

The Arrival of *Aedes (Ochlerotatus) vigilax* (Skuse) in Fiji

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THE SALTMARSH-BREEDING MOSQUITO, *Aedes (Ochlerotatus) vigilax* (Skuse), is a serious pest in parts of Australia, New Guinea, and New Caledonia and is a proved vector of the New Caledonian strain of nonperiodic bancroftial filariasis (Iyengar and Menon, 1956; Iyengar, 1954; Backhouse and Woodhill, 1956). It was reported from Fiji by Lever (1940), but he subsequently decided that this was an error (Lever, 1945). In November, 1957, *A. vigilax* was discovered near Suva and identified with certainty. Some work has been done on this species since its discovery to determine its status as a potential vector of Fijian filariasis and also to find out how it entered the colony. In common with most Pacific territories, Fiji enforces measures designed to limit the importation of pests (especially anopheline mosquitos, which are absent from the group), but *A. vigilax* had obviously evaded these measures.

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ARRIVAL OF *A. vigilax*

The Fiji group consists of two large islands and numerous smaller ones. The southeast as-

pects of all the higher islands, including the two large ones, are wet, receiving 100–300 in. of rain per year, and in normal years are not without rain for more than a week or two at a time. The northwest sides of these islands have a distinct rainy season from December to May, the rest of the year being dry. Ports of entry from overseas are virtually confined to the largest island of Viti Levu (see Fig. 1). There are two seaports concerned, the capital, Suva, in the southwest, and Lautoka in the northwest. On the east side of the Suva peninsula is the military and civil flying-boat base of Lauthala Bay. The international airport of Nandi is not far from Lautoka.

On December 20, 1957, mosquito larvae subsequently identified as *A. vigilax* were discovered by the local mosquito control organization in brackish pools at the mouth of a creek within a mile of the flying-boat base at Lauthala Bay. These pools were oiled as soon as the larvae were found, but on January 13, 1958, both adults and larvae were discovered in and near brackish pools about 100 yd. from shore some 1,000 yd. northeast of the original discovery. On succeeding days the infestation was traced, principally as sparse adults, as far as the extensive delta of the Rewa River. During January and February specimens were found at Korotongo, 60 mi. west of Suva, and at Mau, Wainiambia, and Nukui (Fig. 1). At all these places we had made regular surveys at intervals during the previous 9 months and it is most unlikely that *A. vigilax* would have been overlooked unless it was present in very small numbers indeed. At the end of January and beginning of February unusually high tides, backed by strong winds, produced many brackish pools suitable for breeding, and many places in south and east Viti Levu complained of being attacked by swarms of the new mosquito, which was sufficiently distinctive to attract lay comment as

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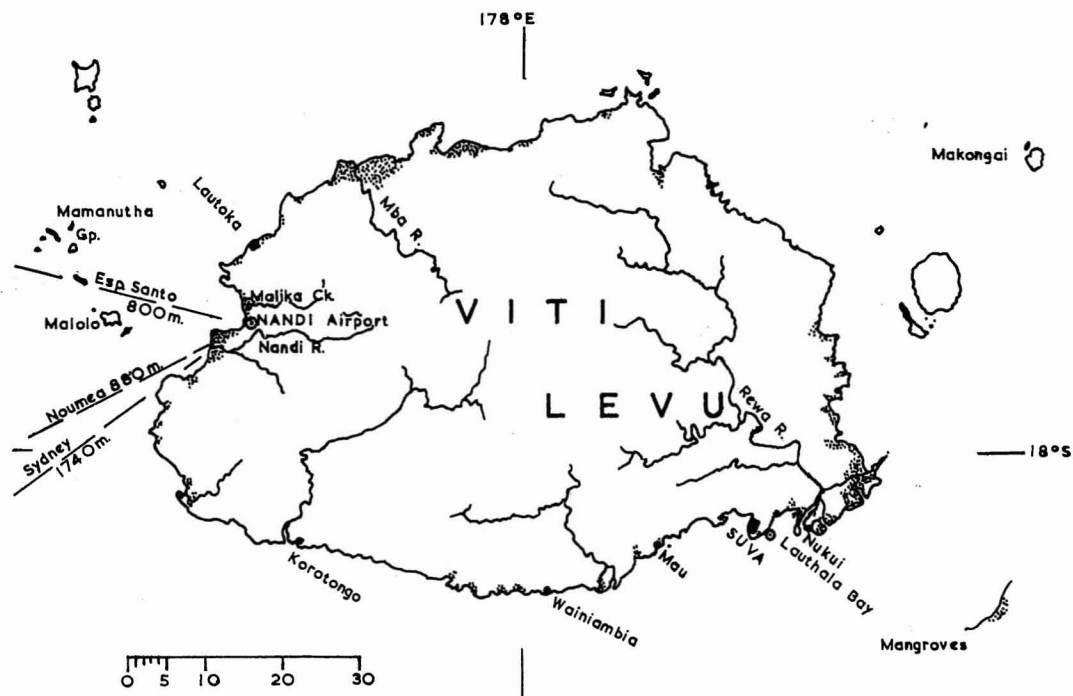


FIG. 1. Viti Levu, Fiji Islands.

something unusual. Suva in particular suffered from prolific breeding in the coastal marshes some 2 mi. distant. In the Rewa delta, breeding was intense in the saline pools left actually within village boundaries by high spring tides. The infestation extended to the dry zone of Viti Levu, being confirmed from Nandi in March, 1958, and near Lautoka in May, while an infestation of plague intensity was found in the Mba delta in June, 1958 (Fig. 1). The inhabitants stated that this had started early in 1958. Thus, shortly after *A. vigilax* was discovered, it became a pest all round the island of Viti Levu, and its initial discovery near the flying-boat base at Lauthala Bay cannot be considered of much significance in deciding its point of introduction. Indeed, although specimens were not obtained near Nandi until March, 1958, there are circumstantial accounts of what was almost certainly *A. vigilax* in the area in October, 1957, and possibly as early as May, 1957. The report originates from the Senior Mosquito Inspector now in charge. He says that when he arrived at Nandi in October, 1957, there were

many complaints of daytime biting by mosquitos, which local informants alleged had started in May, 1957. He identified the mosquitos as *Aedes vexans* (Theo.), with which *A. vigilax* is readily confused, especially if the presence of the latter is not suspected, although *A. vexans* rarely bites by day in Fiji. The infestation was traced to an extensive flooded area 1½ mi. to the north of the airfield where the outlet of the Malika Creek (Fig. 1) had been blocked by a broken floodgate. The water was brackish and the Inspector was surprised to find great numbers of what he took to be *A. vexans* larvae in this brackish water. Unfortunately he took no specimens at the time, but in March, 1958, he collected *A. vigilax* larvae in the same place. When I visited the area in June, 1958, the flood-gate was repaired and the ground was dry, but it was very similar in character to the places where *A. vigilax* larvae had first been reported near Suva.

Retrospective reports made subsequent to the discovery of *A. vigilax* in Fiji should be carefully scrutinised before acceptance, but there

are reasons for accepting this one. There is no doubt that the species was firmly established in Fiji in 1958, and the soil of the area which I was shown in June of that year was saline. *A. vigilax* is the only species likely to breed here in large numbers, except for the easily distinguishable *Culex sitiens* Wied. or possibly *C. annulirostris* Skuse. The origin of the plague of mosquitos at the airport buildings was not likely to have been within a mile of these buildings because surface water is kept to a minimum within this radius by drainage and unavoidable collections of water are inspected regularly. It is characteristic of *A. vigilax* that it may be a serious pest for up to 5 mi. from its breeding place. There is in fact only one other mosquito in Fiji at all likely to be a pest in daylight in the middle of the large bare expanse of the airfield, and this is *A. aegypti*, which could conceivably breed undetected in water collections near the buildings themselves. It would, however, be recognised by even the least competent mosquito inspector. There is no doubt that there was a mosquito nuisance at Nandi in October, 1957, and it is very likely that this was due to *A. vigilax*, but whether it had really been established since the previous May is more doubtful, because reports of a plague at this time are not supported by any written confirmation. The year 1957 was unusually dry in Fiji and serious breeding of any other species would be most unlikely in this area at this time. In any event the October, 1957, report from Nandi precedes by several months reports of *A. vigilax* from elsewhere.

STATUS OF *A. vigilax* IN EARLY 1959

The plague of *A. vigilax* in the southeast of Viti Levu early in 1958 was brought to a sudden end in April, when over 40 in. of rain fell and there were extensive floods. Dense masses of larvae were seen being washed out to sea by the rising Rewa River. Surprisingly, the insect has not reappeared as a pest in the wet southeastern zone although there have been some unusually high tides which have left brackish pools above normal high water. A few larvae were found in the Rewa delta in January, 1959, but these were washed away by floods. In the

dry zone of the island *A. vigilax* has persisted, notably in the Mba delta, in the general vicinity of Lautoka (in small numbers), and near Nandi, where it greatly increased in numbers at the start of the rains in November, 1958 (Fig. 1). It also infests the islands to leeward, e.g., Malolo, where it arrived before May, 1958, when the island was visited in response to a request for help from the islanders. In October, *A. vigilax* was still on Malolo and had reached the Mamanutha Group to the north. It was not found to the windward of Viti Levu until January, 1959, when it was found breeding on Makongai (Fig. 1). It may be assumed that the species is well established and will become a pest again in the wet zone when a suitable combination of conditions arises once more. In Fiji the habits of the insect closely resemble its habits in Australia.

On August 27, 1958, four adult female *A. vigilax* were recovered from an aircraft which had been sprayed on landing at Nandi airport after a flight from Tontouta, New Caledonia. They were fresh and had almost certainly been alive at the time of spraying.

A. vigilax AS A VECTOR OF FIJIAN *Wuchereria bancroftii* AND *Dirofilaria immitis*

A. vigilax from both New Caledonia (Iyengar and Menon, 1956) and Sydney (Backhouse and Woodhill, 1956) have been shown to be highly efficient laboratory vectors of the New Caledonian strain of nonperiodic bancroftial filariasis, and it was feared that it would be equally hospitable to the Fijian strain of the same filaria. The results of various feeding tests are given in Table 1. The mosquitos, aged 2–6 days, were given a single blood meal on the infective subject and were at once isolated in 3" × 1" glass tubes containing a strip of filter paper and closed with mosquito gauze. A drop of sugar solution was placed each morning on the strip of filter paper and in the afternoon a drop of distilled water was added. For the last three feeds some *A. pseudoscutellaris* (Theo.), which is an important vector in Fiji, were included as a check. The three insects dissected immediately after the first feed had been killed,

TABLE 1
LABORATORY INFECTION OF *Aedes vigilax* WITH THE FIJIAN STRAIN OF *Wuchereria bancroftii*
AND WITH *Dirofilaria immitis*

EXPT. NO.	MICROFILARIAE PER 20 CMM. (MEAN OF 2)	DISSECTED MOSQUITOS												
		Days after feed	Total	No. with live larvae (all stages)	MICROFILARIAE		1ST STAGE		2ND STAGE		EARLY THIRD STAGE		MATURE	
					No. mosquitos	Total no. microfilariae	No. mosquitos	Total no. larvae	No. mosquitos	Total no. larvae	No. mosquitos	Total no. larvae	No. mosquitos	Total no. larvae
123	<i>W. bancroftii</i> 5	0	3	0	0									
		7-8	4	0	0									
		9-13	103	2	3	3 (2d*)	2	2 (1d)						
124	17	2-6	9	0	0									
		9-11	49	5	8	16 (d)	1	1	1	2				
125	42	13	20	1	10	14 (13d)								
126	241	13-14	35	3	16	102 (65d)	3	7 (3d)	1	1	1	1	2	2
128	7	2-12	35	2	4	9 (6d)	1	2						
		13-18	73	0	4	5 (d)	1	1 (d)						
Dog 11	<i>D. immitis</i> uncountable	8-10	19	1	5	83 (d)	5	19 (16d)						
		15	10	1	1						1	6		
		17	5	4	4							4	11	
Simultaneous feedings with <i>A. pseudoscutellaris</i>														
125	<i>W. bancroftii</i> 42	13	3	3									3	30
126	241	13	22	18	1	4	1	5	3	11			16	106
128	7	1-10	17	10	1	1	6	14	3	3				
		11-13	19	13							7	11	8	29

* d = dead, frequently disintegrating.

but all mosquitos dissected before the 9th day in experiments 123 and 124, and before the 13th day in the other experiments, died naturally and were dissected the same day. In experiment 128 both species suffered the effects of humidities unusually high even for Suva, with consequent high mortality.

The results (Table 1) contrast strongly with those obtained with a New Caledonian donor by Iyengar and Menon (1956) and by Backhouse and Woodhill (1956). This man showed microfilarial counts ranging from 57 to 154 per 20 cmm. of blood, and infected 94 per cent (Iyengar and Menon, 1956) and 95 per cent (Backhouse and Woodhill, 1956) of all *A. vigilax* fed on him. Backhouse and Woodhill also quote a mature infection rate of 98 per cent in those mosquitos dissected from the 12th day onwards. We obtained only 2 mature larvae, in different insects, among 35 mosquitos that fed on a Fijian with a microfilarial count of 241 per cmm. (mature infection rate, 5.7 per cent). Only

3 (8.6 per cent) of this batch showed live filarial larvae, although 82 per cent of *A. pseudoscutellaris* fed at the same time carried live larvae. Batches of *A. vigilax* fed on other donors with microfilarial counts of 5, 17, 42, and seven showed total live infection rates (no stage later than the second) of 1.8 per cent, 8.6 per cent, 5 per cent, and 1.8 per cent, respectively. *A. pseudoscutellaris* fed on the last two showed live infections in 100 per cent and 64 per cent. It appears that *A. vigilax* is a poor vector of the Fijian strain of *W. bancroftii*.

One feed has been done on a dog which was anaesthetised with nembutal (expt. 11). There was heavy mortality of the fed mosquitos, only five surviving 17 days. Of these, four became infective. This high laboratory mortality of *A. vigilax* is most unusual and contrasts with a complete survival in experiment 126 made about the same time. It is almost certainly due to heavy invasion of the mosquitos' excretory systems as a result of feeding on this very heavy

infection. One would expect a lower mortality if they were fed on an animal with fewer microfilariae, but probably a high final infection rate. Few dissections of *A. vigilax* caught wild have been made, but in a series of 30 mosquitos from Raiwai village on the Suva peninsula, one mature larva of *D. immitis* was found.

DISCUSSION

It was most unexpected to find that *A. vigilax* was refractory to the development of Fijian filariae. The insects which reached Fiji are almost certainly derived from Sydney or from New Caledonia because transport from other parts of the range of this species (Iyengar, 1955) is very rare. Since *A. vigilax* from both these places is an exceedingly efficient vector of the New Caledonian strain, it is very probable that difference is not in the strain of mosquito but in the strain of parasite, although both are nonperiodic. This could be confirmed if mosquitos of known provenance were fed on a Fijian donor.

The failure of *A. vigilax* to develop mature Fijian filarial larvae readily was a considerable relief because its habits differ completely from those of our four native vectors (Symes, 1955, 1956). If it were a vector it would be likely to increase the prevalence of filariasis in places where it is at present unimportant, while to control it would require special measures. The arrival of this pest has been beneficial in one way, for it has drawn public attention to the importance of excluding such immigrants and to the need to reconsider the efficacy of the measures in force and of their application in practice.

There is little doubt that this was a new introduction. The only previous report of *A. vigilax* was Lever's (1940), afterwards declared to be an error (Lever, 1945). Since then much work has been done on Fijian mosquitos (Amos, 1947; Symes, 1955, 1956; Laird, 1956) without the detection of *A. vigilax*, and our regular surveys in south and east Viti Levu found none before the first outbreak. Introduction by ship appears less probable than by air because *A. vigilax* would not be at all likely to breed on a ship and is a strong-flying and active insect

unlikely to remain on board as an adult for the several days required for its transport. Ships coming direct from any part of its range outside the malarial zone are not subject to fumigation in Fiji, but the waterfronts of the two ports appear inhospitable to the insect. Frequent searches were made along the Suva waterfront but *A. vigilax* larvae were found only once, after the city had been invaded from the other side of the Suva peninsula. Only a few larvae were found and there was no recurrence. At Lautoka, although infestation has persisted on this side of the island, *A. vigilax* has not been found near the harbour.

That the species is capable of being transported by air was demonstrated by its recovery in August, 1958, from an aircraft at Nandi. Of the two air stations, Lauthala Bay normally offers the better facilities for the establishment of a mosquito with the requirements of *A. vigilax*. In addition there is a greater chance that an insect will escape from a flying boat than from a landplane before insecticidal treatment, because it is necessary to open hatches for mooring the former before treatment can be carried out. However, very few aircraft land at Lauthala Bay from places within the known range of *A. vigilax*, whereas Nandi receives many scheduled flights from such places. Opportunities for arrival at Nandi are not only frequent but the first reports of mosquitos that were probably *A. vigilax* came from the airport area during a period when conditions there were unusually suitable for the establishment of this species, suggesting that this was the place of arrival and that on this occasion the usual disinsectisation procedure proved inadequate. The mosquito, once established, presumably spread round the island from the edge of one mangrove swamp to another (see Fig. 1) until unusually favourable conditions of tides and weather permitted simultaneous rapid multiplication to plague proportions over a large area. If this account is correct it emphasizes the importance of the unusual feature, the flooding, which provided a refuge and breeding place on arrival. Introduction of a pest to a new country by man-operated transport depends on a sequence of events—the pest must be present near its potential vehicle, it must be able to enter and remain

within it, survive the journey, survive any treatment designed to destroy it, and escape on arrival and find refuge, food, and a breeding place. It and its offspring must then survive to breed. It is virtually impossible to ensure that no insect can survive any particular one of these stages and efforts should be directed to weakening every link in the chain as much as possible. In the present case it is probable that the unusual facilities offered for breeding were decisive in making the introduction of *A. vigilax* possible. There is no reason why a similar accident should not permit the much more serious establishment of a malaria vector, and all reasonable measures should be taken to prevent it.

SUMMARY

Aedes (Ochlerotatus) vigilax (Skuse) is a serious pest in Australia, New Caledonia, and elsewhere. In December, 1957, it was found breeding near Suva and within 3 months it had been found round much of the coast of Viti Levu, the largest island of the group, and was established as the worst pest species on the coast whenever conditions favoured its breeding. Its spread is described and its probable mode of introduction, by air, is discussed.

The species is a very efficient host of the New Caledonian strain of nonperiodic bancroftial filariasis but is a poor host of the Fijian strain of this parasite. One experiment indicates that it may be a good vector of the dog filaria *Dirofilaria immitis*.

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