MOSQUITOES AND MAN

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ABSTRACT

The means by which mosquitoes may have developed a close association with man are outlined. Australian mosquitoes have had less than 200 years to adapt to man-affected habitats. Ways in which they are doing so are discussed.

INTRODUCTION

Practically everyone is aware of some of the effects mosquitoes have on man but, except for health surveyors and entomologists, all too few people realise the effects man can have on mosquitoes. I want to discuss this two-way interaction, especially as it is happening in Australia because we have here a unique opportunity to watch and record how relationships of mosquitoes with man evolve.

Mosquitoes have been around a lot longer than man. The present-day genera Anopheles, Mansonia, Aedes and Culex were flourishing in the Oligocene about 30 million years ago, at the time that the ape-man stock was just beginning to diverge from monkeys.

If we consider the basic needs of a mosquito (Table 1), man directly or indirectly can provide additional breeding places (extended in area and time), shelter for adult mosquitoes, and concentrated aggregations of blood sources, that is, of himself and his domestic livestock. The female mosquito selects both the blood source and the breeding place, which is where she lays her eggs.

Once a species of mosquito is established in a cage-colony, it tends to adapt rapidly to new hosts, because the individuals that will not feed on the new host do not produce offspring. In nature the individuals with an innate preference for the most abundant host will tend to produce the most offspring, and so will gradually come to predominate in the population. Thus in different parts of its range a species may have different feeding habits.

Mosquitoes closely associated with man

No species of mosquito feeds exclusively on man but several have developed a very close association with him and have accompanied him round the world. Three of these have become established in Australia, Culex fatigans (perhaps with the First Fleet), Aedes aegypti (probably with mid 19th century settlement of the tropics and subtropics) and Culex molestus (during World War II). C. fatigans and C. molestus are members of the Culex pipiens complex and are nowadays often treated as subspecies of C. pipiens, a house-resting, bird-biting mosquito widespread in the northern hemisphere; for convenience I will refer to them here as species.

These three species are believed to have originated in lands round the Mediterranean. In all three the adults shelter in large numbers in buildings, and can mate in a small space. If we look at the history of man (Table 2) we can see how they might have developed their close association with him.

Even just one human family group living in a cave during bad weather would be liable to pollute ground water in the cave. If the ground water was too foul, or there was none in or near the cave, water would have to be carried and stored in containers of plant or animal origin, or in clay-lined baskets.

In East Africa there is a forest-dwelling, tree-hole breeding subspecies of A. aegypti that seldom bites man and may represent the ancestral form. Adaptation to breeding in man's containers and to feeding on human blood may have been coupled with increasingly dry conditions in North Africa that led to concentration of the human population along the main rivers and diminished natural breeding places. Man's adoption of stone and pottery jars and permanent houses would finally provide the conditions for A. aegypti to develop into the domestic pest we know today.

C. fatigans and C. molestus breed in highly polluted water. In species that do this the females are apparently attracted to lay their eggs by chemical emanations. It is easy to see that once this became an inbuilt preference, the species would

<table>
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<th>TABLE 1 — A mosquito's basic needs</th>
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<tr>
<td><strong>Female</strong></td>
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<tr>
<td><strong>Male</strong></td>
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<tr>
<td><strong>Larva</strong></td>
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<td><strong>Pupa</strong></td>
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*Australian Institute of Health Surveyors*
tend to be found near the source of pollution which would often also be the most readily available blood source.

C. fatigans flourishes in the tropics and subtropics and will breed both in containers and in outdoor ground waters, but the adults avoid light and seek dark indoor resting sites.

C. molestus, which thrives in temperate climates, is thought to have originated in Europe. It frequently breeds under ground where the even temperature allows it to continue its whole life cycle (including blood feeds) throughout the northern winter, even in complete darkness. However, females can produce a batch of viable eggs without taking a blood meal. One might speculate that it evolved these habits in the deep limestone caves to which man retreated from the rigorous winters of the ice age, and where it would need to maintain itself when he left for summer hunting. Later cellars, dungeons and basements probably provided similar conditions, as did the air-raid shelters in London’s underground tube stations during World War II, where C. molestus was a serious pest.

Many other species of mosquitoes have a much looser association with man but yet sufficiently close to make them important carriers of diseases that have an exclusively man-mosquito-man cycle. This may be because his activities provide increased breeding places, or his buildings make attractive shelter, or because he is the most abundant blood-source. These are exemplified in Table 3; the preferences shown are not exclusive and ‘indoors’ means in houses, cattle sheds or other outbuildings.

Mosquitoes in Australia

With all this in mind, let us now look at our native Australian mosquitoes. It is fairly safe to assume that all our 240-odd species, except perhaps some found only on Cape York Peninsula, were here when the aborigines arrived. In the last 25,000 years, and before, Australian mosquitoes have experienced considerable climatic changes — periods of cooler temperature, much heavier rainfall and strong winds, and periods of aridity when the deserts were more extensive and the rainforests much less than now (Marks 1972). The species that were able to adapt best to changing conditions are likely to be those that are now widespread.

The blood-sources available to mosquitoes before man arrived were mainly marsupials, birds, reptiles and frogs. Some species feed exclusively on reptiles and frogs, but the most adaptable and widespread have a wide host range.

The last of the giant marsupials — wombat-like beasts the size of a bullock and giant kangaroos — died out about 10,000 years ago, but with an abundance of other blood-sources available, their disappearance can have had little effect on the mosquitoes.

For the same reason the presence of the aborigines can have made little difference to the mosquitoes — but not vice versa. Froghatt (1905) reported that in northwest Australia “One of the first things I noticed in the scrub near King’s Sound were large circular shallow pits dug out in the sand, which I afterwards found out were “mosquito camps” constructed by the natives to protect themselves from their bites. When hollowed out, these pits were roofed over with ti-tree bark, leaves and sand, leaving an opening on the side through which they could crawl, and the last man to enter closed it up with a bunch of grass. Here they lay all night.

<table>
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<th>TABLE 2* — Man’s changing way of life</th>
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<tr>
<td><strong>Years before present (BP)</strong></td>
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<tr>
<td>2,000,000</td>
</tr>
<tr>
<td>400,000-45,000</td>
</tr>
<tr>
<td>40,000</td>
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<td>25,000</td>
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<td>15,000</td>
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<td>10,000</td>
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<td>9,000</td>
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<td>8,000</td>
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<td>6,500</td>
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<td>6,000</td>
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<tr>
<td>4,500</td>
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<tr>
<td>3,000</td>
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<tr>
<td>1,000</td>
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<td>186</td>
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* Based on Young (1971), Zeuner (1963).
like a family of wombats, in an atmosphere one could almost cut with a knife before morning."

So it is that a two-way mosquito-man relationship has been evolving here for less than 200 years. As yet no native species shows a preference for feeding on man. After our historical review we might feel complacent that a close association will take thousands of years to develop, but the selection pressures now are on a vastly different scale, especially from habitat alteration, and from total numbers and relative abundance of vertebrate species. For example, Lee et al (1954) found that the major blood sources for Anopheles annulipes were cattle and rabbits, animals introduced by white man, and suggested that the population of this species may now be considerably greater than 150 years ago.

We can agree that in numerous ways man has reduced the breeding places available to Australian mosquitoes (and many of you have had a part in this). What we are concerned with here is how our native species are adapting to large populations of man and his livestock living in permanent settled communities with extensive shelters, to man’s practices in agriculture, water usage and waste disposal, and to competition from the three introduced mosquitoes. We want to know how this might affect their pest status and the incidence of mosquito-borne diseases.

It can be said at once that the introduced species do not appear to compete successfully (if at all) with the native species in unaltered natural habitats. Diseases restricted to a man-mosquito-man cycle (malaria, dengue and filariasis) are no longer present though the vectors are here. Current concern is with zoonoses, that is diseases naturally occurring in birds or mammals, but sometimes transmitted to man, and especially with the diseases caused by Murray Valley Encephalitis (MVE) and Ross River (RRV) viruses. An important point is that these may prove to have a shorter development time in the mosquito (4-6 days) than most other mosquito borne diseases.

For purposes of this discussion we shall consider our mosquitoes in three broad groups based on preferred breeding places, viz. containers, temporary ground pools, and permanent or semi-permanent ground waters.

**Mosquitoes breeding in Containers**

Almost all container-breeders lay their eggs singly, usually on the side of the container at or just above the water level. The eggs do not all hatch at one time, and only when there is breeding in large containers or in many small ones will there be a very large adult population.

Natural containers with limited distribution include leaf-axils, fallen palm leaves, and crab or crayfish burrows. None of the species that breed in these appears to be adapting to man-altered environments, beyond breeding in an occasional jar or tin. In other countries leaf-axil species breed intensively in cultivated plants such as bananas, but not so here, though there may have been a minor dispersal of some species in North Queensland when taro was cultivated by Chinese and south-sea islanders.

The most numerous and widespread natural containers are rock pools and water-holding hollows in standing or fallen trees, and the mosquitoes that breed in these have been best able to take advantage of containers provided by man. The special requirements of rainforest mosquitoes probably limit their ability readily to invade more open and less humid habitats, or at least to compete successfully with others adapted to such conditions. At any rate the most successful species in artificial containers are naturally widely distributed in sclerophyll forest.

By far the most successful is Aedes notoscriptus. It is our commonest and most widely distributed species in tree holes and one of the commonest in small rock pools — an indication of its adaptability to different climatic conditions and to laying on different surfaces. The hollow stumps from land clearing and the wooden barrels and other water-collecting receptacles of the original settlers would have provided an easy transition to new conditions. A hundred years later Skuse (1889) recorded that it was very plentiful in Sydney, occasionally coming into the house in the day time and that from December to March water butts and garden tanks swarmed with the larvae.

**A notoscriptus is now well established in nearly all parts of Australia as a semi-domestic species and a minor pest in house and garden. In artificial containers it can maintain itself in association with A aegypti (except perhaps in very pure water) and with C fatigans (except in very polluted water). It will breed in a variety of containers including rainwater**

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**TABLE 3**

Habits of the Principal Anopheles vectors of Malaria

(1) — associated with agricultural water or ricefields

<table>
<thead>
<tr>
<th></th>
<th>Indoors</th>
<th>In/Outdoors</th>
<th>Outdoors</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed</td>
<td>33</td>
<td>14</td>
<td>3</td>
<td>50</td>
</tr>
<tr>
<td>Rest</td>
<td>22</td>
<td>20</td>
<td>8</td>
<td>50</td>
</tr>
</tbody>
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Total associated with man-affected habitats (agricultural water, rice-fields, borrow pits, canals, ditches, artificial containers) — 34.

*Based on Russell (1952).
tanks, indoor flower vases, bromeliads both in and outdoors, and especially in old motor tyres. So far, although it comes into houses, it has not developed the habit of resting indoors, or the strong attraction to man that we find in *Ae. aegypti*. We should be alert for a change in either of these directions, which would increase its pest and disease-vector potential. *Ae. notoscriptus* is capable of carrying dog heartworm but its importance as a vector has not been established.

The other species which have been recorded on many occasions from man-made containers are treehole species, *Ae. tremulus*, *Tripteroides atripes*, *T. punctotolatari* and *T. tasmaniensis*. *Tripteroides* have much longer life cycles than *Ae. aegypti*, and are therefore less likely to build up large populations. *Ae. tremulus* appears to be more limited to darkened breeding places than is *Ae. notoscriptus* but will breed up in large numbers in suitable sites—such as a new septic tank, a disused grease trap, or sometimes a rainwater tank. A wartime mosquito plague in a Brisbane military hospital due to this species (which is small enough to penetrate normal screening) was traced to a huge salvage tyre heap. Although *Ae. tremulus* appears less adaptable than *Ae. notoscriptus*, in one respect it is more like *Ae. aegypti*; for both sexes frequently come indoors, mainly at dawn. Methods of water storage or disposal of solid water-holding wastes could develop its pest potential. Its disease carrying capability is unknown.

**Mosquitoes breeding in Temporary Groundpools**

The species that breed in transient pools filled by rain or floods have an adaptation to ensure survival of the species. The eggs are laid at the margin of the breeding place and after 24-48 hours in a humid atmosphere they can withstand desiccation and remain viable for months or perhaps years. They require a hatching stimulus (provided by the reduction in oxygen tension that occurs when the pool is filled) and then enormous numbers hatch simultaneously. The aquatic stages are short and the adults all emerge within a period of a few days. This means that eggs are laid while depression margins are still damp and humid. Some eggs in each batch do not hatch until a second or third drying and immersion, so that if disaster befalls the individuals from the first hatch, there will later be others to re-establish the population.

This limits the adaptability of these species and it is only when man reproduces the effect of flooding and drying that he provides conditions suited to them. Species with similar habits are pests in irrigation areas overseas, e.g. in California. Flood irrigation of pastures, or grassy channels that are flooded at intervals and allowed to dry out are most likely to provide suitable conditions through in some circumstances raising and lowering of water level might do so. *Ae. campotorhynchus*, *Ae. theobaldi* and *Ae. vittiger* are temporary pool species sometimes associated with irrigation waters in the Murray Valley area, though I do not know to what extent.

Salting due to overclearing of hillside can favour *Ae. campotorhynchus* (as happens in southwest Western Australia) for it is more tolerant of brackish water than many species.

A special case is the salt marsh mosquito *Ae. vigilax* which is normally dependent on high tides to flood its breeding places. The filling of an enclosed tidal area by pumping a salt water slurry onto it and allowing the runoff water to enter a natural freshwater swamp, can provide conditions for extensive breeding by *Ae. vigilax*. This species can carry Ross River Virus, and other temporary pool *Ae. aegypti* probably can do so. Conditions which promote breeding by inland *Ae. aegypti* when their normal breeding places are dry might prolong the period of virus transmission.

**Mosquitoes breeding in Permanent and Semi-permanent ground water**

Man alters the natural ground waters by impoundment and by channeling and irrigation either with untreated water or with organic effluents. His earthmoving activities provide dams, borrow pits, deep wheel ruts and many other sites. He exposes swamps by felling or killing swamp forests, or introduces a thick vegetable cover, such as water hyacinth, to open waters.

The Australian mosquitoes from these habitats that are of importance to man belong in the genera *Anopheles*’ *Mansonina* and *Culex*. Their eggs do not withstand desiccation and are laid on or at the edge of the water, singly by *Anopheles*, in a cluster or raft by *Mansonina* and in a raft by *Culex*.

Gillies (1973) points out that “A malaria vector must be capable of adapting to the changes in land-use resulting from human activity. Its degree of success will depend on how far these activities influence the three main attributes of a vector, namely numerical dominance, readiness to bite man and longevity.” The other necessity for success of course is to have readily available infective blood sources. Most Australian *Anopheles* have been shown in laboratory experiments to be capable of carrying malaria, indicating that they can survive the 2-3 weeks needed for the parasite to develop in them. *An. farauti* and *An. amictus hilli* have been found naturally infected at Cairns. *An. annulipes* and *An. amictus* are suspect and *An. bancroftii* particularly so in Northern Territory. Where man was the main host available and there were infective blood sources, local epidemics occurred, as a camp in brigalow scrub when the Dalby-Roma railway was being
built in 1877, in many northern Australian mining camps and settlements, and at Lucinda Point as recently as 1946.

From 1963 to 1972 no cases of malaria were notified that had originated in Australia, although in 1971 there were 209 cases that had acquired the infection elsewhere. Prompt treatment is the aim to prevent these patients being infective to mosquitoes, but some must be missed by the health authorities. Another factor operates — our potential malaria carriers show no preference for man but more readily bite cattle or horses. Thus they are less likely to take an infective blood meal, or if infected, to bite a susceptible human 15 days or more later. The risk of transmission is greatest where there are concentrated populations of man, and few cattle. An larauti is an efficient vector that can rapidly colonise fresh or brackish pools in wheel ruts, and muddy excavations, and thus the risk is greatest at developmental projects and isolated mining towns in north Queensland and Northern Territory.

During and immediately after World War 1 there was great concern that malaria might become established in the Murrumbidgee rice-growing area, and several Anopheline surveys were made. I do not know whether An anulipes has adapted to breeding in rice fields.

Mansonina larvae and pupae obtain air from roots or stems of aquatic plants and do not come to the water surface until the adult is about to emerge. This makes them exceedingly difficult to find and the early stages are unknown for Mansonina linealis which is a common day-biting mosquito in Victoria (often now placed in a separate genus Coquillettidia). Water hyacinth appears particularly favourable both for Mansonina breeding, and for shelter for the adults. Near Mackay, where a teatree swamp forest had been uprooted and left lying, a dense growth of grass in the many pools inaccessible to cattle provided ideal conditions for intensive Mansonina breeding.

Three species of Culex should concern us. Culex sitiens is a pest species that breeds in brackish water, often in the larger pools supporting A vigilax but also in more permanent swamps. It will colonise saltings due to overclearing of hillside, and phenomenally heavy breeding occurred at Gladstone where a huge area of salt water was impounded, causing death of mangroves.

Culex australicus, a member of the Culex pipiens complex, feeds mainly birds and small mammals (including rabbits) and is not attracted to man. However it will breed in artificial containers round houses, and sometimes in huge numbers where pastures are irrigated by effluents from sewage treatment works or from piggeries. The adults are attracted to light and readily enter houses, but they cannot mate in a confined space. We should watch for any indication of a change in its feeding habits.

Lastly we have the species that has concerned many health sur-

veyors this summer, Culex annulirostris, considered the main vector of Murray Valley encephalitis, and also a carrier of Ross River virus. This very widespread species breeds in a great variety of groundwaters, but especially in partly sunlit sites with emergent or floating vegetation. Where after floods or heavy rain water lies on lowlying grassy areas for a couple of weeks or more, C annulirostris can breed up in enormous numbers. In a very wet summer like the last, the extent of natural breeding places renders insignificant any caused by man, but man may provide for maintenance of fairly large populations in unfavourable seasons.

Many situations associated with flood irrigation provide suitable conditions for C annulirostris, as do sometimes effluents from sewage treatment works. Raising the water level of a storage dam so that it extends over shallow grassy banks will promote C annulirostris breeding and it would be interesting to know whether the weirs on our western rivers have provided it with more extensive breeding places. C annulirostris feeds on birds and mammals. Cattle, besides providing a blood source, produce hoofprints at the water’s edge where larvae are less subject to predators. There is a cumulative effect on the mosquito population. The question is whether, with greater numbers of hosts in more concentrated populations than ever before, virus transmission might be maintained for longer periods or continuously.
Conclusion

Health surveyors are better placed than any other group of people to observe or be informed of possible changes in mosquito behaviour, or adaptation to new habitats. This is not merely a matter of great biological interest but could be of major importance to public health. It should not be forgotten also that a mosquito with unusual behaviour may not be a native species at all but a new introduction from overseas.

In outlining the habits of our mosquitoes, I may have given the impression that we know a great deal about their biology and behaviour. The truth is that for any particular species we have very little of the detailed knowledge that is needed if we are to control their numbers effectively and understand their natural role in disease transmission and how man's activities are affecting them. Entomologists have sought unsuccessfully for grants to support this type of research. It is clear that money will not be forthcoming unless there is public demand. If you feel strongly that such research is needed, for instance in the irrigation areas, then you must stir public interest to bring political pressure to bear in the right quarters. I wish you success.

References