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Reprinted from AMERICAN JOURNAL OF TROPICAL MEDICINE AND HYGIENE
Vol. 4, No. 3, May, 1955, 543 - 549
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During 1951 yellow fever appeared in the Atlantic drainage of Costa Rica, producing a widespread epizootic in monkeys and a number of human cases with some fatalities (Elton, 1952; Vargas and Elton, 1953). Following the first recognized human fatality contracted near Puerto Limon, the authors were invited by Dr. Oscar Vargas Mendez, Director General of Public Health of Costa Rica, to undertake investigations of the mosquito fauna associated with sylvan yellow fever in the area. An attempt was also to be made to establish the vector or vectors by isolation of virus from mosquitoes caught in the vicinity of proven yellow fever fatalities.

A field investigation of this first human case revealed that the victim had been supervising a crew of men thinning out the forest trees used as shade at a cacao plantation on a tract of land known as Wauchope, about 10 miles southwest by narrow gauge rail from Puerto Limon. Two local woodsmen were engaged to build rough ladders into the canopy of trees bordering the cacao plantation, and to collect alive in shell vials such blue mosquitoes as attempted to bite them during the daylight hours they were stationed in the trees. These men were put under the daily supervision of a local sanitary inspector kindly made available by Dr. Vargas. By instructing the men to catch only "blue mosquitoes" we restricted the collections almost entirely to mosquitoes of the genus *Haemagogus* *Aedes* of the subgenus *Finlaya*, and certain of the sabethines. Thus we eliminated from the collections virtually all of the ground breeding mosquitoes such as *Psorophora*, *Mansonia*, and *Aedes* of the subgenus *Ochlerotatus* in which we were not interested. The human fatality contracted at Wauchope had occurred on July 24th. The infection had presumably been contracted about a week previous. As the work at Wauchope was begun on August 9th, we were approximately three and a half weeks late in starting the collecting. Mosquito captures were continued here through September 13th.

Since we were so late in getting started at Wauchope, we attempted to estimate by projection where yellow fever might be expected during the following month so that we might have additional mosquito collecting stations located where yellow fever was concurrently active. This estimate was based on our experience with the ecological preferences of *Haemagogus spegazzinii falco* and *Aedes leucocelaenus clarki*, two known South American vectors of yellow fever which we had found present at the locations where yellow fever had appeared in Panama the previous two years (Galindo *et al.*, 1950; Trapido *et al.*, 1955). Thus we sought a location supporting true tropical rain forest on slopes 100 to 500 meters above sea level, if possible within 50 or 75 miles of the already known focus. Another consideration was that of selecting a site from which the collections of living

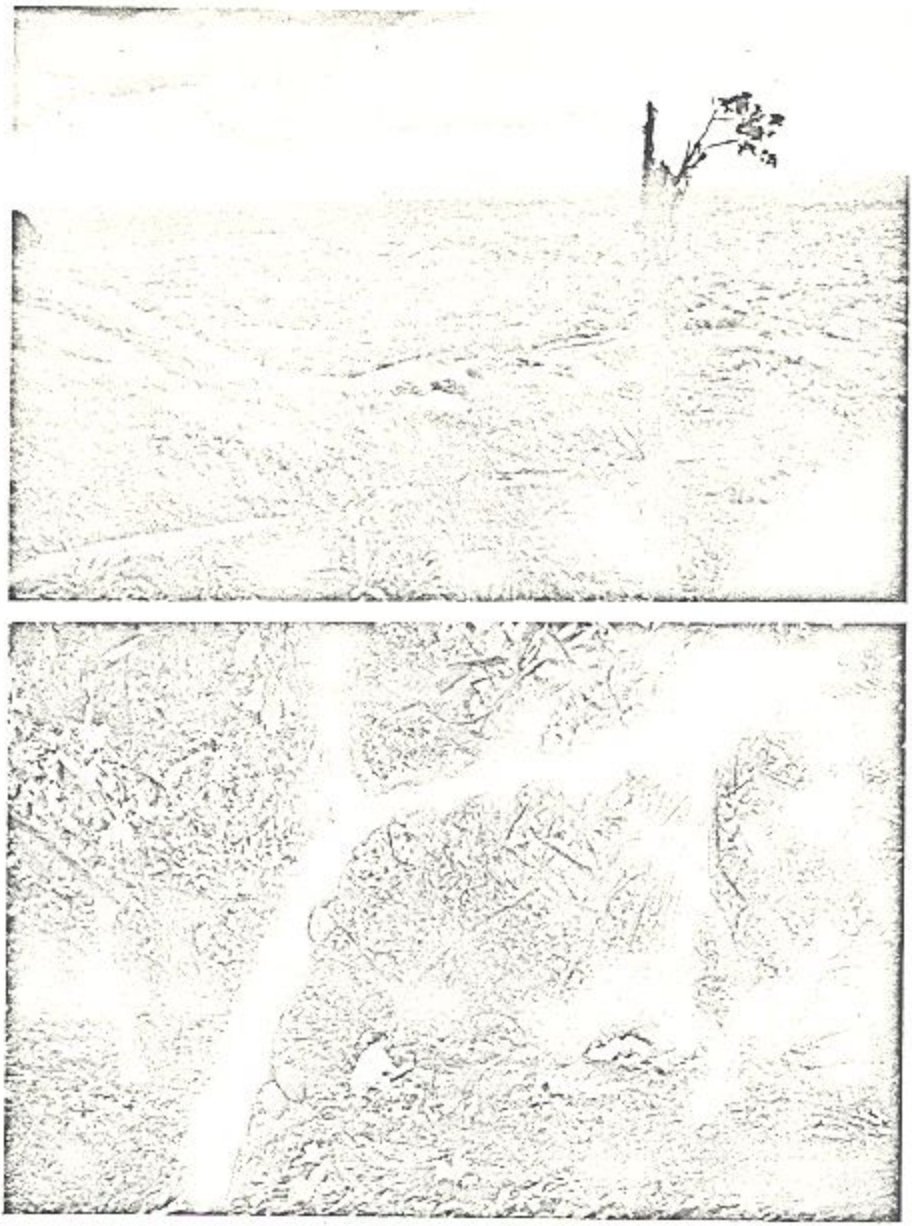

FIG. 1 (Upper). San Miguel, Costa Rica. View of the rolling hill country of the basin of the Rio Sarapiqui from the base of the Cordillera Central. The rain forest here is only partially disturbed by cultivation.

FIG. 2 (Lower). Collecting *Haemagogus* at ground level in cacao plantation at Wauchope. The broken canopy of the original rain forest permits the filtering through to the ground level of the microclimatic conditions of the upper stories of the forest.

mosquitoes could be gotten out for shipment by air on a daily basis to our laboratory in Panama. The second locality chosen for these reasons was in the vicinity of San Gerardo. This settlement was located in the basin of the Rio Sarapiqui, seven hours by horse from San Miguel, in the rolling hill country at the northern

foot of the Cordillera Central (see Figure 1). The elevation was about 250 meters. During the reconnaissance of this area on August 11th and 12th local persons told us of monkey mortality, and San Gerardo was specifically chosen as a collecting site when a woodsman took us to the decomposed carcass of a spider monkey (*Ateles*). Subsequently, human cases of yellow fever contracted in this area were diagnosed. The collections were begun here on August 13th and continued until September 18th. At this locality four men were employed to make the collections in the same manner as at Wauchope.

During the weeks following the establishment of these collecting stations, various delays were experienced in getting the mosquitoes to Panama. We found it took from three to 11 days for the mosquitoes to reach us, and as much as 80 or 90 per cent mortality was experienced, although the individual vials in which the mosquitoes were captured and shipped were provided with cotton plugs moistened in sugar solution. While the attempts at virus recovery were thus handicapped, and in fact results were negative, a good sample was obtained of the forest canopy mosquito fauna associated with sylvan yellow fever in this newly invaded area.

DISCUSSION OF RESULTS

A summary of the mosquitoes taken is given in Table 1. The literature covering the present knowledge of the status of various mosquitoes as vectors of yellow fever has recently been summarized by Whitman (1951), and for the sake of brevity the original references will not be individually cited here. They may be found in Whitman.

Of greatest interest are the collections of *Haemagogus*, the genus widely implicated in the transmission of sylvan yellow fever in South America. The most abundant *Haemagogus* at Wauchope was *H. spegazzinii falco*, a species from which yellow fever virus has repeatedly been isolated in Colombia. The species was at this place more abundant than we had found it at the Panama localities where yellow fever appeared (Galindo *et al.*, 1950). At San Gerardo it was less common, but even so the numbers were greater than those taken at the same time of year at the Panama stations. While it is always possible that there are sylvan vectors of yellow fever about which we do not know, the association of *spegazzinii falco* with yellow fever in this case may best be taken at face value.

In Panama it had been our experience that *spegazzinii falco* was a mosquito of primary tropical rain forest, and that it was absent or rare in second growth, or in areas of relatively low rainfall which supported only deciduous tropical forest. The species is also strongly arboreal. It was thus with some surprise that we found in our initial survey at Wauchope that *spegazzinii falco* was attacking in some numbers on the ground in the cacao plantation which was only partially shaded by the residue of forest trees. This experience was repeated when we returned to Wauchope on a short visit in 1954. It would seem that in areas of abundant rainfall where the shade utilized for the growing of cacao is obtained by only partially clearing the original rain forest cover, the conditions of light, temperature and humidity which comprise the microclimate of the forest canopy

TABLE 1

Forest canopy mosquito collections from Costa Rica, 1951

	San Gerardo Alajuela Prov. 9 Aug. to 15 Sept.	Wauchope, Limon Prov. 13 Aug. to 18 Sept.	Total
Haemagogus equinus	24	123	147
Haemagogus lucifer—iridicolor	331	157	488
Haemagogus spegazzinii falco	96	331	427
Total Haemagogus	451	611	1,062
Aedes leucocelaenus	5	2	7
Aedes leucotaeniatus	3		3
Aedes fulvus	1		1
Aedes serratus	1		1
Aedes angustivittatus	2		2
Psorophora ferox	12	2	14
Psorophora lutzii	3		3
Psorophora sp.	1		1
Total Culicini	479	615	1,094
Wyeomyia (Wyeomyia)	15	4	19
Wyeomyia (Dendromyia)	21	13	34
Sabethes cyaneus	26	39	65
Sabethes tarsopus	17	24	41
Sabethoides chloropterus	86	111	197
Total Sabethini	165	191	356
Anopheles neivai	2		2
Total Anophelini	2		2
Total all mosquitoes	646	806	1,452

are similated at ground level, and the vertical distribution of such mosquitoes as *spegazzinii falco* is thereby modified (See Figure 2 and 3). A similar situation where forest trees have been permitted to remain as shade for coffee is reported by Bugher *et al.* (1944). In some places the shade desirable for the propagation of coffee and cacao is obtained by artificial plantings of shade trees after complete clearing. Under these conditions *Haemagogus spegazzinii falco* would not be expected, probably at least in part because there has not been adequate time for the appearance of rot holes in the trees necessary for larval development. The significance of this modification of the forest cover which brings the microclimate of the canopy down to ground level is that in such situations there is danger of contracting sylvan yellow fever on the ground. In undisturbed primary rain forest, the ecological conditions in the canopy are so different from those on the ground, that persons may pass with relative safety through such forest without

FIG. 3. Mosquito collecting station at Wauehope, Costa Rica. The original primary tropical rain forest has been thinned by selective cutting, permitting the sunlight to reach the ground level which is utilized as cacao plantation. Under these conditions arboreal mosquitoes come down to ground level.

being exposed to biting by canopy mosquitoes which may have become infected from feeding on arboreal primates.

Haemagogus equinus, which had been the commonest species of the genus found in the Panama studies, was the least common *Haemagogus* at the Costa Rican stations. This species is known to be capable of transmitting yellow fever in the laboratory, but virus has never been recovered from it with certainty in nature. As it was outnumbered by *spegazzinii falco* at both localities studied, we have no need to hypothesize its involvement in the transmission at these places.

Haemagogus iridicolor replaces *Haemagogus lucifer* in western Panama and Costa Rica, but as the two are not readily separable as females they are recorded together, although the collections probably represent only *iridicolor*. These slightly outnumbered *spegazzinii falco* in the collections. There is no information available on the ability of either of these species to transmit yellow fever.

Another proven vector of sylvan yellow fever in nature is *Aedes leucocelaenus clarki*. In the present collections it was so rare, only seven individuals being taken in all, that it may be excluded from consideration. Significant numbers of other *Aedes* and *Psorophora* were not taken in the tree canopy as the collectors concentrated on capturing "blue mosquitoes."

The commonest sabethine mosquito taken was *Sabethes chloropterus*. We have suspected that this species might be involved in sylvan yellow fever transmission in Panama on the basis of its habits, distribution, association with the appearance of yellow fever, and the fact that there is some partial evidence in support of its ability to carry virus. In Panama it was generally present in about the same numbers as *spegazzinii falco*, but differed in that captures were made throughout the dry season when *spegazzinii falco* could not be found. In the present case it is not necessary to hypothesize its involvement since such substantial numbers of *spegazzinii falco* were present, although we consider it of interest that once again it can be shown to be associated with the presence of sylvan yellow fever. The other sabethines were present in lesser numbers and appear to be of no special interest.

SUMMARY AND CONCLUSIONS

During August and September 1951, forest canopy mosquito collections were made at two localities in Costa Rica where sylvan yellow fever was active. *Haemagogus spegazzinii falco*, a species which has been found naturally infected with yellow fever on a number of occasions in Colombia, was the commonest species of the genus present at Wauchope and was at least as abundant at San Gerardo as it had been at localities where yellow fever appeared in Panama in the two years previous. The conservative course would be to take this association at face value and consider this species the probable vector in this outbreak.

Haemagogus spegazzinii falco is ordinarily an inhabitant of the upper stories of primary tropical rain forest, but at Wauchope we found it commonly at ground level in cacao plantation in which the original forest cover had been thinned to provide the partial shade necessary for cacao trees. In these circumstances the canopy habitat is simulated at ground level and the stratification of

spegazzinii falco is less pronounced. Such a situation provides conditions under which there is danger of sylvan yellow fever transmission on the ground.

Other *Haemagogus* present were *H. equinus* and *H. lucifer-iridicolor*. The former is known to be capable of transmitting virus in the laboratory but has never been found infected with certainty in nature. Nothing is known of the vector status of the latter two species. As the numbers of *H. spegazzinii falco* present were ample to explain the transmission of yellow fever in the area, these species need not be considered in the present circumstance.

The commonest sabethine mosquito present was *Sabethes chloropterus*. Its status as a vector is unknown, but on epidemiological grounds we considered it suspect in Panama, and note with interest its present association with yellow fever.

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