eradication of *A. darlingi* from Guyana (GIGLIOLI, 1963) led to an increase in the human population, a corresponding increase in mechanised farming, and a reduction of the number of farm animals. The formerly exophilic and zoophilic *A. aquasalis* turned to endophagous and anthropophilous habits, with a return of malaria transmission. Also, *A. darlingi* itself reappeared in the cleared area, protected only by barrier spraying (GIGLIOLI and CHARLES, 1954). In both cases the resulting transmission was halted by DDT. In Surinam (VAN THIEL, 1962) the replacement of the eradicated *A. darlingi* by *A. nuneztovari* is regarded as a potential danger.

A. aquasalis.

In Venezuela this species both bites and rests outdoors (GABALDON, 1957, MOUCHET, 1965) and is therefore regarded as an obstacle to eradication (GABALDON, 1957). It now attacks man in areas from which *A. darlingi* was eradicated in Guyana (GIGLIOLI, 1963), but the resulting transmission has been halted by DDT. In French Guiana it is regarded as a potential vector only (FLOCH and FAURAN, 1958). Increased salinity in rivers due to public works led to an increase in its density in Puerto Rico (MORALES, 1961).

A. nuneztovari.

In Venezuela the principal obstacle to the completion of eradication is considered to be the exophagic and exophilic behaviour of this vector (Gabaldon, 1957), which survives where there is much vegetation near houses (Gabaldon *et al.*, 1965). The distribution of bites on man outdoors and indoors was observed as 71 : 29 per cent, respectively (Cova-Garcia, 1959). Recent observations of its habits in Colombia (Elliott, 1968) indicate a more equal distribution of indoor and outdoor biting, especially at the season of highest density. In Surinam (Van Thiel, 1962) it is expected to cause problems by replacing *A. darlingi* after eradication of the latter.

A. punctimacula.

Regarded as a main vector in Ecuador (Montalvan, 1953) and in areas of high altitude in Colombia such as the Cauca Valley (Ronnefeldt, 1957), this species was in the latter country observed to respond to DDT by a decrease in indoor resting density, but not in total density (Ronnefeldt, 1957). This conclusion, of increased exophily, has been criticised (Muirhead-Thomson, 1960) on the grounds of inadequate figures.

A. albitarsis.

In Brazil, where it has been observed to have a flight-range of 19 km (Correa *et al.*, 1950), this species is regarded as a vector.

A. aztecus and A. quadrimaculatus.

These North American vectors were found to resemble *A. albimanus* in their preference for dark resting surfaces (Correa *et al.*, 1950), but were found less irritable than that species (Hecht et Corzo, 1960).

A. apicimacula.

This species may be a main vector in Mexico (North Puebla), where it bites man preferentially on the ankle (Martinez-Palacios, 1960).

A. (Kerteszia) belator and cruzii.

These species were observed still to rest in unsprayed houses in Brazil after ten years of DDT-spraying in the district ; it is considered that this indicates no change in habits (Forattini *et al.*, 1961).

GÉNÉRAL

A great deal of valuable material on the habits of vectors undoubtedly exists in unpublished reports, which cannot be reviewed, because of the physical difficulty of access to the sources, and because quotation of tentative conclusions would be unfair to the authors. For example, a great deal of information exists on temporal changes in the mean physiological ages of populations, but it cannot be said that the Russian techniques have yet provided any information usable operationally. Similarly techniques for study of the kinetic response to insecticides have been pioneered in the region, but with the exception of the work on *A. albimanus* in El Salvador (Rachou *et al.*, 1965), interpretation of the results in termes of the effect and importance of hyper-irritable strains on persistence of transmission has been difficult. The region as a whole stands in need of systematic observations on the times and places of man-mosquito contact and their modification in presence of insecticides, in different conditions of weather, anopheline densities, housing types, peridomestic surroundings and human habits. There is also a need for a certain amount of taxonomic work on some elements of the *Nyssorhynchus* group which still present difficulties in identification.

Bibliography

BORDAS (E.) & DOWNS (W. G.), 1951. — *Amer. J. Hyg.*, **53**, 217.

BROWN (A. W. A.), 1958. — *Bull. Wld. Hlth Org.*, **18**, 667.

CORREA (R. R.) *et al.*, 1950. — *J. nat. Malariol, Soc.*, **9**, 280.

CORREA (R. R.), FORATTINI (O. P.), GUARITA (O. F.) & RABELLO (E. X.), 1961. — *Arq. Hig. Saude. publ.*, **26**, 333.

COVA GARCIA (P.), 1959. — *Indian J. Malariol*, **12**, 331.

DIAZ NAJERA. (A.) 1964. — *Rev. Inst. Salubridad y Enfermedades trop.*, **24**, 31.

DURET (J. P.), 1961. — *Bol. Ofic. sanit. pan-amer.*, **51**, 285.

DURET (J. P.), 1964. — *Bol. Ofic. sanit. pan-amer.*, **57**, 259.

ELLIOTT (R.), 1968. — *Bull. Wld. Hlth. Org.*, **38**, 239.

FLOCH (H.) & FAURAN (P.), 1958. — *Bull. Wld. Hlth. Org.*, **18**, 667.

FORATTINI (O. P.) *et al.*, 1961. — *Arq. Hig. Saude publ.*, **26**, 249.

GABALDON (A.), 1949. — *Trans. r. Soc. trop. Med. & Hyg,*, **43**, 113.

GABALDON (A.), 1957. — *Amer. J. trop. Med. & Hyg.*, **5**, 966,

GABALDON (A.) *et al.*, 1965. — *Kasmera*, **2**, 5.

GIGLIOLI (G.), 1956. — *Bull. Wld. Hlth. Org.*, **15**, 461.

GIGLIOLI (G.) & CHARLES (L. J.), 1954. — *Amer. J. trop. Med. & Hyg.*, **3**, 808.

GIGLIOLI (G.), 1963. — *Bull. Wld. Org.*, **29**. 131.

HECHT (O.) & CORZO (J. H.), 1957. — *Z. Tropenmed. u Parasit.*, **8**, 391.

HECHT (O.), MANCERA (O.) & BARRERA (A.), 1960. — *J. econ. Ent.*, **53**, 634.

LOEZA (R. McG.), 1960. — *Acta zool. mex.*, **5**.

MACDONALD (G.), 1965. — *P. H. Repts*, **80**, 870.

MARTINEZ-PALACIOS (A.), 1960. — *C.N.E.P. Bol.*, **4**, 117.

MARTINEZ-PALACIOS (A.), & ZULUETA (J. DE), 1964. — *Nature*, **203**, 940.

MONTALVAN (C.), 1953. — *Rev. ecuat. Hig. Med. trop.*, **8-9**, 34.

MORALES (D.), 1961. — *Rev. venezol. Sanid. Asist. soc.*, **26**, 878.

MOUCHET (J.), 1965. — *Bol. Inform. Direc. Malariol. Venez.*, **5**, 223.

MUIRHEAD-THOMSON (R. C.) & MERCIER (E. C.), 1952. — *Am. J. trop. Med. Parasit.*, **46**, 103.

MUIRHEAD-THOMSON (R. C.), 1960. — *Bull. Wld. Hlth. Org.*, **22**, 721.

MUNIZ (R.) & BARRERA (R.), 1960. — *Acta. zool. mex.*, **4**.

RACHOU (R. G.), 1961. — *Rev. bras. malariol.*, **12**, 59.

RACHOU (R. G.) *et al.*, 1965. — *Amer. J. trop. Med, & Hyg,*, **14**, 1,

REHN (J. W. H.) *et al.*, 1950. — *J. nat. Malariol. Soc.*, **9**, 176.

ROMERO ALVAREZ (H.), 1964. — *Salud. publ. mex.*, **6**, 1123.

RONNEFELDT (F.), 1957. — *Z. Tropenmed. u Parasit.*, **8**, 376.

SENIOR-WHITE (R.), 1954. — *Nature*, **173**, 730.

TAYLOR (R. T.), 1966. — *Mosquito New*, **26**, 393.

TRAPIDO (H.), 1952. — *Amer. J. trop. Med. & Hyg.*, **1**, 853.

VAN THIEL (P. H.), 1962. — *Trop. geogr. Med.*, **14**, 259.

WOKE (P. A.), 1962. — *Proc. N. J. Mosq. Ext. Ass.*, **49**, 181.

YEKUTIEL (P.), 1960. — *Bull. Wld. Hlth. Org.*, **22**, 669.

YOUNG (M. D.), 1966. — *J. Parasit.*, **52**, 3.

ZULUETA (J. de), 1964. — Riv. Malariol., **43**, 29.

ZULUETA (J. de) & CULLEN (J. R.), 1963. — *Nature*, **203**, 940.

ZULUETA (J. de) & GARRETT-JONES (C.), 1965. — *Amer. J. trop. Med. & Hyg.*, **14**, 63.