risen enormously, and the island has become a health resort. For almost a year no adult *Anopheles* have been found in the numerous traps or elsewhere, but an occasional larva is still found in the remaining water collections, the swamps and temporary small pools. Dr. Horace Gillette, the Director of the Malaria Division, believes that the species can be eradicated in another two years. Even should he prove too optimistic, the campaign has already more than justified itself.

These are only a few examples of the solid control work being done in South America, and Central America. If time had been available, I should have mentioned also the active and fruitful field and laboratory investigations being carried out in connection with the control activities. However, most of the published reports are abstracted in *Mosquito News* or in other journals.

As one result of the universal use of residual insecticides, the old malaria organizations are being given responsibility for the control of other arthropod-borne diseases, such as yellow fever, filariasis, typhus, plague, trypanosomiasis, bartonellosis, and fly-borne gastro-intestinal diseases. This is a logical step, and one to which I am sure the members of this Association are giving increasing attention.

While the enthusiasm for the residual insecticides is justified in spite of the rapid development of resistance by many species of insects—even including certain species of *Anopheles*—I believe it is significant that the use of "permanent" measures of control has not been abandoned, and in some instances is being increased. I need not go into the arguments for or against the exclusive use of residual insecticides, but I submit that they are to be considered as an additional powerful weapon in the continuing fight against pest insects and insects that transmit diseases to man, and not as the final and complete answer to the complex problem of their control.

FOREST MOSQUITO STUDIES IN AN ENDEMIC YELLOW FEVER AREA IN PANAMA

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Although sylvan yellow fever has been prevalent for many years in several countries in northern South America, particularly in adjacent Colombia, its presence in Panama was not generally known until January, 1949. Reports by Clark (1938) and Kumm and Crawford (1943) called attention to the fact that yellow fever had been active in relatively recent years east of the Canal Zone, but it required the actual recognition of several human deaths caused by yellow fever to cause this disease to be recognized as an important problem in Panama.

Entomologists had been active in the Canal Zone and adjacent Republic of Panama during most of the first half of this century, but they were concerned chiefly with the mosquito vectors of malaria. Thus, little was known of the composition of the mosquito fauna and its activity throughout the extensive forests covering much of the country. Following the recognition, in January 1949, of several deaths caused by sylvan yellow fever in the Pacora area, some twenty miles east of Panama City, the writers undertook a study of the composition and activities of the diurnal forest mosquitoes that relate to the possible vectorship by these insects of sylvan yellow fever in this area. At first,

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during the year 1949, the study was limited to areas in the Canal Zone and in Central Panama, but later, during 1950, was extended to western Panama and adjacent Costa Rica, as the disease showed signs of moving westward.

Sylvan yellow fever is principally a disease of monkeys in the deep forests, transmitted from monkey to monkey by mosquitoes living mostly in the forest canopy. The disease is occasionally transmitted to humans, particularly hunters, lumbermen and those engaged in farming small cultivated areas adjacent to the heavy forests.

In nearby Colombia, *Haemagogus spegazzinii falco* Kumm *et al.* and *Aedes leucocelaenus* Dyar and Shannon have been found infected with yellow fever virus in nature and have transmitted the virus by bite. In addition, the virus has been recovered by inoculation from a mixed group of sabethine mosquitoes, including *Sabethes (Sabethoides), Limatus, Wyeomyia* and *Trichoprosopon* (Shannon *et al.,* 1938). Evidence obtained both from field and laboratory work in South America has incriminated *Haemagogus spegazzinii* and *Aedes leucocelaenus* as the most important vectors of sylvan yellow fever in that area.

A few years ago, Komp (personal communication) had obtained a few larvae of *H. spegazzinii falco* in a tree-hole on Barro Colorado Island in the Canal Zone, but the species was not found again. The species was first recorded in the literature from Panama by Galindo *et al.,* (1949) and described as a common forest species on the heavily forested slopes of Cerro La Victoria where sylvan yellow fever was first recognized in Panama in 1949.

METHODS OF STUDY. During January, 1949, a series of four mosquito collecting stations was established in the heavy forests, from about sea-level to 2100 feet altitude, in the Pacora area, near the location where several fatal cases of yellow fever had occurred. In addition, one station was established in a heavy rain forest near Fort Sherman, on the Caribbean side, and another at Juan Mina on the Chagres River, midway across the Isthmus. Each of these stations consisted of a tree in the dense forest to which platforms were attached about midway up the trunk and in the crown of the tree. These platforms were made accessible from the ground by strong ladders. The upper platform at these stations ranged from 40 feet to 71 feet above the ground, depending on the height of the trees in each particular locality. During 1951 and 1952 all stations were equipped with a single platform located in the forest canopy (Figure 1).

Simultaneous catches were made of mosquitoes either biting or approaching to bite human collectors stationed at ground level and on the platforms, one day each week at each station (Figures 2 and 3). During the first year of study, thirty-minute collections were made each hour from 8:00 a.m. to 5:30 p.m. Common species of ground pool breeding mosquitoes, including *Aedes taeniorhynchus* (Wiedemann), *A. serratus* (Theobald), *Mansonia* spp. and *Psorophora* spp., were usually captured in chloroform tubes and then transferred to appropriately labeled pill boxes for subsequent identification. The collectors soon learned to recognize metallic colored species and other true forest mosquitoes, and these were allowed to feed and were then captured in small oviposition vials, each provided with a wad of moist cotton and a circle of filter paper on the bottom. The vials containing the live specimens were carried to the laboratory, where the females were held for oviposition. Much valuable information relating to their identity and habits was obtained from these ovipositing females and their progeny (Galindo *et al.,* 1950).

Information was obtained on the breeding habits of mosquitoes in the forest by making weekly collections of larvae from nearby tree-holes and miscellaneous water containers in each station area, and through the use of bamboo larval traps, hung on the station tree and nearby trees (Galindo *et al.,* 1951a).

Two types of bamboo larval traps were used in these studies, those with the top open (Figure 4), and those with the top covered with a lid or hood, and a small

FIG. 1. Tree station used for collecting mosquitoes in the forest. Ladder, platform in forest canopy, and assistant used as bait and collector are shown.

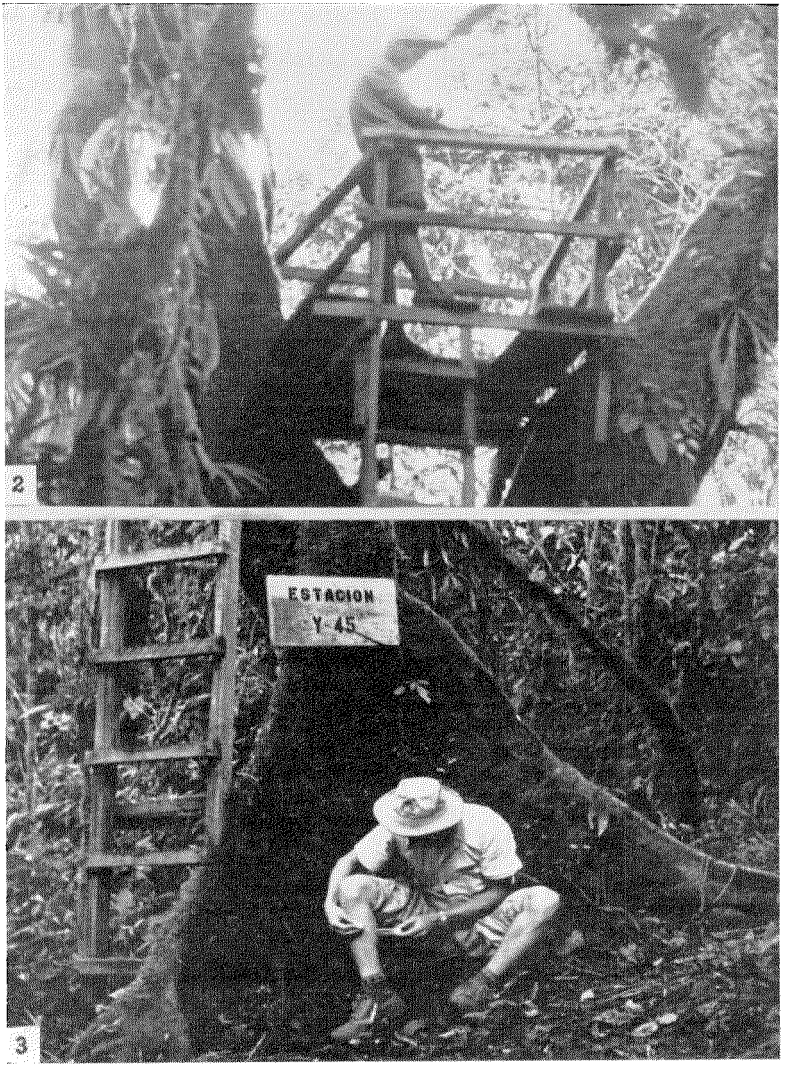

FIG. 2. Collecting mosquitoes on platform in canopy of the forest.

FIG. 3. Collecting mosquitoes at ground level at tree station in the forest.

hole cut through the side (Figure 5). We realized early during this work that we were not getting larvae of *Haemagogus spegazzinii falco* and *Sabethes* spp. in numbers commensurate with the adult catches of these species, and the closed top bamboo trap, with the small opening through the side, was designed in an attempt to meet the breeding requirements of these mosquitoes. This type of larval trap solved our problem with *Sabethes cyaneus* (Fabricius) and *S. chloropterus* (Humboldt) but apparently did not meet the breeding requirements of *H. spegazzinii falco*.

The bamboo traps were examined for larvae once each week at each station. When larvae were found, they were transferred to appropriate containers and carried to the laboratory for immediate identification or for rearing and associating the adult with the larval and pupal exuviae. The bamboo traps with the tops open were left empty after each weekly examination during the rainy season, to be refilled by rainfall. It was necessary to carry water and refill these bamboo traps by hand during the dry season. Bamboo traps with the closed top had to be refilled by hand each week during both the dry and rainy seasons.

Several additional adult mosquito collecting stations were established and operated for specific purposes during brief periods of the first year of the study. Four such tree stations, consisting of a single platform each, were established near Buena Vista, between the Trans-Isthmian Highway and Gatun Lake, where two fatal cases of yellow fever occurred in August, 1949. Unsuccessful attempts were made to recover yellow fever virus from mosquitoes captured at these tree stations during the remaining few weeks of the rainy season. Six similar stations were established and operated simultaneously for this purpose on Cerro La Victoria near Pacora.

One station was established in a mangrove swamp near the ruins of Old Panama for the purpose of studying the habits of *Haemagogus chalcospilans* Dyar. Another station was established on Flamenco Island, one of the three small islands at the Pacific entrance to the Panama Canal, to obtain information on the habits of *Haemagogus argyromeris* Dyar and Ludlow. No platforms were built at these two stations, at Old Panama and Flamenco Island, but biting collections were made at ground level one day during each week.

During 1950, the second year of this work, 38 tree stations, consisting of a single platform each, were established and operated during the rainy season, throughout eastern and western Panama. These stations were located in Darien and Colon Provinces, east of the Panama Canal, and in Panama, Cocle, Herrera, Veraguas and Chiriqui Provinces west of the Canal Zone. One of the writers, Carpenter, went to Costa Rica in May, 1950 and set up four tree stations in Puntarenas Province, two each at Esquinas and Jalaca. These stations in Costa Rica were operated with the assistance of personnel of the Golfito Division of the United Fruit Company. The presence of *H. spegazzinii falco* and *A. leucocelaenus* in Costa Rica was definitely established during this work in 1950, even though the Costa Rican stations were operated for only a short period (Galindo *et al.*, 1951b). Hourly catches, from 9:00 a.m. to 3:00 p.m. one day each week, were made of mosquitoes approaching the collectors to bite at both ground and canopy levels at each of the tree stations operated during 1950.

In April, 1951, one of the natives in the group surveying for the right-of-way for a road from Almirante to Boquete in Northwestern Panama died in the Almirante Hospital of yellow fever. Four tree stations were immediately established in this area in northwestern Panama in Bocus del Toro Province and our catches from these stations yielded more *H. spegazzinii falco* than we had obtained any place in Panama, except in Cocle Province in midwestern Panama.

Later during the summer, 1951, there were reports of sylvan yellow fever in Costa Rica, particularly in Limon Province, adjacent to Bocus del Toro Province of Panama. The disease has since

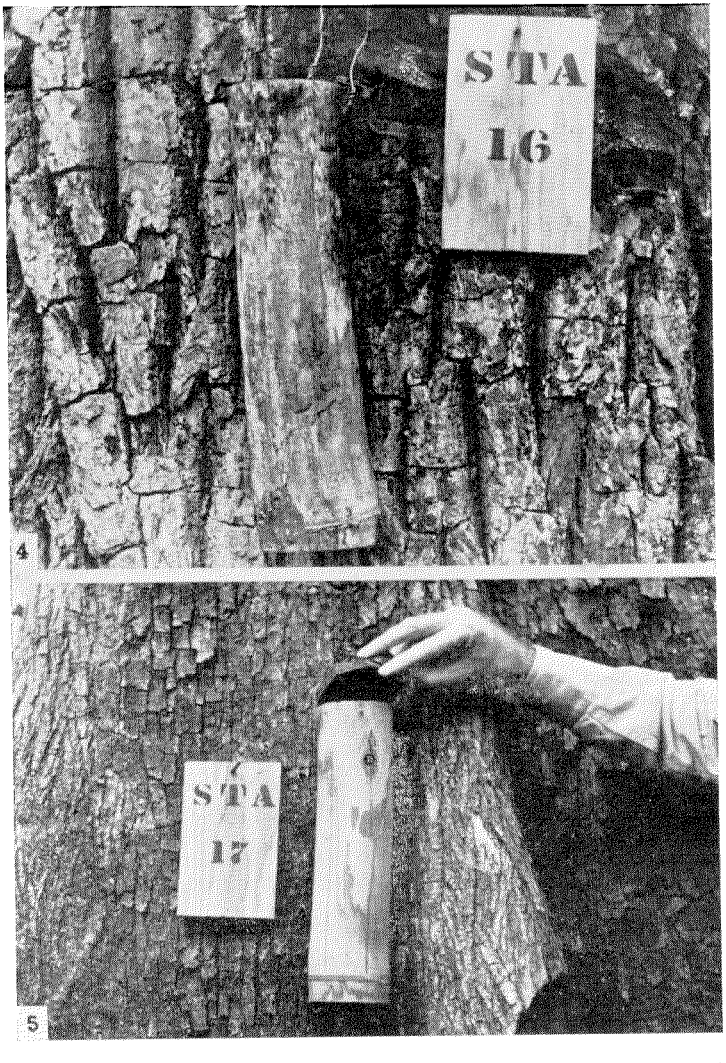

FIG. 4. Bamboo section larval trap used for studying the breeding habits of mosquitoes in the forest.

FIG. 5. Bamboo larval trap with a cover for the large opening in the top. The hollow bamboo section is made accessible to mosquitoes by means of a small opening cut through the side.

occurred in other provinces in Costa Rica. During July, August and September, 1951, there were over 170 cases diagnosed as yellow fever in Costa Rica, with between 30 and 40 deaths.

Two of the writers, Galindo and Trapido, went to Costa Rica at the beginning of August, 1951, and set up four tree stations at two places (Wauchope, in Limon Province, and at San Gerardo in Alajuela Province, north of San Jose) in an attempt to get mosquitoes through to Panama for recovery of virus. The shipments of live mosquitoes were usually delayed in reaching the laboratory and virus was not recovered. However, we were able to get considerable information on the mosquito fauna of the forest canopy in these areas during August and September, 1951.

DISCUSSION OF SPECIES. Three species of *Haemagogus, H. spegazzinii falco, H. equinus* Theobald and *H. lucifer* Howard, Dyar and Knab are generally abundant and widely distributed in the forests of Panama and Costa Rica. Three other species, *H. argyromeris* Dyar and Ludlow, *H. chalcospilans* Dyar and *H. iridicolor* Dyar are less abundant or are more limited in their distributions.

Haemagogus spegazzinii falco, the principal known vector of sylvan yellow fever in northern South America, is found in the virgin rain forests, particularly on the slopes of the mountains, throughout much of central and western Panama and Costa Rica. The females are predominantly arboreal and are avid feeders on man under these conditions.

During these studies, we observed that this species tends to have a spotty distribution within the forest. For example, one tree station in a given area would often yield a large catch, while a nearby tree station would be negative for the same period. It may be that the activities of the females are largely confined to areas of the forest where optimum conditions exist for such activity; however, we were not able to recognize any significant differences in either of these environments. The males of this species were never encountered in the forest, and we were able to get males only by rearing larvae or by obtaining eggs from gravid females and hatching and rearing the larvae.

Although the larvae were found in tree-holes and in bamboo traps on several occasions, we were never able to find them in numbers commensurate to the number of adults found in the area. For a while, we were of the opinion that the larvae might be more abundant in rot cavities high up in the trees, in the forest canopy. During 1950, a large series of tree-holes were located in the forest canopy by climbing, and were subsequently examined each week over a period of two and one-half months for larvae. Larvae were not any more abundant in these tree cavities in the forest canopy than in bamboo traps situated in similar locations.

It was interesting to note that the eggs of *H. spegazzinii falco* apparently do not begin hatching until after at least two or more floodings and drying of their breeding places. The adults appear much later in the forest after the beginning of the rainy season than do other *Haemagogus* spp. The maximum number of larvae found in a breeding container during a single examination was seldom more than four or five. The fact that the eggs do not all hatch following a single flooding, insures the species against adversity.

Haemagogus spegazzinii falco was particularly abundant at our Pacora stations in central Panama where the outbreak of sylvan yellow fever occurred in January 1949. Our catches also showed heavy populations in Cocle Province in midwestern Panama, at Almirante in Bocus del Toro Province in Northwestern Panama, where yellow fever occurred in May, 1951, and in Costa Rica at Wauchope in Limon Province and at San Gerardo in Alajuela Province, north of San José. At Almirante in northwestern Panama, the total catch of *H. spegazzinii falco* was almost as great as the combined total of *H. equinus* and *H. lucifer*. At Wauchope in Costa Rica, where a large number of cases of yellow fever occurred in humans, *H. spegazzinii falco* outnumbered all other *Haemagogus*.

Haemagogus equinus and *H. lucifer* are also found mostly in the deep virgin forests and also feed in greater numbers in

the canopy of the forest than at ground level. These species are widespread throughout the area studied, and are generally more abundant than *H. spegazzinii falco* in many areas. The larvae of both species, *H. equinus* and *H. lucifer,* were plentiful in tree-holes and bamboo traps during the rainy season. *Haemagogus equinus* was particularly addicted to breeding in bamboo traps, more so than any other *Haemagogus* spp. found in the area.

The mating of males and females of both *H. equinus* and *H. lucifer* was observed by the writers on several occasions. The males were attracted to the collector in the forest and remained in flight a distance of three or four feet away, until the females arrived to feed. As the females approached the collector, they were caught by the males and copulation took place during flight.

Other *Haemagogus* spp. occurring here are either less numerous or are more restricted in their distribution. *Haemagogus argyromeris* is generally found in or near second growth timber and rarely invades the deep virgin forest. *Haemagogus chalcospilans* breeds mostly in rot cavities in mangrove trees found in the tidal marshes.

Aedes leucocelaenus, a known vector of sylvan yellow fever in northern South America, but generally of lesser importance than *H. spegazzinii falco,* is a prominent member of the mosquito fauna of the heavy virgin forests in this area. The females of *A. leucocelaenus* feed at ground level and in the forest canopy, appearing to favor the canopy for feeding in many areas.

Other members of the subgenus *Finlaya* commonly occurring in the forests in Panama are *A. leucotaeniatus* Komp and *A. terrens* (Walker). One member of the subgenus *Howardina, A. quadrivittatus* (Coquillett) which occurs in western Panama displayed a distinct preference for feeding in the forest canopy.

Members of the genus *Sabethes* may be regarded with some suspicion as possible vectors of sylvan yellow fever, since they appear to be the only diurnal, canopy feeding mosquitoes remaining in the forests in numbers during most of the dry season, when *Haemagogus* spp. and *Aedes* (*Finlaya*) spp. have practically disappeared as adults.

Sabethes chloropterus is predominantly a canopy-feeding mosquito and is widely distributed and abundant in many areas in Panama and Costa Rica. *Sabethes cyaneus* and *S. tarsopus* Dyar and Knab are somewhat less common than *S. chloropterus* but likewise show a preference for feeding in the forest canopy. The larvae of *Sabethes* develop in water in deep tree-holes having small openings. The larvae of two of the species, *S. cyaneus* and *S. chloropterus,* readily took to breeding in bamboo traps which had the top closed and a small opening cut through the side, simulating their natural breeding places.

One member of the genus *Trichoprosopon, T. magnum* (Theobald), which breeds in water collections found in the leaf axils of plants, proved to be predominantly arboreal in its feeding; however, the species has a rather limited distribution in the area.

At some of our lower stations, pest species, particularly *Aedes* and *Mansonia,* were very annoying to our collectors situated at ground level during certain seasons of the year. At one station, located near extensive salt marshes, *A. taeniorhynchus* was at times so abundant that it was almost unbearable for the collector situated on the ground, yet this mosquito was rarely encountered by the collector situated on a platform only twenty feet above the ground.

SUMMARY. A study of the distribution, occurrence and habits of diurnal forest mosquitoes in Panama and Costa Rica is described, following an outbreak of sylvan yellow fever which was first recognized in Panama in January, 1949.

Adult mosquitoes were captured in the forest at ground level and also in the forest canopy, where human collectors were stationed on platforms reached by ladders. Larvae were collected regularly in the forest from tree-holes and bamboo larval traps.

Pertinent information is given on outbreaks of sylvan yellow fever occurring in

central Panama during 1949 and in northwestern Panama and Costa Rica during 1951.

The habits of common species of canopy-feeding mosquitoes of this area, belonging to the genera *Haemagogus, Aedes* (*Finlaya*), *Sabethes* and *Trichoprosopon,* are described.

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MOSQUITO CONTROL IN THE SOUTH PACIFIC

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A trip to Tahiti to attend a conference on filariasis provided a good opportunity to observe the mosquito situation on some islands in the Pacific. Because mosquito-borne diseases are a major health problem and because of fast air transportation, the possibility of these diseases spreading from these islands to Hawaii necessitates constant vigilance in our control program.

Both filariasis and dengue are common in many islands of the South Pacific. It is because of the wide prevalence of filariasis and the importance of its control, that the South Pacific Commission held a conference on this disease to improve the health of this part of the world.

Tahiti was chosen for the site of the conference because an active program of filariasis control is being carried on there. Intensive research on filariasis is being conducted by the Institute of Medical Research of French Oceania located on the island of Tahiti with headquarters in Papeete, the capital. The Institute is housed in a well-equipped building, with a staff of twenty-seven persons. French and American scientists cooperate in the work of the Institute in solving the problem of filariasis control.

The principal vector of filariasis in the South Pacific is *Aedes pseudoscutellaris.* Its control is complicated by the many empty coconut shells lying around the plantations which furnish suitable breeding places for this mosquito. As the production of copra is an important industry on these islands, coconut plantations are numerous.

Mosquito control inspectors are attempting to educate the planters not to leave empty coconut shells on the ground but to assemble them into piles and to destroy them by burning. Another mosquito control measure around the house and on the plantations consists of keeping down weeds and shrubbery, as the vector mosquito has