of application residual control may extend to several days. This possibility will be evaluated in future tests.

As with any mechanical system, persons attempting to use this method of application are bound to encounter certain problems. Because of the small orifices, the nozzles likely will become plugged. Any residues inside the tank, pump or booms will be loosened by the undiluted malathion and possibly by certain other insecticides used in their undiluted form. We overcame the problem of clogged nozzles by constructing a new boom and installing a special screen between the pump and the boom. Because some of the insecticides presently being used are corrosive, we recommend that booms be made of aluminum or possibly plastic. One other modification we recommend is that the insecticide be recycled through the pump rather than returned to the tank. The Plant Pest Control Division tests showed that when the malathion was returned to the tank, aerating and foaming occurred.

Should this method of application prove feasible, the area that can be covered by an airplane in a single flight will be limited only by its fuel capacity, not the payload that it can carry.

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DISTRIBUTION IN ALTITUDE OF MOSQUITOES IN NORTHERN THAILAND

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INTRODUCTION. The land mass of Southeast Asia has a particularly rich mosquito fauna, which has received relatively little attention in recent years. Earlier works by Barraud (1934) and Christophers (1933) were devoted largely to the fauna of the Indian subcontinent, and the work of Borel (1930) in the area then known as French Indochina was not completed due to his untimely death. More recently, excellent studies of the Malaysian mosquitoes have been published by Mattingly (1957 *et seq.*), Macdonald (1957) and others. Of particular significance to the present report is the work by Thurman (1959) on the mosquitoes of Northern Thailand. Many of Thurman's records are from the same mountain area discussed in the present report. Unfortunately, Thurman's studies of the mosquitoes of Northern Thailand have not been completed. Detailed taxonomic or biological studies of the important manbiting genera have not been published, although she did publish lists of the species found in Thailand.

The present study is part of a large scale research program on mosquito-borne diseases begun at the Southeast Asia Treaty Organization (SEATO) Medical Research Laboratory in Bangkok in 1961. Part of this program, a taxonomic and ecological

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TABLE 1.—Man-biting mosquitoes, Doi Pui, Chiengmai, Thailand.

Species	Number of collections	Valley 1000 feet 80	1500–2500 feet 57	2500–4500 feet 141	4500 feet to summit 37
Anopheles (*Anopheles*)	*aitkenii* James	0	0	+	0
	annandalei Prashad	0	0	0	+
	argyropus (Swell.)	+	0	0	0
	barbirostris V.d. Wulp	0	+	+	0
	barbumbrosus Str. & Chou.	0	0	+	0
	nigerrimus Giles	+	0	0	0
	peditaeniatus (Leic.)	+	0	0	0
	sinensis Wied.	+	0	0	0
Anopheles (*Cellia*)	*aconitus* Dönitz	+	0	0	0
	balabacensis Baisas	0	+	+	0
	jeyporiensis James	+	0	0	0
	karwari (James)	0	0	+	0
	kochi Dönitz	+	+	0	0
	maculatus Theo.	+	+	+	+
	philippinensis Ludlow	+	0	0	0
	splendidus Koizumi	+	0	0	0
	subpictus Grassi	+	0	0	0
	tessellatus Theo.	+	0	0	0
	vagus Dönitz	+	+	+	0
Mansonia (*Coquilletidia*)	*crassipes* (V.d. Wulp)	+	0	+	0
Mansonia (*Mansonioides*)	*annulifera* (Theo.)	+	0	0	0
	dives (Schiner)	+	0	0	0
	indiana Edw.	+	0	0	0
	uniformis (Theo.)	+	0	0	0
Heizmannia	*aureochaeta* (Leic.)	0	+	+	0
	covelli Barraud.	+	+	0	0
	communis (Leic.)	0	+	0	0
	mattingly Thurman	0	+	+	+
	metallica (Leic.)	0	+	0	0
	reidi Mattingly	0	+	0	0
	sp.	0	+	0	0
Aedes (*Mucidus*)	*ferinus* (Theo.)	+	0	0	0
Aedes (*Finlaya*)	*alboniveus* Barraud	0	+	0	0
	albolateralis (Theo.)	+	+	+	+
	assamensis (Theo.)	0	+	0	0
	aureostriatus (Dol.)	0	+	+	0
	chrysolineatus (Theo.)	0	0	+	+
	elsiae (Barraud)	0	+	0	+
	feegradei Barraud	0	+	0	0
	formosensis Yamada	0	+	+	+
	harveyi (Barraud)	0	+	+	+
	khazani Edw.	0	0	0	+
	macfarlanei (Edw.)	0	+	+	0
	niveus (Ludlow) (s.l.)	+	+	+	+
	pallirostris Edw.	0	0	+	0
	pseudotaeniatus (Giles)	0	0	+	0
	saxicola Edw.	0	0	+	+
	shortii (Barraud)	0	0	0	+

TABLE 1.—*Continued*

Species	Number of collections	Valley 1000 feet	1500–2500 feet	2500–4500 feet	4500 feet to summit
		80	57	141	37
Aedes (Stegomyia)	*aegypti* (L.)	+	0	0	0
	albopictus (Skuse)	+	+	+	+
	annandalei (Theo.)	0	+	0	0
	mediopunctatus (Theo.)	0	+	0	0
	subalbopictus Barraud	+	+	0	0
	vittatus (Bigot)	+	+	0	0
	w-albus (Theo.)	+	+	+	+
Aedes (Aedimorphus)	*mediolineatus* (Theo.)	+	0	0	0
	taeniorhynchoides (Chr.)	+	0	+	0
	vexans (Meig.)	+	+	+	0
Aedes (Neomelaniconion)	*lineatopennis* (Ludlow)	+	0	+	0
Aedes (Diceramyia)	*iyengari* Edw.	+	0	0	0
Aedes (Aedes)	*andamanensis* Edw.	+	0	0	0
Armigeres (Armigeres)	*aureolineatus* (Leic.)	0	+	0	0
	durhami (Edw.)	0	0	+	0
	malayi (Theo.)	0	+	0	0
	subalbatus (Coq.)	+	+	+	+
	theobaldi Barraud	+	+	+	0
Armigeres (Leicesteria)	*annulitaris* (Leic.)	0	+	+	0
	dentatus Barraud	0	+	0	0
	dolichocephalus (Leic.)	0	+	0	0
	flavus (Leic.)	0	+	+	+
	longipalpis (Leic.)	0	0	+	0
	magnus (Theo.)	0	+	0	0
	omissus (Edw.)	+	+	+	+
Culex (Culiciomyia)	*pallidothorax* Theo.	0	0	+	0
Culex (Culex)	*annulus* Theo.	+	+	+	0
	barraudi Edw.	0	0	+	0
	fuscocephalus Theo.	+	+	+	0
	gelidus Theo.	+	0	+	0
	pseudovishnui Colless	+	+	+	+
	quinquefasciatus Say	+	+	+	0
	sinensis Theo.	+	+	+	0
	tritaeniorhynchus Giles	+	0	+	0
	whitmorei (Giles)	+	0	+	0
Udaya	*argyrurus* (Edw.)	0	0	+	0
Special total		44	44	43	18

study of the mosquito fauna of Thailand, is still in progress. It has now been extended to cover all of Southeast Asia, with the cooperation of the Smithsonian Institution and other military and civilian organizations. The present report deals with an attempt to relate the activity of manbiting mosquitoes to altitude and vegetation type. Mosquitoes from this study were also examined for presence of mosquito-borne viruses, and the results of this phase of the study will be reported elsewhere.

MATERIALS AND METHODS. The study was centered on the city of Chiengmai, the second largest city in Thailand, an ancient capital of the northern portion of the country. The city lies in the valley of the Mae Ping river, at an altitude of approximately 1,000 feet. The valley is bounded on the east by portions of the Khun Tan mountain range, and on the west by elements of the Thanon Thong Chai range, which forms the border between Thailand and Burma. The closest mountain to the city is a 6,000-foot peak, Doi Pui, the site of many zoological collecting expeditions. A road was cut by hand to a lower peak, Doi Sutep, in 1935 to provide easy access to a famous monastery on that prominence. More recently the road was extended to the peak. All of the area is included in a National Park.

During 1962 and 1963, mosquitoes were collected by teams of Thai technicians at several sites on Doi Pui. The collections at the lowest level (1,000 feet) were made at the SMRL field station in the semi-rural area on the western edge of the city, very close to the point at which the mountain road begins its climb. The area is rather open, with clumps of bamboo and trees, and it is included in the discussion in order to provide a contrast with the forested slopes of the mountain. Collections were made in a uniform manner, as follows: each collector was equipped with plain glass tubes or a chloroform tube and a flashlight. He sat on the ground, rolled his pants legs to the knee and collected all of the mosquitoes which landed on his legs in a half-hour period. Most of the specimens were actually taken in the act of biting but some represent landing collections. No effort was made to separate the latter from the specimens which actually took a blood meal. The routine catches were made in the evening hours at the field station, and in the day and evening hours at ground level in the forest. The present report deals only with the identity of the species collected at several levels on the mountain. The quantitative data will be presented elsewhere, in connection with virus isolation studies. Observations were made on the terrain and the vegetation encountered at the various catching stations.

RESULTS. The species collected at four levels from the field station on the valley floor to the summit of Doi Pui are listed in Table 1. These levels were selected to reflect changes in the vegetation cover of the mountain slopes, as diagrammed in Figure 1. The area of the valley floor was originally heavily forested, but at the time of these studies only isolated clumps of trees remained. The lower hills at the foot of the mountain are also covered by remnants of dipterocarp savannah forest. The soil is so poor however, that the trees, predominantly *Pentacme siamensis* and *Shorea obtusa,* exhibit rather poor growth.

On the lower slopes of the mountain proper broad-leafed deciduous trees also predominate. There is a decided leaf-fall in the dry months of February to May. At that time fires, natural and man-made, burn almost continuously on the lower exposed slopes. From approximately 2,500 feet tall trees, predominantly dipterocarp species and oaks begin to predominate, especially in the shaded steep-sided valleys which cut the slopes. In these stands of tall trees the canopy is almost complete, and while the ground dries appreciably in the dry season, it does not reach the sere condition of the lower slopes. In many pockets on the slopes from 2,500 to 5,000 feet there are dense stands of very large, tall trees (*Quercus, Castanopsis* and *Dipterocarpus*) which form a completely closed canopy through which very little light penetrates. These form areas of

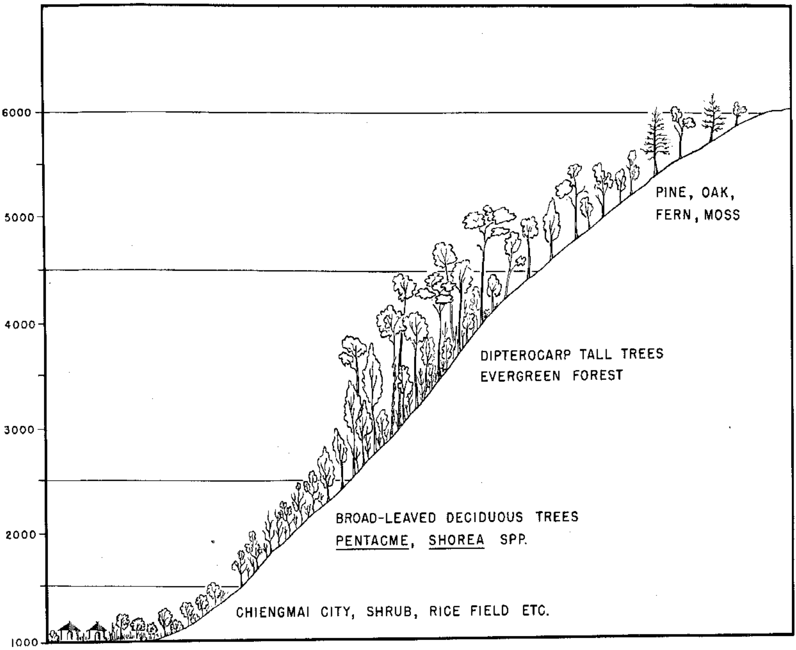

FIG. 1.—Schematic diagram of vegetation on Doi Pui Mountain, Chiengmai. Photograph from Audio Visual Department, Walter Reed Army Institute of Research.

various sizes which can be characterized as tropical evergreen forest. The upper levels of the mountain (5,000 to 6,000 feet approximately) consist largely of open forest, including small oaks and small numbers of conifers (*Pinus*). These are interpersed with small fields of tropical grasses, probably resulting from the cultivation of opium-producing poppies by the Meo tribesmen who have lived on the mountain from time to time.

It was found, therefore, that there was a succession of habitats on Doi Pui, rather readily characterized. The road distance from the collection site at the edge of Chiengmai to the crest of the mountain was approximately 10 miles, the straight line map distance was found to be approximately 4.7 miles.

The total number of species of mosquitoes biting or landing on man was almost the same for the lowest three levels (Table 1), while the number of species dropped sharply for the uppermost level. The number of collections (each being one-half man-hour in duration) was not equal for each level, since the collectors were engaged in other duties which brought them to some collection sites more frequently than others. However, it is believed that the number of collections as a whole is sufficient to present a qualitative picture of the mosquito fauna.

Relatively few species were found at all levels. These included: *Anopheles maculatus, Aedes albolateralis, Ae. albopictus, Ae. w-albus, Armigeres subalbatus, Ar. omissus,* and *Culex pseudovishnui.* Of these, *Ae. albopictus* is almost certainly a vector of dengue virus, and *An. maculatus* is known to transmit malaria in some areas of Southeast Asia. Its status as a malaria vector in Thailand is still under study.

Before proceeding to a discussion of the various genera and subgenera found at the several mountain levels examined, it may be well to point out that the list presented in this report by no means exhausts the mosquito species found by us on Doi Pui. Many additional species and genera (*Tripteroides, Orthopodomyia, Toxorhynchites,* and others) were reported from the area by Thurman (1959) or are present in the SMRL collections. The present paper deals only with those species attracted to man. Many other species either do not take blood meals at all, or have unknown hosts in the jungle.

Anopheles: Most of the *Anopheles* mosquitoes, by species or number of individuals, were collected at the lowest level. These are predominantly surface water or rice field breeders (*An. argyropus, nigerrimus, peditaeniatus, sinensis, aconitus, jeyporiensis candidiensis, kochi, philippinensis, subpictus* and *tessellatus*). *Anopheles vagus* penetrated much further into the mountain forest than had been expected, but this is a very abundant species, apparently capable of breeding in a variety of surface waters. *Anopheles annandalei* is a tree-hole breeding species generally found only in heavy forest. *Anopheles barbirostris, aitkenii* and *barbumbrosus* larvae may be found in pools and seepages along streams in the forest, but *barbirostris* also occurs in surface waters at lower levels, and its absence from the field station collections was somewhat surprising. *Anopheles balabacensis* is an important malaria vector in some parts of Thailand, and it is the only definitely proven Thai malaria vector included in this list. There have been no recent reports of malaria from the small population living on the mountain. This species is characteristically found on forested lower slopes, the larvae occurring in small collections of water along streams.

Mansonia: The finding of *Mansonia crassipes* at the 2,500–4,500-foot level in the forest was somewhat surprising, since this species, like other *Mansonia*, breeds in ground pools covered with floating vegetation, or in swampy areas. There are a number of marshy depressions in the forests at this level, but the breeding site of the species was not found. The remaining *Mansonia* species, as expected, were confined to the rural area around the field station and the surrounding woods. This genus contains a number of important vectors of human filariasis, but human filarial infections do not appear to occur in the Chiengmai area.

Heizmannia: The members of this genus are almost restricted to the forest environment. The larvae are found chiefly in tree-holes and bamboo stumps, but the breeding places of many of the species have yet to be detected. Since they are known to feed readily on man and other animals in the forest canopy it is possible that considerable breeding takes place in tree-holes which are not readily reached from the ground. In many ways these species resemble the New World Sabethini, both in morphology and biology. They are not known to play a role in the transmission of human disease, but their frequent occurrence in human biting collections in the forest indicate the necessity for further study of the group.

Aedes: The single *mucidus* species collected feeds primarily on domestic mammals and does not enter the forest. The taxonomic status of the species is still under investigation. The species of the subgenus *Finlaya*, on the other hand, are largely forest species, with the majority of the species occurring in the middle levels of the mountain in the present study.

Two species, *Ae. albolateralis* and *Ae. niveus*, were found at the field station on the valley floor, and both of these may be severe pests under some conditions. The *Finlaya* species are an important component of the man-biting mosquitoes in the deciduous and evergreen forest of Thailand. They have not yet been implicated as vectors of human disease organisms in Thailand. The subgenus *Stegomyia*, however, includes the known human disease vectors, *Ae. aegypti* and *Ae. albopictus*. The distribution of these species is an important consideration in Thailand, where both species may be vectors of dengue virus.

As shown in Table 1, *Ae. aegypti* was limited to the valley floor at the field station, while *Ae. albopictus* was found there and at all levels on the mountain. *Ae. albopictus* is one the most important man-biting mosquitoes throughout Thailand, except in the more urban areas where it is largely replaced by *Ae. aegypti*. All of the *Stegomyia* species found in the forest were cavity or container-breeding species. *Aedes w-albus* was found at all levels, but was not abundant anywhere. The *Stegomyia* species appeared to be more limited to the lower and middle slopes of Doi Pui than the *Finlaya* species.

Aedes vexans is a common forest mosquito species in many parts of the world, although it is also common in more open areas. It and the other two *Aedimorphus* species appeared to be more characteristic of scrub or open forest, even though *vexans* was found at times in heavy forest at all but the highest levels on the mountain. *Aedes lineatopennis* feeds readily on domestic animals and it is common in agricultural areas. It was somewhat surprising to find it at the 2,500–4,500-foot level on Doi Pui. Both *Aedes iyengari* and *Aedes andamanensis* are found chiefly in the forest fringe or in scrub areas; neither was abundant.

Armigeres: As noted above, *Armigeres subalbatus* has a particularly wide distribution in various habitats in Thailand. It breeds readily in polluted water in domestic containers or ground water in urban areas, and in bamboo stumps and tree holes in the deepest forest. It was one of the most abundant species in day or evening biting collections in the forest. Specimens from many different habitats were examined to see whether several species might be involved, but no morphological differences were detected among the various populations. *Armigeres subalbatus* has not yet been found to transmit disease organisms in Thailand. *Armigeres flavus* and *Ar. omissus* were also important components of the catch in the forest, and *omissus* was found at all levels on the mountain. *Armigeres theobaldi* was locally abundant except at the highest level. The overall impression of the *Armigeres* obtained in these collections is that members of both subgenera may be very important elements of the mosquito fauna. The larvae of most species of both subgenera are found in tree holes or bamboo sections.

Culex: Most of the species of the subgenus *Culex* were abundant to extremely abundant in the area around the field station. These are surface-water-breeding species which feed readily on domestic animals. The concentration of these species at the 2,500–4,500-foot level on Doi Pui, however, was unexpected. *Culex annulus* and *C. pseudovishnui* were particularly abundant in the night-time catches in the forest, and both of these species were found feeding in the human-biting catches made in the forest canopy. *Culex tritaeniorhynchus* and *C. gelidus* are known vectors of Japanese encephalitis virus in Thailand. Their status as vectors has not been fully investigated in the Chiengmai area, but cases of encephalitis are reported to have occurred there recently (Gould, 1965). *Culex pallidothorax* was found in the moist forest at the 2,500–4,500-foot level, where the larvae were found in numbers in elephant footprints. Only small numbers were collected biting or landing on man.

Udaya: The single species of this genus collected on Doi Pui was taken in very small numbers in the moist forest. It is not an important component of the man-biting mosquito fauna.

Summary. Mosquitoes were collected in bare-leg catches during the day and evening hours at various levels of Doi Pui mountain, and on the edge of the nearby city of Chiengmai in Northern Thailand. Eighty-four species were collected, but relatively few of these were very common, and fewer extended through all of the levels at which collections were made. Numbers of species collected were similar, but of varying composition, up to the 4,500-foot level. From that point to the summit of the mountain a much smaller number of species was collected. It is

apparent that there is a considerable potential for mosquito transmission of various disease organisms to man at all levels on the mountain.

ACKNOWLEDGMENT. The writers would like to express their appreciation to the three field technicians who participated in these studies. Without the patient work of Mr. Samarn Manewongsee, Mr. Inkan Inlao and Mr. Preesha Ruangvija it would not have been possible to accumulate these biting data.

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TRUSTEES AND COMMISSIONERS SESSION

In the oral presentation of the papers in this section, the speakers could eliminate or condense parts where there may have been overlapping coverage. In order to achieve a similar continuity and directness in the written versions, the editor has taken the liberty of making changes at appropriate points in the assembled manuscripts.

THE ROLE OF THE TRUSTEES IN ESTABLISHING AND MAINTAINING TECHNICAL SUPPORT FOR A MOSQUITO CONTROL PROGRAM

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Trustee, Salt Lake City Mosquito Abatement District

Members of governing boards of mosquito control organizations agree, when they accept the position, that they will serve as trustees to insure that all operations of the district including the expenditure of funds will be in the best interests of mosquito control. This places the board member in a position of considerable responsibility to the public that provides the funds for mosquito control programs. The operations in an efficient, modern mosquito abatement district are very complex, quite different from the early programs in which a few men were employed by a district to find and treat with oil, small mosquito producing sites, in or near communities within the district.

In the operation of a modern mosquito control program it is essential that technical support be established and maintained and that it becomes an active part of the control program. Technical assistance in mosquito control is required in many special fields, such as entomology, engineering, public health, law, business management, and public relations, to name only a few. Although in