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MOSQUITOES IN AUSTRALIA'S ARID ZONE

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Dr. I. M. Mackerras recently pointed out to a meeting of the Australian Entomological Society in Brisbane that Australia's desert regions, which are of relatively recent development, offer a unique opportunity for the study of the evolution of adaptations of insects to aridity.

These days, while professional entomologists are mainly in coastal areas, an increasing number of people travel through the interior of Australia, or are temporarily or permanently resident there, and many, if they knew how they might help, would be interested to add to scientific knowledge.

While study of physiological adaptations is a task for research scientists, insects may have behavioural adaptations enabling them to survive adverse periods, which can be revealed or suggested by field observations by naturalists. It is a common phenomenon that one particular stage of an insect's life-cycle is specially adapted to survive long periods of aridity; observations on the time after drought-breaking rains at which a given stage of an insect appears, or is abundant, will throw light on its probable life-cycle; they may also enable the scientist to judge when he might plan to study it in the field. The accumulation of locality and habitat records for a species may indicate that its distribution is restricted to, or that it occurs in greatest abundance in, a certain climatic zone or a particular type of plant community.

Mosquitoes comprise the family Culicidae of the order Diptera (true flies). Because the females of most species require a blood meal to provide the vitamins necessary for production of viable eggs, and some species can carry diseases of man or domestic livestock, almost everyone can distinguish mosquitoes from other flies, and has the opportunity to collect them if strong-minded enough not to slap them first. It is relatively easy, therefore, for an amateur collector in a remote area to make a useful contribution to our knowledge of Australian mosquitoes.

Fig. 1: Australia's arid zone. [Map by the author.]
Particularly is this so in the drier areas, where these insects may occur in abundance for only a short period soon after rain.

The "arid zone"

Before we look at what we know and do not know about mosquitoes of the drier parts of Australia, we need to define the area to be considered. It seems appropriate to select the area which Australian scientists have agreed should be included in the "arid zone", the boundaries of which correspond approximately to the 10-inch rainfall line in the south, the 15-inch in New South Wales, the 20-inch in central Queensland, and the 25-inch in the north (fig. 1).

Sources of information

Where can we find information on the mosquitoes of this area? It is mostly hidden in published and unpublished reports, or in taxonomic papers and regional lists which deal also with species from other climatic zones, or on the labels of specimens in collections. The present paper makes no pretence to be comprehensive. It is based on records by E. P. Hodgkin and E. J. Britten from the Onslow-Roebourne district of Western Australia, plus collections seen by the writer from other localities shown in fig. 1.

The only collections that appear ever to have been made regularly throughout the year in a district within the arid zone are those of Mr J. Wright, who, as Rabbit Control Officer for the Cunnamulla district, has a particular interest in mosquitoes as potential vectors of myxomatosis. Since September, 1965, he has sent in for identification over 1,000 specimens, representing eighteen species, and has shown that the commonest mosquitoes in his district after heavy rain are species previously rare in collections and still undescribed, while some species common 250 miles further east, which it had been expected would occur at Cunnamulla, are apparently rare or absent.

How many of our mosquitoes occur in the arid zone?

Approximately 230 species of mosquitoes are known from Australia (excluding three introduced species which are not considered in this paper) and at least thirty-five of these have been collected in the arid zone. Only four a few of these have been collected in abundance elsewhere and only these appear to survive. How could we explain this ?

The "arid zone" of which we speak is a region the climate of which is such that only vegetation can exist. Fou fou

Fig. 2: A pool at the foot of Mt Olga where larvae of *Anopheles annulipes* and *Culex australicus* were collected and *Aedes explorator* was biting. (This is the type locality for *Aedes explorator.*) [Photo: Author.]
four are, so far as we know, restricted to it; several others appear to reach their greatest abundance within it; others again, common elsewhere, are widely distributed within it and clearly well adapted to aridity; it is only these species that we shall consider here.

How can mosquitoes survive aridity?

The larval and pupal stages of mosquitoes must be passed in water, therefore it must be the eggs or the adults which are able to survive prolonged dry periods. The stage that is adapted to cope with adverse climatic conditions seems to be characteristic of a genus wherever it occurs.

Four genera are known from Australia’s arid zone. *Anopheles*, *Culex* and *Aedes* are of worldwide occurrence and *Tripteroides* occurs in the Oriental and Australian regions. Records of *Tripteroides* within the zone are few; they breed in container habitats; we know nothing of their adaptations to aridity, though these may be expected to be similar to those of *Aedes* favouring the same sites.

Although we have no experimental evidence, there is quite strong circumstantial evidence on the general means by which our arid-zone *Anopheles*, *Culex* and *Aedes* survive. This is based on what is known of these genera overseas; on observations of the same Australian species in higher-rainfall areas; and on records of the occurrence of larvae and adults, and of the habits of adults, in relation to weather information.

This evidence indicates that in *Anopheles* and *Culex*, which lay their eggs on the water surface of the breeding place, the adults are adapted by their habits to survive dry periods. They hide away deep in hollows and crevices, and females with fully developed eggs will still take blood when opportunity offers, to sustain them until a suitable site is available in which to lay. In *Aedes* it is the egg which survives, due in part to its physical structure and in part to the microclimate of the oviposition site selected by the female. A stimulus is needed to hatch it, usually the reduction of oxygen in its surroundings, which occurs when there is sufficient depth of water over it to last while its larval and pupal stages are completed. Further to ensure survival of the species, hatching of some eggs in a batch may be delayed until the second, third or fourth time that the breeding place is filled.

The genus *Aedes* is a very large one and is divided into numerous subgenera, some of which occur on all continents. Of particular interest to us in their adaptations to aridity are mosquitoes belonging to the subgenera that are not known outside Australia and New Guinea, *Pseudoskusea*, *Macleaya* and *Chaetocruiomyia*. As will be shown, there is suggestive evidence that, in these, adults as well as eggs can survive long periods of drought, so that they are doubly insured against disaster.

Mosquito breeding places in the arid zone

These may be permanent, semipermanent, or temporary. The permanent ones include waterholes in river beds, springs, bore drains, dams, earth tanks and large rock holes such as those at the base of Ayer’s Rock. Semi-permanent breeding places are generally of the same type, but smaller, and last at least a couple of months. Temporary sites include depressions that are filled by heavy rains or floods and hold water for a week or more, smaller rock pools, hollows in trees and stumps, and artificial containers such as domestic tanks, watering troughs, oil drums and old tyres.

Some mosquitoes of the arid zone

Two mosquitoes, *Anopheles annulipes* and *Culex australicus*, have been collected at almost every locality shown in fig. 1. *Ae.* *annulipes* is common throughout Australia; *C. australicus* occurs almost everywhere south of 17° S. except the tropical coast of Queensland. In the arid zone they are usually found breeding together, as in the pool at Mt Olga shown in fig. 2. *Ae.* *annulipes* breeds in the types of permanent and semipermanent breeding place listed above, in temporary ground and rock pools that last about 2 weeks or more, and occasionally in artificial containers. *C. australicus* does likewise but is less common in very large permanent sites and more common in artificial containers. *C. australicus* rarely bites man, for it prefers small mammals and birds, but *Ae.* *annulipes* attacks him readily.

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Myxomatosis workers have shown that adults of both species harbour in rabbit warrens (*An. annulipes* up to 4 miles from its breeding places) and may feed below ground. Mr Wright has found them in warrens and resting in rock shelters in the Cunnamulla area. Thus these species survive aridity by their ability to breed successfully in a wide variety of sites and to shelter and feed deep in crevices in rock or below ground where extremes of temperature and aridity can be avoided. We do not know whether there may be biologically distinct races of these species in the arid zone and in high-rainfall areas, nor has anyone looked at the eggs of arid zone females to see whether they could in fact survive drying.

The other common widespread Australian *Culex*, *C. annulirostris*, apparently is not well adapted to aridity. It favours breeding places with plenty of aquatic vegetation, and in the arid zone is associated mainly with large waterholes and bore drains. It has not been taken in central Australia.

The arid zone species of *Aedes* fall into two groups, those breeding in temporary ground pools (fourteen species in four subgenera) and those breeding in treeholes, small rock pools, and artificial containers (eleven species in four subgenera). In fact we have never found breeding places for some species, but can deduce what they are likely to be.

*Aedes* which breed in temporary ground pools have a slender pointed tip to the abdomen (fig. 3) which can be greatly extended as an ovipositor to deposit the eggs well down in the mud or soil of drying-out breeding places. The eggs require a high humidity for a day or two. Then, with the larvae fully formed, the shells become impermeable to moisture and they can remain for months, or in some cases years, before the breeding place is filled again and the eggs stimulated to hatch. In hot climates the larval and pupal stages are short, for development must be completed before the pool dries out.

Within our arid zone no one has actually collected eggs from the soil or observed them being laid there. *Aedes* larvae have been collected in pools resulting from recent rain. Mr Wright has taken *Aedes* biting 2 to 3 weeks after rain filled depressions in winter, and 6 days after in summer. There seems no doubt, then, that these species have drought-resistant eggs.

*Ae. (Pseudoskusea) bancroftianus* larvae are among those collected from temporary ground pools in the Cunnamulla district, and adults have been taken there and at Charleville, Longreach and Richmond in Queensland, and Palm Valley in central Australia. This species has quite a wide distribution in the southern half of Australia, including Western Australia and coastal districts of south Queensland. Again, we do not know whether the inland race might be biologically distinct. At Palm Valley, where adults were taken biting beside a rock pool in September, 1958, there had been no rain since May. These females were rather aged-looking, with scales rubbed off. There is no evidence that *Ae. bancroftianus* ever breeds in pools without its eggs first undergoing a period of drying, and the inference is that it had not bred at Palm Valley since May, but females which had since been
resting in sheltered sites sought the opportunity for a blood meal.

Most of the arid-zone ground-pool *Aedes* belong to the subgenus *Ochlerotatus*. We have no evidence yet to suggest that they, too, might survive as adults, but Mr Wright finds them resting in rock shelters. One species, *Ae. (O.) explorator* (fig. 2), is known only from Mt Olga, where females were biting at the site shown in fig. 2 a few weeks after a heavy storm. Until males are found we cannot tell the affinities of this species. The life-history also has not been worked out, though one larva found in a nearby site probably belonged to this species. Females which were held in a cloth cage for 2 days seemed well adapted to survival in a dry climate.

*Ae. (O.) sapiens* also is known only from the arid zone, from Richmond, Thargomindah, Bourke and Wilcannia, but has been found in large numbers only at Wilcannia, where females were rising in clouds from flooded country. Dr F. H. Drummond reared a male from a pupa from a roadside pool at Bourke but the larva is still unknown.

Two ground-pool *Aedes*, which Mr Wright has found in plague proportions after heavy rain in parts of the Cunnamulla district, are still undescribed and known by the temporary designations *Ae. (O.)* sp. No. 71 and *Ae. (O.)* sp. No. 85. *Ae. (O.)* sp. No. 71 is the most widely recorded arid zone *Aedes*; it has been taken also at Charleville, Longreach and Richmond in Queensland, and at Coolgardie, Leonora and Onslow in Western Australia; records from in between would be of great interest. *Ae. (O.)* sp. No. 85 has been taken in large numbers also at Wilcannia and is known from Charleville and Richmond, and recently a specimen was sent in from Alice Springs. Both these species seem to occur in greatest numbers within the arid zone. At Richmond, during a severe drought in 1952, their larvae were found in temporary pools filled by overflow of a bore drain after damage to its bank. However, during another dry period in 1962, when the same depressions were deliberately flooded from the bore drain, no *Aedes* larvae appeared in the temporary pools.

*Ae. (O.) pseudonormanensis*, another ground-pool breeder, is recorded from Cunnamulla, Longreach and Cloncurry, and from Onslow and Roebourne. Dr E. P. Hodgkin has indicated that this may be a plague species in northwest Australia.

*Aedes* which breed in treeholes and other containers have less tapering abdomens (fig. 4) and usually deposit their eggs on the side of the breeding place just above the waterline. Australia's commonest treehole-breeding *Aedes*, *Ae. (Finlaya) notoscriptus*, has been recorded from Cunnamulla, Charleville and Coolgardie, but is undoubtedly more widespread. It is often a minor domestic pest, breeding in water tanks.

The most interesting arid zone container breeders belong to the subgenera *Chaeotocnemiya* (two species) and *Macleaya* (five species). The former is represented by *Ae. (C.) calabyi* (fig. 4) and *Ae. (C.) wattensis*. These are quite easy to recognize with the naked eye as small mosquitoes (wing length about 2 mm or less), with a thick-set, humpbacked appearance. They have wide white bands on their hind legs and the front half of the top of the thorax is clothed with dense white or creamy scales. They also have strong thorn-like bristles on the hind tibiae. They are quite vicious biters, usually in the late afternoon or early morning. *Ae. calabyi* occurs in the south of Western Australia and the southeast of South Australia; records within the arid zone are from Queen Victoria Spring, and Kalgoorlie and Coolgardie districts. *Ae. wattensis* occurs in inland eastern Australia, including Victoria and Northern Territory; arid zone records are Koonamore (in the northeast of South Australia), Cobar, Cunnamulla, Richmond and Lawn Hill. Breeding isabits of these two species are unknown, but are expected to be similar to those of others of the subgenus, whose larvae have been found in deep, narrow pipes, an inch or less in diameter, such as may occur in quite small stems or branches of eucalypts, acacias, or melaleucas, and whose eggs are flattened on one side, suggesting that they adhere to the surface on which they are laid.

It is presumed that the eggs can survive dry periods and we have good evidence that adults can do so too. Mr J. H. Calaby reported that at Queen Victoria Spring there was no surface water; it was in an arid area with, as far as he knew, no free water
surface within many miles. In mid-afternoon a thunderstorm came up. After the humidity began to rise, and a quarter of an hour or so before any rain fell, considerable numbers of *Ae. (C.) calabyi* and *Ae. (Macleaya) tremulus* appeared and continued to attack during the half-hour that rain fell. From September to December, 1965, Mr. Wright collected occasional *Ae. (C.) wettensis* adults in the Cunnamulla district, which was still suffering from a severe drought but receiving scattered thunderstorms. Curiously, he had not collected it again to the end of October, 1966, although the drought had broken and breeding places should have been available. He thinks the humidity was higher when it was collected; one cannot help wondering if atmospheric pressure also might influence its activity. *Ae. wettensis* has been collected from a rabbit warren in New South Wales.

The subgenus *Macleaya* is closely related to *Chaetocruiomyia*; the adults differ in lacking the distinctive white dorsal scaling on the thorax; breeding places are treeholes, including in one case a moth-hole a quarter of an inch in diameter and 12 inches deep. One species, *Ae. tremulus*, is widespread, with arid zone records from Onslow, Roebourne, Leonora, Queen Victoria Spring, Koonamore, Cunnamulla and Longreach. It sometimes becomes a domestic pest when it colonizes domestic sites such as water tanks. From Calaby's notes, it too must be able to survive dry periods in the adult stage. The species of *Macleaya* are difficult to tell apart. There appear to be also four undescribed species in the arid zone, one known only from Coolgardie and one only from Cunnamulla, life-histories of both being unknown. The other two are known from Richmond, and one of them from Longreach also, but a planned revision of the subgenus will undoubtedly reveal specimens from other localities as well.

It will be seen that, although Chaetocruiomyia and Macleaya are well adapted to aridity, we have as yet no records of them from central Australia, and none of Chaetocruiomyia from the north of Western Australia.

How the amateur collector can help

Mosquitoes caught indoors in established towns are often common domestic species, but plagues of mosquitoes attracted to light may include valuable males which, of course, do not seek blood meals. The collections most likely to advance our knowledge are those made in the bush, on the outskirts of towns, in camps, or in homestead gardens. Larvae can be preserved in methylated spirit. Adults are best preserved dry and can be placed in a matchbox, tin or clean, dry tube between layers of very soft paper tissue. This container must then have at least 1 inch of insulation, such as wood-wool, round it to protect specimens from damage in transit. The information needed with a specimen is locality, date, collector's name, time of capture, type of breeding place, and whatever else seems pertinent in the light of what has been said above.

"ENDEAVOUR" REPORTS

The Fisheries Branch of the Commonwealth Department of Primary Industry, Canberra, was recently asked by the National Library of Australia to advise on an appropriate method of disposing of stocks of the Biological Results of the Fishing Experiments carried out by F.I.S. "Endeavour". It was for many years believed that the stocks of the Endeavour Reports, as they are commonly known, had been either exhausted or accidentally destroyed.

Under the scientific command of the first Commonwealth Director of Fisheries, H. C. Dannevig, the voyages of F.I.S. Endeavour, which was lost with all hands on a voyage from Macquarie Island in 1914, provided marine scientists from many countries with an opportunity to study Australian marine fauna on a scale which has probably never since been equalled. The work of these scientists laid the foundations for fisheries such as the southeastern (distant seine) trawl fishery and the east coast prawn fishery, as well as defining the Bight trawling grounds and providing the basis for much of our present information on the distribution and identity of species.

The bibliographic description of the set is as follows: Australia—Dept of Trade and Customs, Biological results of the fishing experiments carried out by the F.I.S. "Endeavour", 1909-1914. Syd., 1911-1933, 6v, illus, diagr 25 cm all issued. Title varies: v. 1-3, Zoological results . . .


The National Librarian, Mr. H. White, has given approval for the offering, by gift or exchange, of stocks of the report to learned institutions and marine research centres. Applications will be considered only when submitted formally by the librarians of such bodies, and should be addressed to The National Library of Australia, Canberra, A.C.T. (Attention: Clearing Centre). This offer by the library will terminate on 31st October, 1967.