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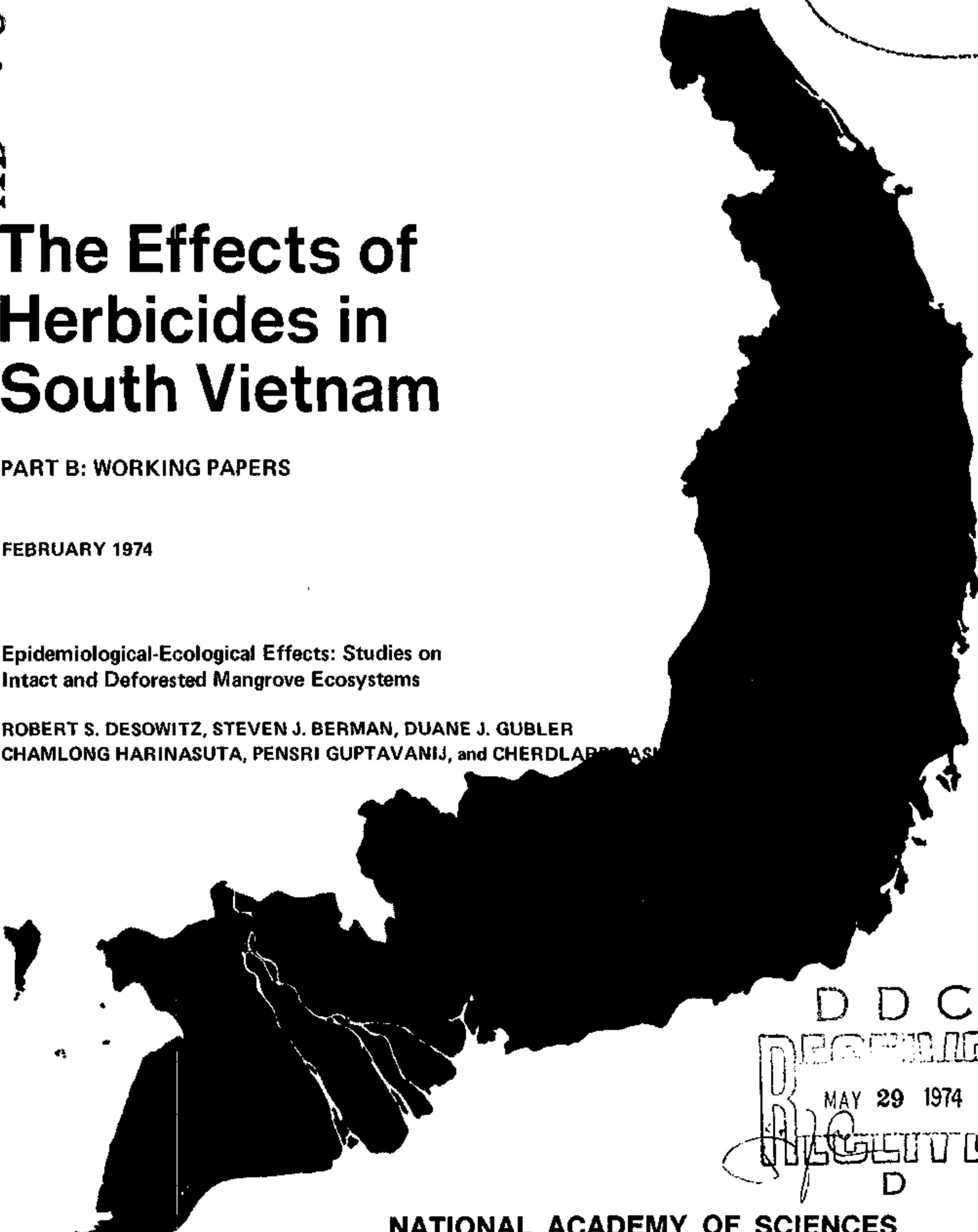

PART B: WORKING PAPERS

FEBRUARY 1974

Epidemiological-Ecological Effects: Studies on Intact and Deforested Mangrove Ecosystems

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WASHINGTON, D.C. 20418

Epidemiological-Ecological Effects: Studies on Intact and Deforested Mangrove Ecosystems

ROBERT S. DESOWITZ, STEVEN J. BERMAN, DUANE J. GUBLER, CHAMLONG HARINASUTA, PENSRI GUPTAVANIJ, AND CHERDLARP VASUVAT[a]

The objective of this study was to determine whether the ecological effects of herbicides have resulted in altered epidemiological patterns, particularly with respect to vector-borne infectious diseases. The premise that such epidemiological alterations may occur is based on the hypothesis that the changed ecological settings could provide suitable new breeding habitats for arthropod vectors and rodent reservoirs of these infections.

BACKGROUND

The current attention of medical science in technologically developed nations is largely directed toward the physiologic, neoplastic, and psychologic diseases, while in the less sophisticated areas of the tropical world the infectious diseases continue, as they have for countless millenia, to be the major causes of sickness and death. Many of the causative agents of infection--viruses, bacteria, protozoan and helminth parasites--require an invertebrate intermediate host (the vector) to transmit the pathogen from man to man or animal to man.

In South Vietnam (SVN) vector-borne diseases constitute a major

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health problem. Malaria, filariasis, arboviruses (dengue, viral encephalitides) transmitted by mosquitoes, plague, and various forms of typhus transmitted by arthropod ectoparasites of rodents--all are epidemic and endemic. Malaria is a particularly important health problem in SVN and other parts of Southeast Asia. MacKenzie (1969) in his report to the World Health Organization states that in Thailand and other tropical zones malaria "has long been recognized as the greatest impediment to community progress." Because wartime conditions have made any comprehensive malaria surveillance impossible, the current epidemiological status is largely unknown. However, the World Health Organization at the Twenty-first World Health Assembly, in considering the epidemiological situation in SVN, noted that as late as 1960-61 the GVN reported over 400,000 cases of malaria. Because of the existing and potential magnitude of the malaria problem in SVN the Committee has focused upon this area of study.

HOST-VECTOR-PARASITE RELATIONSHIPS

Vector Bionomics

Obviously, the nature of man-vector contact greatly influences the kind and intensity of disease present in a community. An important factor in this relationship is the life cycle of vectors in interaction with the environment. Each vector species exhibits characteristic biological and behavioral traits that influence its interaction with man. Thus the selection for breeding water, host preferences, and resting behaviors are all genetically controlled biological characteristics that may or may not place a particular mosquito species in proximity to man. Mosquitoes are remarkably selective in their choice of breeding habitats and are very precise in selecting exactly the right kind of water in which the larvae are best suited to develop.

Within the context of the present study, two hypothetical models can be given. Anopheles maculatus is a highly efficient vector of malaria in Vietnam and other areas of Southeast Asia. The principal breeding sites of this mosquito are hillside streams exposed to sunlight. Defoliation could expose formerly forest-shaded streams to sunlight and convert them to favorable breeding environments. The increased anopheline population might then result in intensified malaria endemicity in the exposed adjacent communities.

Similarly, following defoliation of the mangrove forest, the sunlight-exposed brackish water pools would provide a more ideal breeding site for Anopheles sundaicus, another efficient malaria vector, than an environment shaded by mangrove trees.

Rodent Reservoir

Another factor influencing the spread of some infections is the presence of a reservoir host. These are wild or domesticated animals that harbor the pathogen and act as a source of infection to man. In Southeast Asia various species of rats are reservoir hosts for plague, leptospirosis, and scrub typhus.

Again, we may take a hypothetical model pertinent to this study. Rattus jalorensis is a rat that inhabits the scrub-grassland of Southeast Asia and is a reservoir host for scrub typhus and leptospirosis. In the event that the forest is succeeded by grass subsequent to defoliation, then R. jalorensis could become established in this new habitat and initiate the dissemination of its transmissible infections to the nearby population.

Human Factors

Still another factor influencing the epidemiological pattern is man himself. In most instances, humans living under stable endemic conditions achieve a sort of balance, often a precarious armed truce, with their parasites. This is chiefly accomplished by the body's immunological response, but this defense is often not absolute. The disease may take a heavy toll of the relatively (immunologically) immature children and of adults when they are confronted with strains and species of pathogens to which they have had no previous immunological experience. Medical history is studded with examples of populations forced to flee their traditional homelands because of the devastation of newly-introduced diseases, and of nonimmune immigrant groups similarly decimated by the pathogenic organisms present in their new settlements.

Man himself is frequently instrumental in causing conditions that initiate epidemics and maintain endemic infectious diseases. We have only begun to recognize that efforts designed to provide the "good life" for the less privileged peoples of the world, e.g., building of dams and introduction of new agricultural practices, often result in ecological changes that provide highly suitable habitats for the breeding of disease vectors. War is another human activity that has been known since ancient times to leave epidemic sickness in its wake. However, the conflict in Indochina is unique in that it has caused drastic ecological change in so vast an area. Many military activities have contributed: e.g., bombing, Rome-plowing, burning, and abandonment of agricultural land by dislocated populations. The present study has attempted to discern the impact of only one such factor: herbicide spraying. The study was carried out during a period of active conflict in Vietnam and the constraints thus imposed severely limited the time and scope. Despite these limitations, we have been able to draw some tentative conclusions upon which further, better designed studies can be carried out when conditions permit.

METHODS

Design of Field Studies

An ideal study plan, based on previous experiences in SVN and other regions of Southeast Asia, was developed by the medical zoologist responsible for coordinating the study (R.S.D.) and a consultant physician specialist in tropical medicine (S.J.B.) before they visited SVN. This "master protocol" was developed for use primarily as a frame of reference that could be reduced and/or modified by the conditions then existing in SVN. Under the master protocol the investigation was formulated as follows.

Study Sites. Three different ecologies where herbicide spraying had been carried out and where there was presently a demonstrable effect in terms of botanical succession, etc., were to be selected as study sites. These ecological settings were to be (1) forested mountains, (2) mangrove, and (3) lowland rice and other agricultural farm land.

Any assessment of the effects of herbicides must obviously be based on information of pre-spray conditions. These data can be obtained by searching the literature for past relevant investigations and/or by selecting unsprayed control sites of congruent ecological character, i.e., an ecosystem similar to that of the study areas before herbicides were applied. The relative paucity of reliable information revealed by the literature search for current epidemiologic patterns, vectors, and reservoirs of infectious diseases in SVN indicated that it could only be adjunctive to information gained by actually carrying out investigations in congruent control sites.

The "master plan" also required that a stable, nonmigratory community be situated in each of the study and control sites.

Vector and Reservoir Host Investigations. The primary objective of this study was to determine whether mosquito populations, particularly anopheline vectors of malaria, had altered quantitatively and qualitatively in each of the three defoliated ecosystems. Entomological surveys of medically important mosquitoes require day--and nighttime collections, to coincide with specific biting habits, made over a period of days. Collection is best made by a variety of methods: human biting collections, collections from animal bait, and light traps. This will not only give a comprehensive picture of the species composition of the mosquito population, but will also indicate which species readily feed on man. It is also necessary to collect larvae (immature forms) to identify breeding sites. Since rainfall and surface water influence mosquito populations, at least two surveys were to be carried out, one in the rainy season and the other during the dry season.

The protocol provided for the trapping of rodent reservoirs. These animals were to be taxonomically identified. Samples of their organs and blood were to be collected and sent to a participating laboratory for isolation and serological identification of pathogens causing plague, murine typhus, scrub typhus, and leptospirosis. Ectoparasites (mites, ticks, fleas, etc.) were to be collected from the trapped rodents and identified.

Studies on Humans. The proposed protocol called for the examination of 1000-5000 individuals in each of the three experimental and three control communities. This was to be an age-stratified sample encompassing a range of individuals from infants to the aged. Personal and clinical histories would be taken from each person. Blood samples were to be obtained for laboratory diagnosis, mainly from immunoserologic techniques, of malaria, amoebiasis, arboviruses, scrub typhus, murine typhus, typhoid, paratyphoid, and leptospirosis.

Stool samples would be obtained and also sent to the laboratory for diagnosis of vibrios (cholera) and other enteric bacterial pathogens and for parasitic intestinal protozoa and worms.

Modifications of Design

After discussions in Saigon with American military analysts, Vietnamese and American public health officials, and other members of the Committee, it soon became apparent that the comprehensive study plan was hopelessly unrealistic and overambitious under the limitations of safety, time, and money within which the study was to be conducted. Such an investigation would take at least a year and the Committee was running out of working time.

On the basis of our discussion and over-flights and visits to defoliated areas we came to the following conclusions, decisions, and actions:

1. There were no appropriate areas in SVN sufficiently secure to permit a protracted visit by a multidisciplinary team of medical specialists. In particular, it would be especially hazardous for medical entomologists to make night-biting mosquito collections.

2. As far as could be determined, the most ecologically devastating and permanent effect of herbicide application occurred in the mangrove forest. The extensive estuarine region of former mangrove south of Saigon known as the Rung-Sat had been particularly affected by defoliants and appeared almost totally denuded of trees. The Rung-Sat was also readily accessible and seemed to be relatively secure. It was therefore decided that, if possible, a single pilot study would be carried out on the epidemiological-ecological effects of defoliation on a mangrove ecosystem using the Rung-Sat as a study area. It was also concluded that it was not possible to carry out any extensive studies on the human population, with the possible exception of a blood survey for malaria, and that the primary objective would have to be limited to an investigation of the mosquito vector population.

3. No comparable unsprayed, intact, relatively secure estuarine mangrove forest could be found to serve as the control study site.

4. The lack of a control mangrove area constituted a serious impediment to conducting a scientifically valid study. This deficiency was compounded by the fact that the mangrove ecosystem has been almost entirely neglected by medical zoologists and epidemiologists; thus there was very little background information available on the species of mosquitoes or reservoir hosts or the kinds of infections that occur among the resident inhabitants of the mangrove forests of Southeast Asia. It was therefore decided to search for a congruent area in Thailand that could serve as a control study site(s).

The Study Sites

The following three sites were selected for study, one in SVN and two in Thailand. A community in a defoliated estuarine mangrove southeast of Saigon (called both Tran-Hung-Dao and Tac-Ong-Nghia) was selected as the study site in SVN[a] (see Figure 1). Not only was this site in a heavily defoliated area, but it had the double advantage of being situated in a special RVN Navy Zone (the Rung-Sat) and the headquarters of an army battalion, in a relatively secure area.

An estuarine mangrove forest area near Chantaburi, Thailand (Figures 2 and 3) was selected as the control site to serve as comparison to the defoliated area of the Rung-Sat. Botanical analysis of this site[b] indicated that the composition of this forest was probably similar to that of the Rung-Sat prior to deforestation (see Figures 4 and 5).

A partially deforested coastal mangrove area of Thailand was also selected as a study site. Situated between Cholburi and Ang Sila (Figure 2), this mangrove forest appeared similar to the type fringing the delta region of SVN. Some years ago an extensive part of this area was almost completely deforested by cutting in preparation for a large-scale housing project; no houses had yet been built.

The Field Work

The field work was carried out in November-December 1972 at the

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[a]For a description of the Rung-Sat mangrove, see Ross, P. The effects of herbicides on the mangrove of South Vietnam, Part B of the Report on the Effects of Herbicides in South Vietnam.

[b]This work was carried out by the Faculty of Forestry of Kesetsart University, Bangkok, Thailand, under the direction of Dr. Sanga Sabhasri.

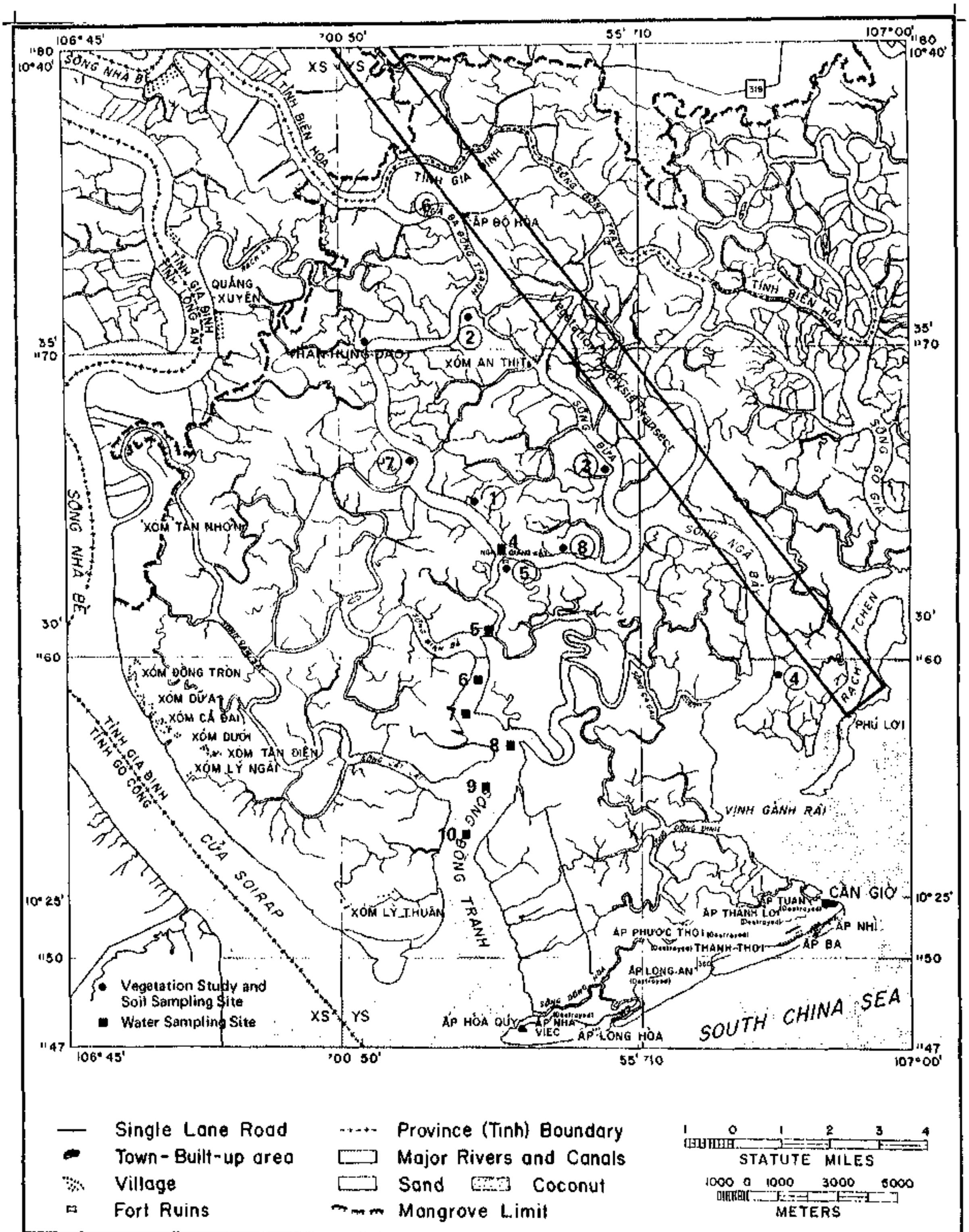


FIG. 1. Map showing hamlet of Tan-Hung-Dao. Numbers represent the water, soil, and vegetation study sites discussed in Section IV-C, Mangroves, Part A of the Report on the Effects of Herbicides in South Vietnam.

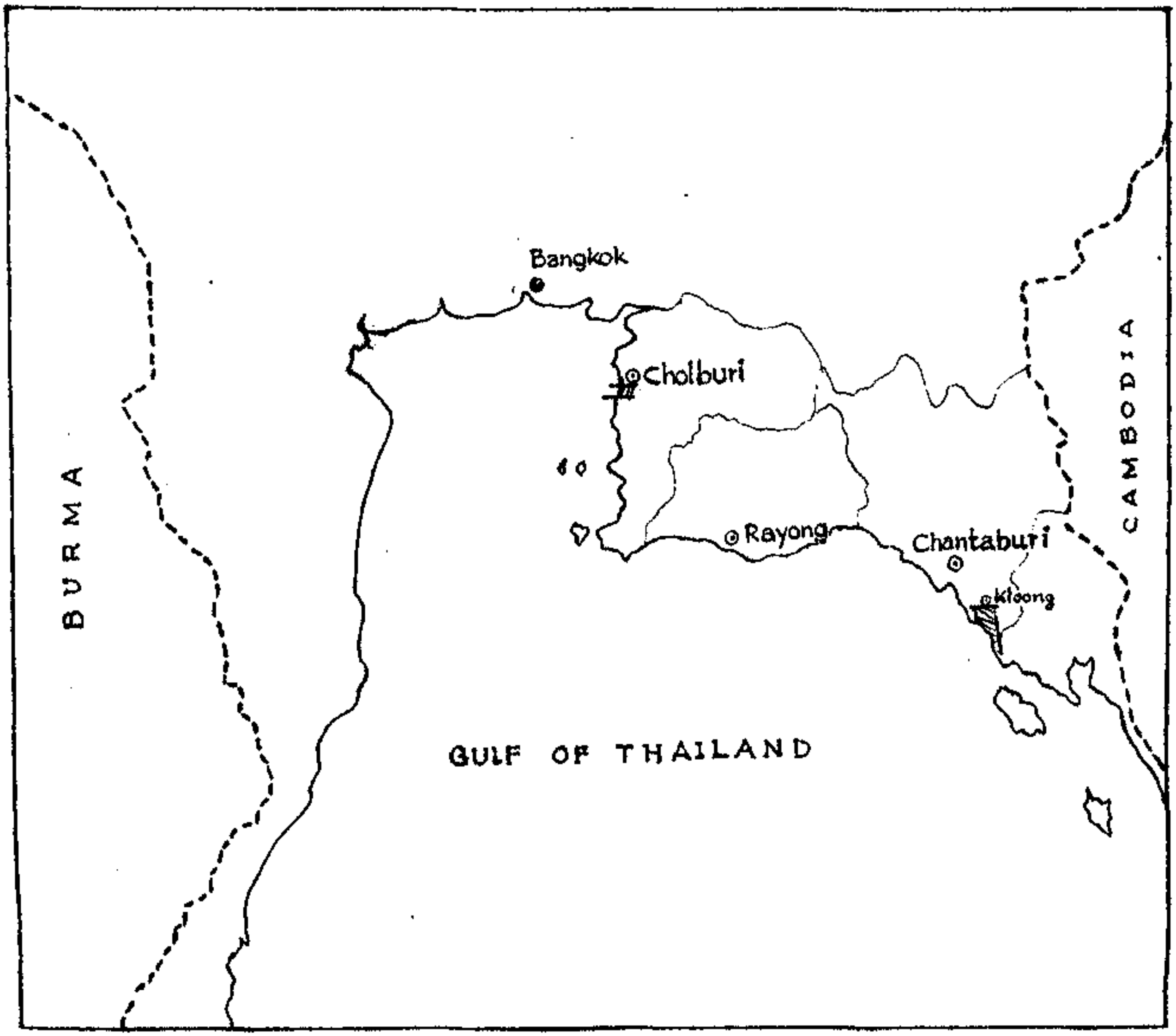


FIG. 2. The Chantaburi and Cholburi Provinces along the east coast of the Gulf of Thailand where the studies were carried out.

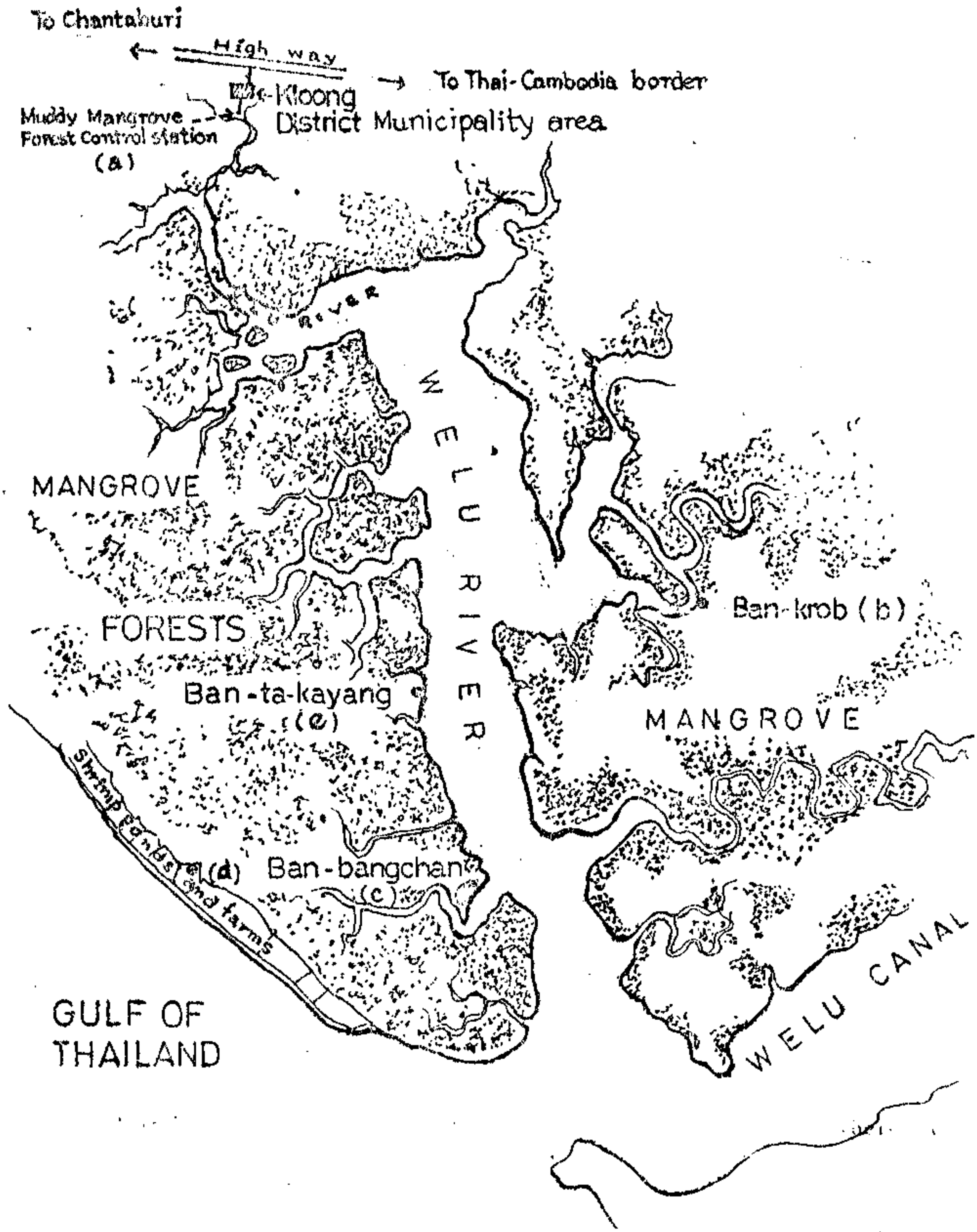
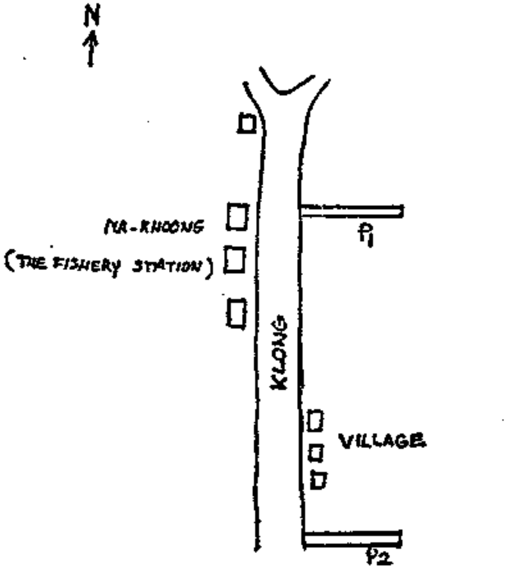


FIG. 3. The five areas of the estuarine control site (a,b,c,d, and e) where the investigation was carried out.

TRANSECT PLOT 1 - CHANTABURI

Location: Na-Khoong, opposite to the Fishery Station

Plot Size: 100 X 2 m^2

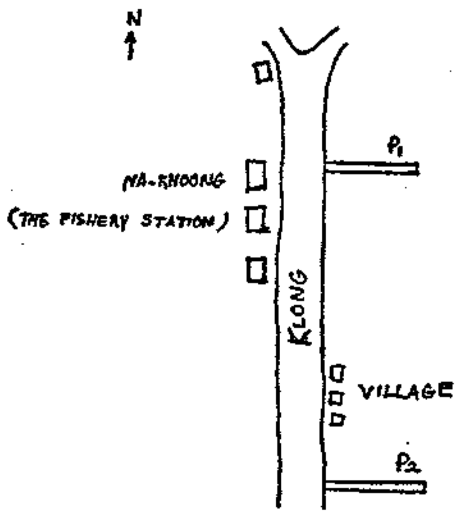


Tree Species	Occurrence (Nos.)
Rhizophora candelaria	110
Rhizophora mucronata	27
Ceriops roxburghiana	16
Avicennia alba	29
Xylocarpus moluccensis	5
Bruguiera conjugata	15
TOTAL	202

TRANSECT PLOT 2 - CHANTABURI

Location: Na-Khoong, opposite the Fishery Station near the village

Plot Size: 100 X 2 m^2

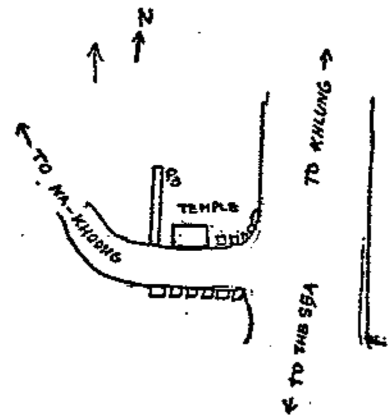


Tree Species	Occurrence (Nos.)
Rhizophora candelaria	244
Bruguiera conjugata	25
Avicennia alba	1
Xylocarpus moluccensis	1
Acrostichum aureum	1
TOTAL	272

TRANSECT PLOT 3 - CHANTABURI

Location: Bang Chan (near the Temple)

Plot Size: 100 X 2 m^2



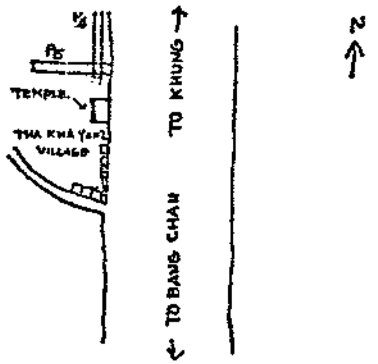
Tree Species	Occurrence (Nos.)
Rhizophora candelaria	145
Rhizophora mucronata	33
Avicennia alba	7
Xylocarpus moluccensis	2
Bruguiera conjugata	47
Nypa fruticans	67
TOTAL	301

FIG. 4. Botanical analysis of Chantaburi, Thailand estuarine mangrove forest control site.

TRANSECT PLOTS 4,5 - CHANTABURI

Location: Tha Kha Yang (near the Temple); Plot 4 located from the residential area to the forest (plot was located parallel to Klong, Plot 5 from Klong

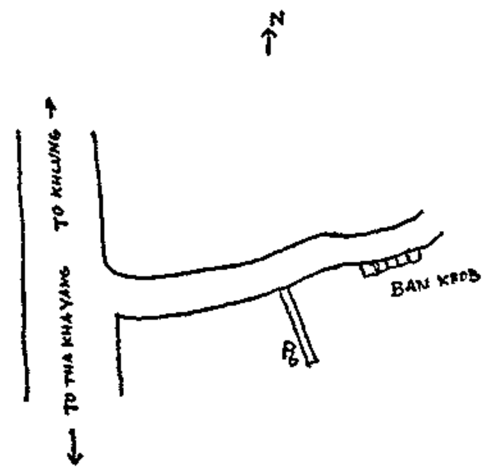
Plot Size: 100 X 2 m^2



Tree Species	Occurrence (Nos.) PLOT 4	PLOT 5
Rhizophora candelaria	277	137
Avicennia officinalis	3	-
Xylocarpus moluccensis	9	2
Ceriops roxburghiana	10	315
Bruguiera conjugata	39	2
Sonneratia alba	1	-
Nypa fruticans	6	6
Bruguiera parviflora	-	1
Acrostichum aureum	-	4
Lumnitzera coccinea	-	4
TOTALS	345	471

TRANSECT PLOT 6 - CHANTABURI

Location: Ban Krob
Plot Size: 100 X 2 m^2



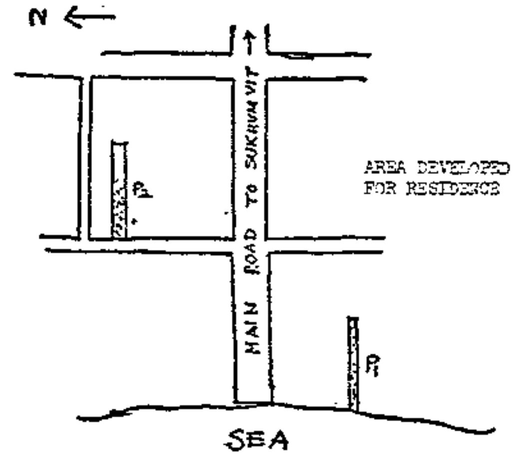
Tree Species	Occurrence (Nos.)
Rhizophora candelaria	112
Bruguiera conjugata	9
Bruguiera parviflora	13
Xylocarpus moluccensis	6
Ceriops roxburghiana	121
Lumnitzera racemosa	1
TOTAL	262

TRANSECT PLOT - CHOLBURI

(Area developed for residence)

PLOT 1: Drained area; mud is about 0.75-1.00 m thick

PLOT 2: Undrained area; mud is harder than Plot 1, salt crystal found at the surface



Tree Species	Occurrence (Nos.) PLOT 1	PLOT 2
Avicennia officinalis	252	142
Avicennia alba	224	-
TOTALS	476	142

FIG. 4, continued.

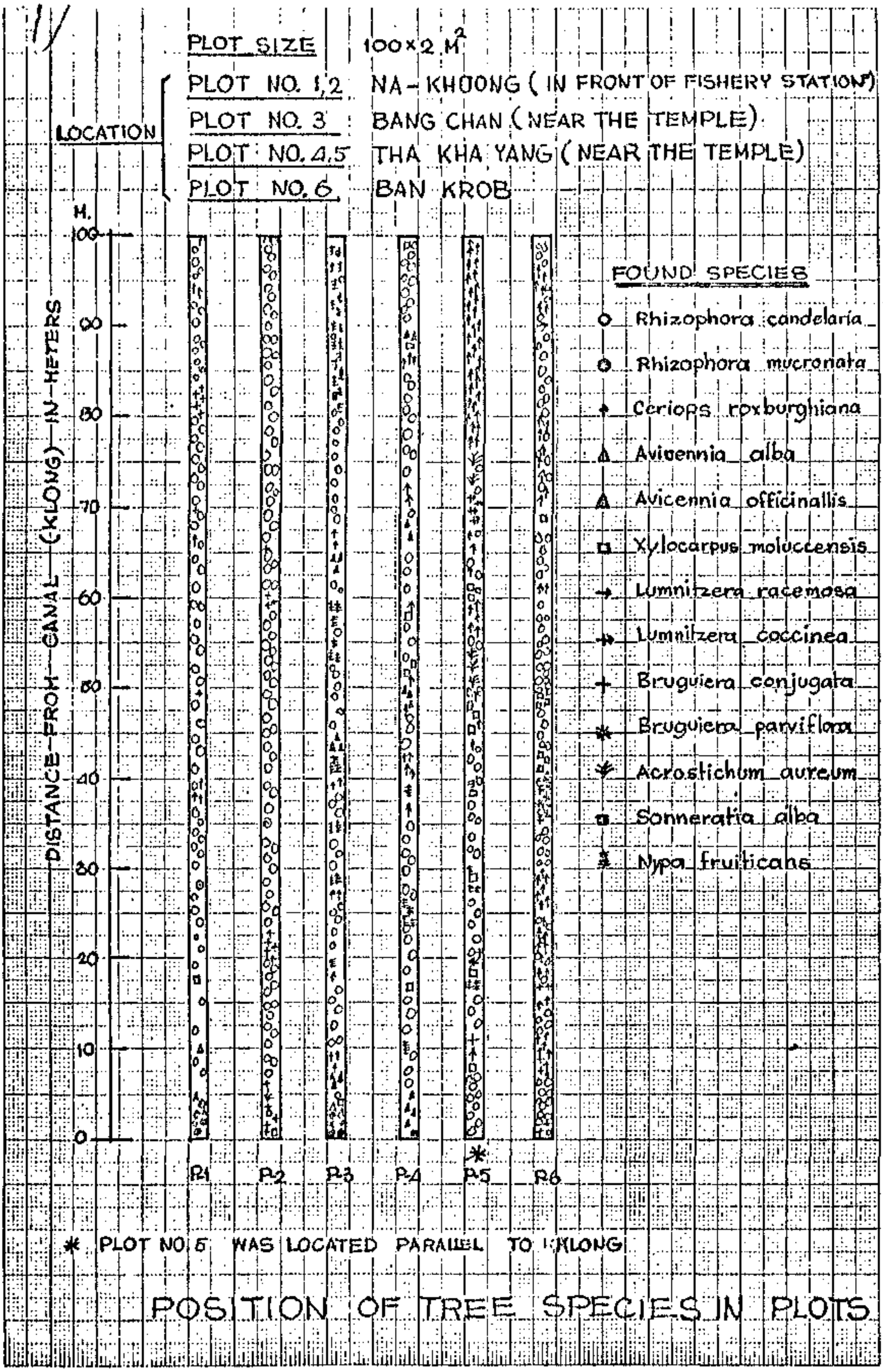


FIG. 5. Botanical analysis of Chantaburi, Thailand estuarine mangrove forest control site.

end of the rainy season, a time when a high mosquito population would be expected. The work was done first in Thailand and then in SVN.

Investigations in the two areas of Thai mangrove were carried out by the staff of the Bangkok School of Tropical Medicine, Mahidol University, in collaboration with the medical zoologists (R.S.D. and D.J.G.) from the University of Hawaii. The team made mosquito (adult and larval) collections, estimated rat populations by trapping, collected ectoparasites from rats, and carried out malaria surveys.

The investigations of vectors carried out by Drs. Desowitz and Gubler at the SVN study site in the Rung-Sat were more limited than those in Thailand because of security conditions. Although the area was relatively secure, collections could not be made from some potential mosquito larva breeding sites because of the possible presence of Viet Cong forces; nor could light-trap collections outside the village be made because of the possibility of their being booby-trapped during the night. It was possible, however, to make a collection of mosquitoes and to make a limited blood survey of 84 school children for malaria.

Two follow-up visits were made to this site by Dr. Kunstadter, the medical anthropologist Committee member. He was able to obtain much valuable information as to the history of the village, farming practices before and after defoliation, and other data that would have bearing on ecologically related factors influencing the kind of disease vectors and reservoirs in the area.

RESULTS

The relatively brief working period and limitations imposed by conditions then existing in SVN do not permit firm conclusions to be made from this study. With this caveat in mind, the salient findings of the epidemiological-ecological studies in intact and deforested mangrove of SVN and Thailand are discussed below and summarized in Table I.

Estuarine Mangrove: Mosquitoes

Intact Forest Control (Chantaburi, Thailand). Very little is known regarding the mosquito fauna present in the mangrove forests of Southeast Asia and the present report probably represents the first systematic collection from that ecosystem in Thailand and Vietnam. Nguyen-Thuong-Hien (1963) records *Anopheles sundaicus* and *A. subpictus* from coastal brackish water areas, but it is not known if his collections were made in mangrove. Dr. D. Gould of the Entomology Department, SEATO Medical Research Laboratory, Bangkok, noted (personal communication) that the only mosquito records from the Cholburi-Chantaburi mangrove concerned the aedine species *Ae. aegypti*, *albopictus*, and *seatoi*, and *Armigeres subalbatus*. *Ae. aegypti* and *albopictus* are ubiquitous species that usually breed in domestic water collections such as rainwater storage jars; they cannot be considered peculiar to the mangrove habitat. Traub and Elisberg (1962a,b) and Wharton et al. (1963) record mosquito species from the *Nypa* palm-mangrove swamps of Malaya, but this habitat may not be strictly comparable to the estuarine mangrove forests of SVN and Thailand.

In order to obtain a good representation of the mosquito species present, a variety of collection methods was used: net trap with human bait, bare leg catch (BLC), CDC light trap, and larval collections from breeding sites. Collections were made at five areas, designated in Figure 3 by the letters a through e.

Table I.

Summary of findings in intact and deforested mangrove ecosystems of S. Vietnam and Thailand.

Area	Mosquitoes: Predominant species composing population	Mosquitoes: Medical importance	Mosquitoes: Comment	Malaria	Rodents
Intact estuarine mangrove (Chantaburi, Thailand)	Aedine: *Aedes dux*	Not known	Breeds mainly in fresh water found in tree holes. Readily bites man.	*Not present*. No positive blood films in 384 children surveyed. No enlarged spleens detected.	*Rattus losea* predominant species. Trapping results indicate rat population not very high in dense mangrove forest.
	Aedes taenorhynchoides	Not known	Known breeding places are ground pools. In current survey, found in brackish pools in middle of mangrove swamp. These mosquitoes readily attack man.		
	Aedes longirostris	Not known	Known breeding places are pools in mangrove swamps and in crab holes. Found in brackish pools in mangrove in current survey. Does not attack man readily.		
	Culicine: *Culex sitiens*	No known disease relationships.	Breeds in brackish water in coastal areas, breeding habitats includes ground water as well as artificial containers such as water collected in boats, barrels, etc.		
	Ficalbia: *Ficalbia hybrida*	No known medical importance.	Tree hole breeder. Does not readily bite man, most specimens caught in light trap.		

Table I, continued.

Area	Mosquitoes: Predominant species composing population	Mosquitoes: Medical importance	Mosquitoes: Comment	Malaria	Rodents
Herbicide-deforested estuarine mangrove (Rung Sat, S. Vietnam)	Anopheline: *Anopheles sinenses*	Vector of malaria in China. Can also transmit Bancroftian filariasis.	This species is normally a zoophilic species but it was found to bite man readily in the Rung Sat and will fly indoors to do so. Suspected larval habitat is in standing water of rice fields. This is its normal breeding habitat.	*Present*. Six positive cases in 84 children examined (7%). Surveys by U.S. Aid and Vietnamese malariologists indicates mesoendemic malaria to be present in Rung Sat.	No collections made. Farmers complain of high rat population destroying rice.
	Anopheles lesteri paraliae	Unknown	Often appears to be associated with coastal brackish-water conditions.		
	Culicine: *Culex sitiens*	See above.	Found breeding in brackish water of "salt marsh" and in brackish water collected in boats.		
Intact coastal mangrove (Cholburi, Thailand)	Aedine: *Aedes dux*	See above		Not known. Probably not present.	*Rattus rattus* only trapped but relatively few in number.
	Aedes taenorhynchoides	See above			
	Culicine: *Culex sitiens*	See above			
Cut-deforested coastal mangrove (Cholburi, Thailand)	Aedine: *Aedes taenorhynchoides*	See above		No people residing, as yet in area but presence of potential vector makes preexisting hazard when settlement takes place.	*Rattus rattus* only collected. Four times as many rats trapped in this site than in adjacent intact mangrove
	Anopheline: *Anopheles subpictus*	Malaria vector in some areas of Indonesia, but not in India or rest of S.E. Asia. Has also been found infected with *W. bancrofti*.	Breeding site found to be exposed salt marshes. Also breeds in ground pools. Man is not a preferred host of this species.		

1. Area a: region around the Muddy Mangrove Forest Control Station. The total number of mosquitoes caught was 2586 (2323 by net trap and BLC method, 263 by light trap). The total species included 6 *Aedes*, 1 *Aedeomyia*, 6 *Anopheles*, 1 *Armigeres*, 5 *Culex*, 1 *Ficalbia*, and 2 *Mansonia*. The results are shown in Table II. *Culex sitiens* and *Aedes dux* were predominant (52.0% and 33.2%, respectively). The females of these two species started to bite about 15 minutes after sunset and remained active all night. The number of biting females decreased in the early morning hours. Table III shows all-night catching of mosquitoes by net trap and BLC at Area a, around the Muddy Mangrove Forest Control Station.

A survey on mosquito larvae in Area a was carried out to determine the breeding sites of the mosquitoes, and the species involved were observed for their habitat in natural and artificial environments. It was found that 34 out of 52 natural and artificial containers served as breeding places for seven species of mosquitoes. *Aedes aegypti* was commonly found in artificial containers while *Ae. dux* was found in the holes of mangrove trees (Table IV).

On the basis of larval collections, *Ae. dux*, species of the *Ae. niveus* group, and *Ficalbia hybrida* are considered to be the only mosquitoes truly indigenous to the mangrove; the other species captured--e.g., the anophelines--are believed to be strays from breeding sites (rice paddies, etc.) immediately outside the mangrove area. As will be seen, these mosquitoes were not found in collection areas in the deepest part of the mangrove forest.

2. Area b: region surrounding Ban-krob Hamlet. Six nights of mosquito capture using net trap, BLC method, and light trap were carried

Table II.

Number and species of mosquitoes caught by net trap (human bait), Bare Leg Catch (BLC) method, and CDC light trap at Area a (4 nights).

Species	No. of mosquitoes caught by			Total
	light trap	BLC	net trap	
Aedes aegypti	0	2	0	2
Ae. dux	48	789	21	858
Ae. longirostris	55	0	0	55
Ae. niveus	0	1	0	1
Ae. taeniorhynchoides	0	67	1	68
Ae. vallistris	0	4	6	10
Aediomyia catasticta	0	1	1	2
Anopheles hyrcanus lesteri	1	0	0	1
An. h. nigerrimus	3	0	0	3
An. h. sinensis	0	2	0	2
An. subpictus malayensis	2	4	0	6
An. s. subpictus	2	4	2	8
An. umbrosus	0	13	6	19
Armigeres subalbatus	0	1	0	1
Culex fatigans	1	8	10	19
C. fuscocephalus	0	0	1	1
C. gelidus	0	1	0	1
C. sitiens	10	1263	73	1346
C. tritaeniorhynchus	11	2	12	25
Ficalbia hybrida	127	0	1	128
Mansonia dives	0	4	0	4
M. uniformis	3	15	8	26
Total	263	2181	142	2586

Table III.

Results of all-night mosquito capture by net trap and BLC method at Area a.

Species	18.00-19.00	19.00-20.00	20.00-21.00	21.00-22.00	22.00-23.00	23.00-24.00	24.00-01.00	01.00-02.00	02.00-03.00	03.00-04.00	04.00-05.00	05.00-06.00	06.00-07.00
Aedes dux	111	8	3	13	7	3	17	6	2	2	0	0	24
Ae. taenorhynchoides	3	1	0	1	0	2	1	0	2	0	0	0	1
Ae. vallistris	3	1	0	0	0	0	3	0	0	0	1	0	1
Aediomyia catasticta	0	0	0	0	0	0	0	0	0	0	0	1	0
Armigeres subalbatus	1	0	0	0	0	0	0	0	0	0	0	0	0
Anopheles suppictus subpictus	1	0	0	0	0	0	0	0	0	0	0	0	0
An. umbrosus	18	0	0	0	0	0	0	0	0	0	0	0	0
Culex fatigans	6	1	1	1	0	0	0	0	1	0	0	0	0
C. sitiens	89	32	22	47	16	58	52	31	18	6	5	3	3
C. tritaeniorhynchus	10	0	0	0	0	2	0	0	0	0	0	0	0
Mansonia uniformis	5	1	0	0	0	0	0	1	0	0	0	0	0
Total	247	44	26	62	23	65	77	38	23	8	6	4	29

Table IV.

Species of mosquitoes found in the natural and artificial breeding places at Area a.

Container type	Species found
Mangrove tree holes	Ae. dux (10),[a] Ae. niveus group (3) Ficalbia hybrida
Rice field	An. philippinensis (1) C. tritaeniorhynchus (1) An. h. sinensis (2)
Irrigation canal	An. h. sinensis (1) C. tritaeniorhynchus (1)
Jar	Ae. aegypti (11) Ae. albopictus (5) C. fatigans (2)
Drum	Ae. aegypti (4)
Tire	Ae. aegypti (1)

[a]Numbers in parentheses indicate number of breeding places where respective mosquito larvae were found.

out at Area b in Ban-krob Hamlet. A total of 1538 mosquitoes was collected and consisted of 5 Aedes, 7 Anopheles, 4 Culex, 1 Ficalba, and 2 Mansonia species. Aedes dux and Culex sitiens were predominant (69.5% and 12.4%, respectively). The biting activities of Ae. dux and C. sitiens females were the same as those found in Area a. The details are shown in Tables V and VI.

A survey for breeding places of mosquitoes was carried out around the hamlet. Table VII shows that 46 out of 58 natural and artificial containers served as breeding sites for 5 species of mosquitoes. Again Ae. aegypti and Ae. dux were commonly found in artificial containers and mangrove tree holes, respectively (Table VIII).

3. Area c: region surrounding Ban-bangchan. Five nights of mosquito capture using net trap, BLC method, and light trap were carried out at Area c in Ban-bangchan Village. A total of 2548 mosquitoes was collected, and consisted of 4 Aedes, 2 Culex, and 1 Mansonia species. The predominant species was Culex sitiens (87.8%). The biting activities of C. sitiens were found to be similar to those at Areas a and b. The details are shown in Tables IX and X.

A total of 98 natural and artificial containers at Area c were examined for mosquito larvae. It was found that 61 of them harbored 4 species of mosquitoes. The habitats of Ae. aegypti and Ae. dux were found to be the same as those at Areas a and b; also Culex fuscodephalus was observed to breed in brackish water containers (Table XI).

4. Area d: shrimp farm near Ban-bangchan. Two nights of mosquito capture were performed in Area d at a shrimp farm near Ban-bangchan. A total of 425 mosquitoes was collected; it consisted of 4 Aedes, 2 Culex, and 1 Mansonia species. The predominant species was Culex sitiens (64.5%).

Table V.

Number and species of mosquitoes caught by net trap (human bait), Bare Leg Catch (BLC) method, and CDC light trap at Area b in Ban-krob Hamlet (6 nights).

Species	No. mosquitoes caught by			Total
	light trap	BLC	Net trap	
Aedes aegypti	0	2	2	4
Ae. dux	167	841	61	1069
Ae. mediolineatus	0	1	0	1
Ae. taenorhynchoides	1	20	1	22
Ae. vallistris	0	12	0	12
Anopheles hyrcanus nigerrimus	10	7	1	18
An. h. sinensis	0	2	0	2
An. kochi	1	0	0	1
An. philippinensis	0	2	2	4
An. subpictus malayensis	0	2	0	2
An. s. subpictus	2	3	0	5
An. vagus	0	1	0	1
Culex fatigans	0	1	6	7
C. fuscocephalus	2	0	6	8
C. sitiens	38	120	32	190
C. tritaeniorhynchus	4	0	2	6
Ficalbia hybrida	183	0	0	183
Mansonia arassipes	0	1	0	1
M. uniformis	3	0	0	3
Total	411	1015	113	1539

Table VI.

Results of all-night mosquito capture by net trap and BLC method at Area b.

Species	18.00-19.00	19.00-20.00	20.00-21.00	21.00-22.00	22.00-23.00	23.00-24.00	24.00-01.00	01.00-02.00	02.00-03.00	03.00-04.00	04.00-05.00	05.00-06.00	06.00-07.00
Aedes dux	38	0	0	0	1	1	1	3	0	5	6	3	11
Ae. taenorrhynchoides	4	0	1	0	0	0	1	1	0	0	0	0	0
Ae. vallistris	1	0	0	0	0	0	0	0	0	0	0	0	0
Anopheles h. nigerrimus	2	0	1	0	1	1	2	0	1	0	0	0	0
An. h. sinensis	0	0	0	0	0	0	0	1	0	0	1	0	0
An. s. subpictus	0	0	0	0	0	0	1	0	1	0	0	0	0
An. vagus	0	0	0	0	0	0	0	1	0	0	0	0	0
Culex fatigans	0	1	0	0	0	0	0	0	0	0	0	0	0
C. sitiens	3	3	0	0	0	2	0	0	1	4	2	1	3
C. tritaeniorhynchus	0	0	0	0	0	0	0	1	0	0	0	0	0
Mansonia crassipes	0	0	0	1	0	0	0	0	0	0	0	0	0
Total	48	4	2	1	2	2	5	7	3	9	9	4	14

Table VII.

Positive results for mosquito larvae in natural and artificial breeding places in Area b.

Container type	No. containers examined	No. containers positive for mosq. larvae	% of containers positive for mosq. larvae
Mangrove tree hole	24	19	79.2
Jar	31	24	77.4
Drum	2	2	100
Tire	1	1	100
Total	58	46	79.3

Table VIII.

Species of mosquitoes found in the natural and artificial breeding places at Area b.

Container type	Species found
Mangrove tree holes	Ae. dux (12),[a] Ae. niveus group (5) Udaya argyrurus (1)
Jar	Ae. aegypti (21), Ae. dux (2) Ae. niveus (1)
Drum	Ae. aegypti (2)
Tire	Ae. aegypti (1)

[a]Numbers in parentheses indicate number of breeding places where respective mosquito larvae were found.

Table IX.

Number and species of mosquitoes caught by net trap (human bait), Bare Leg Catch (BLC) method, and CDC light trap at Area c in Ban-bangchan (5 nights).

Species	No. mosquitoes caught by			Total
	light trap	BLC	net trap	
Aedes aegypti	0	19	4	23
Ae. dux	0	19	0	19
Ae. longirostris	33	0	0	33
Ae. taeniorhynchoides	0	218	6	224
Culex fatigans	0	5	0	5
C. sitiens	175	1955	109	2239
Mansonia dives	0	4	1	5
Total	208	2220	120	2548

Table X.

Results of all-night mosquito capture by net trap and BLC method at Area c in Ban-bangchan.

Species	18.00-19.00	19.00-20.00	20.00-21.00	21.00-22.00	22.00-23.00	23.00-24.00	24.00-01.00	01.00-02.00	02.00-03.00	03.00-04.00	04.00-05.00	05.00-06.00	06.00-07.00
Aedes dux	2	0	0	0	0	0	5	0	0	0	0	0	0
Ae. taeniorhynchoides	25	3	2	3	2	2	2	1	1	0	0	0	5
Culex fatigans	0	0	0	0	0	0	0	1	0	0	0	1	2
C. sitiens	157	53	41	36	43	60	27	67	43	26	31	17	0
Total	184	56	43	39	45	62	34	69	44	26	31	18	7

Table XI.

Species of mosquitoes found in the natural and artificial breeding places at Area c.

Container type	Species found
Mangrove tree holes	Ae. dux (2)[a]
Jar	Ae. aegypti (43), Ae. dux (4) C. fatigans (5) C. fuscocephalus (3)
Drum	A. aegypti (8) C. fuscocephalus (1)

[a] Numbers in parentheses indicate number of breeding places where respective mosquito larvae were found.

The details are shown in Table XII.

A larval survey in and around the area revealed that 22 out of 32 natural and artificial containers served as breeding places for 2 species of mosquitoes; these species were Aedes dux and Ae. aegypti (see Table XIII).

5. Area e: region surrounding Ban-ta-kayang Hamlet. Six nights of mosquito capture using net trap, BLC method, and light trap were carried out at Area e in Ban-ta-kayang Hamlet. A total of 2250 mosquitoes was collected and consisted of 7 Aedes, 4 Anopheles, 1 Armigeres, 3 Culex, 1 Ficalbia, 2 Mansonia, and 1 Udaya. Again the predominant species were Culex sitiens and Aedes dux. Unfortunately, the night during which all night catching was performed the mosquitoes were not plentiful; thus studies on the activities of C. sitiens and Ae. dux were not entirely satisfactory. The details are shown in Tables XIV and XV.

A larval survey around the hamlet was also performed; 22 out of 28 natural and artificial containers were positive for 5 species of mosquito larvae. The habitats of Ae. aegypti and Ae. dux were observed to be the same as those at Areas a, b, and c (Table XVI).

Deforested Mangrove (Tac-Ong-Nghia, Rung-Sat, SVN). The consultant medical zoologists, Drs. Desowitz and Gubler, spent four days in Tac-Ong-Nghia making adult and larval mosquito collections in and around the village. Night biting collections, from 7:00 to 10:00 P.M., were made from human bait. Indoor resting collections were also made during this time. CDC light traps were placed around the perimeter of the village and by the biting-collection stations. It was impossible to place light traps in the deforested area because our ARVN hosts warned that they would

Table XII.

Number and species of mosquitoes caught by net trap (human bait), Bare Leg Catch (BLC) method, and CDC light trap at Area d, shrimp farm near Ban-bangchan (2 nights).

Species	No. mosquitoes caught by			Total
	light trap	BLC	net trap	
Aedes aegypti	0	0	1	1
Ae. dux	0	16	3	19
Ae. longirostris	0	0	5	5
Ae. taeniorhynchoides	0	120	2	122
Culex fuscocephalus	1	0	0	1
C. sitiens	51	207	16	274
Mansonia uniformis	1	2	0	3
Total	53	345	27	425

Table XIII.

Species of mosquitoes found in the natural and artificial breeding places at Area d.

Container type	Species found
Mangrove tree holes	Ae. dux (8)[a]
Nypa leaf axils	Ae. dux (1)
Jar	Ae. aegypti (13)

[a]Numbers in parentheses indicate number of breeding places where respective mosquito larvae were found.

Table XIV.

Number and species of mosquitoes caught by net trap (human bait), Bare Leg Catch (BLC) method, and CDC light trap at Area e surrounding Ban-ta-kayang Hamlet (6 nights).

Species	No. mosquitoes caught by			Total
	light trap	BLC	net trap	
Aedes aegypti	0	7	4	11
Ae. dux	12	655	25	692
Ae. longirostris	189	5	12	206
Ae. mediolineatus	0	1	0	1
Ae. niveus	0	1	0	1
Ae. taenorhynchoides	0	7	2	9
Ae. vallistris	0	13	0	13
Anopheles hyrcanus sinensis	0	2	0	2
An. subpictus subpictus	0	2	0	2
An. sundaicus	0	1	0	1
An. umbrosus	0	3	1	4
Armigeres subalbatus	0	1	1	2
Culex fuscocephalus	2	0	1	3
C. sitiens	71	1120	38	1229
C. tritaeniorhynchus	16	15	3	34
Ficalbia hybrida	27	1	3	31
Mansonia dives	0	1	0	1
M. uniformis	1	6	0	7
Udaya argyrurus	0	1	0	1
Total	318	1842	90	2250

Table XV.

Results of all-night mosquito capture by net trap and BLC method at Area e.

Species	18.00-19.00	19.00-20.00	20.00-21.00	21.00-22.00	22.00-23.00	23.00-24.00	24.00-01.00	01.00-02.00	02.00-03.00	03.00-04.00	04.00-05.00	05.00-06.00	06.00-07.00
Aedes dux	25	0	2	0	1	2	0	0	0	0	0	0	0
Ae. longirostris	0	0	0	0	0	1	0	0	0	0	0	0	0
Ae. vallistris	4	0	0	0	0	0	0	0	0	0	0	0	0
Anopheles umbrosus	1	2	0	0	0	0	0	0	0	0	0	0	0
Culex sitiens	18	18	8	5	0	1	2	0	0	1	1	0	0
Udaya argyrurus	0	0	0	0	1	0	0	0	0	0	0	0	0
Total	48	20	10	5	2	4	2	0	0	1	1	0	0

Table XVI.

Species of mosquitoes found in the natural and artificial breeding places at Area e.

Container type	Species found
Mangrove tree holes	Aedes dux (6)[a]
Weed ponds	Ae. taeniorhynchoides (1) Ae. dux (1) Ae. longirostris (2) An. subpictus subpictus (2)
Crab holes	Ae. dux (1) An. subpictus subpictus (1)
Nypa leaf axils	Ae. dux (2)
Bamboo stump	Ae. aegypti (1)
Jar	Ae. aegypti (8)

[a]Numbers in parentheses indicate number of breeding places where respective mosquito larvae were found.

probably be booby-trapped during the night. Of the collections made over three nights, one was unsatisfactory because of a violent monsoon storm. The biting collections were composed almost entirely of anophelines. These were later identified as Anopheles sinensis and A. lesteri paraliae.[a] The indoor resting collections were also mainly anophelines, but Culex sitiens was also quite common. These were taken resting indoors during the latter part of the evening. Six Mansonia specimens were also taken resting indoors. (A few anophelines and C. sitiens only were taken in the light traps.) Larvae of C. sitiens were found in an abandoned bunker and in a marshy-grassland site. No larvae were found in the holes of the few trees left standing or in any other site, except for Aedes aegypti in village water storage jars. It was not possible to locate the breeding site of the anophelines. It is believed that the anophelines were breeding in the rice fields outside the village, the known preferred breeding site of A. sinensis and lesteri. However, security prevented us from making any collections in the rice fields.

Estuarine Mangrove: Malaria

Intact Control Area (Chantaburi, Thailand). A total of 384 children from one to nine years of age, living in collection sites b (Ban-krob), c (Ban-bangchan), and e (Ban-ta-kayang) were examined for the presence of malaria by blood film examination and splenic palpation. No positive blood films were found nor did any of the children have an enlarged spleen. Thus, there is no evidence of malaria transmission in this forested estuarine mangrove. This is interesting in view of the fact that the

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[a]We are grateful to Drs. de Meillon and Harrison of the Southeast Asia Mosquito Project, Smithsonian Institute, for confirming the taxonomic diagnosis.

area a few miles away, in the foothills bordering Cambodia, is considered one of the "hottest" malaria areas in Thailand. A. balabacensis is the primary vector in that locale.

Deforested Mangrove (Tac-Ong-Nghia, Rung-Sat, SVN). A blood survey was carried out on 84 randomly-selected school children of Tac-Ong-Nghia Village. Six of the 84 stained blood films were found to be positive, one with Plasmodium vivax and six with P. falciparum; the point prevalence rate was thus 7 percent. There was no opportunity to carry out a fever detection or spleen rate survey, but it is believed that had these methods been employed there would have been indication of an even higher malaria incidence.

That malaria transmission is now occurring in many communities of the Rung-Sat is further evidenced by information kindly supplied by the Malaria Section of the AID Public Health Division, Saigon. Prior to 1968 the malaria prevalence rate in Gia-Dinh Province, which includes the Rung-Sat, was very low, probably less than 0.1 percent. From 1969 to 1971, there were a number of outbreaks of malaria (P. falciparum and P. vivax, mainly, but a few cases of P. malaria were also reported) in villages of Rung-Sat districts of Can-Gio, Quang-Xuyen, and Ap-Binh-Hoa. In some instances the point prevalence rate was approximately 50 percent. Further comments on the malaria situation in the Rung-Sat will be given in the succeeding "Discussion" section of this report.

Estuarine Mangrove: Rodents and Rodent Ectoparasites

Intact Control Area (Chantaburi, Thailand). Baited traps were set in areas of high, short, and cutover mangrove areas and in the houses of the settlements in the area. In all, 1292 traps were set; the results are shown in Tables XVII and XVIII. The captured rodents were killed, their fur was combed to collect the ectoparasites, and finally they were skinned to obtain the pelt and skull for definitive taxonomic identification in the laboratory.

As shown in Tables XVII and XVIII, relatively few rats were trapped in areas of high mangrove forest; most animals were taken in the cutover area and in the short "scrub" mangrove. Of the six species of rodents caught, Rattus losea predominated, with R. rattus running a close second.

Out of 230 rodents caught from five mangrove areas in Chantaburi Province, 80 were found to harbor chigger mites and lice of medical and nonmedical importance. However, far fewer ectoparasites were recovered from each animal than were found on the rodents caught in nonmangrove inland areas.

Three species, including Rattus rattus, R. losea, and R. norvegicus, were observed to harbor seven species of chigger mites: Leptotrombidium deliense, G. (w) disparangue disparangue, Laurentella indica, Lau. audyi, Lau. roluis, Laelaps spp. (Laelapidae), and Hemogamasidae, and one species of lice, Anoplura. Tupaia glis also harbored some unidentified arthropods.

Of all chigger mites found, L. deliense is the most important, since it is a potential vector of scrub typhus. It was found on R. rattus (8 chiggers from 11 animals[a]) trapped in the high mangroves in Area a, and on R. losea (1 chigger from 33 animals[b]) caught in the short mangroves in Area b. Moreover, R. rattus caught in houses in Area b harbored some

[a]Chigger index in R. rattus = 8/11 = 0.73.
[b]Chigger index in R. losea = 1/33 = 0.03.

Table XVII.

The number and species of rodents trapped in Chantaburi control mangrove forest.

Condition of mangrove	No. of cages used	*Rattus rattus*		*Rattus norvegicus*		*Rattus losea*		*Rattus exulan*		*Tupaia glis*		*Callosiurus ferruginens*		Total	
		No. trapped	% trapped	No. trapped	% trapped	No. trapped	% trapped	No. trapped	% trapped	No. trapped	% trapped	No. trapped	% trapped	No. trapped	% trapped
High	467	14	3.0	2	0.4	10	2.1	1	0.2	-	-	1	0.2	28	6.0
Short	454	65	14.3	-	-	100	22.0	-	-	3	0.7	1	0.2	169	37.2
Cut-down	279	-	-	-	-	8	2.9	-	-	-	-	-	-	8	2.9
In houses	92	7	7.6	8	8.7	4	4.4	6	6.5	-	-	-	-	25	27.2
Total	1,292	86	6.7	10	0.8	122	9.4	7	0.5	3	0.2	2	0.2	230	17.8

Table XVIII.

Number and species of the rodents trapped from Areas a-e, Chantaburi control mangrove forest. (R. nor. = Rattus norvegicus, T. glis = Tupaia glis, Call. = Callosiruus ferruginens.)

Area	High mangrove		Short mangrove		Cut-down mangrove		In houses		Total	
	No.of cases used	No.& species of animals trapped	No.of cases used	No.& species of animals trapped	No.of cases used	No.& species of animals trapped	No.of cases used	No.& species of animals trapped	No.of cases used	No.& species of animals trapped
a	305 (4 nights)	11 R.rattus 1 R.nor. 2 R.losea							305	11 R.rattus 1 R.nor. 2 R.losea
b			95 (6 n)	4 R.rattus 33 R.losea	279 (6 n)	8 R.losea	32 (5n)	5 R.rattus 2 R.losea 3 R.exulan	406	9 R.rattus 43 R.losea 3 R.exulan
c	113 (5 n)	2 R.rattus 1 R.nor. 5 R.losea 1 R.exulan 1 Call	49 (3 n)	12 R.rattus 15 R.losea 1 T.glis			42 (2 n)	1 R.rattus 5 R.nor. 1 R.losea 3 R.exulan	204	15 R.rattus 6 R.nor. 21 R.losea 4 R.exulan 1 T.glis 1 Call
d	49 (2 n)	1 R.rattus 3 R.losea	38 (2 n)	7 R.rattus 2 R.losea 1 Call			18 (2 n)	1 R.rattus 3 R.nor. 1 R.losea	105	9 R.rattus 3 R.nor. 6 R.losea 1 Call
e			272 (7 n)	42 R.rattus 50 R.losea 2 T.glis					272	42 R.rattus 50 R.losea 2 T.glis

L. deliense (3 chiggers from 5 animals[a]). However, it was noted that there were very few chiggers on each of the animals in these areas. These results are shown in Tables XIX through XXIII.

Deforested Mangrove (Tac-Ong-Nghia, Rung-Sat, SVN). It was not possible to make any collections in the Rung-Sat and the only information available is from local farmers who report that the rat population has increased so enormously in recent years that the rodents are destroying half the rice crop. They attribute the increase in rat population to the grass and debris (suitable breeding habitats) that have replaced the mangrove forests. We have been unable to obtain any epidemiological information regarding the presence of reservoir-associated diseases, i.e., plague, leptospirosis, typhus, in the Rung-Sat.

Coastal Mangrove: Mosquitoes

Intact Forest (Cholburi, Thailand). The mosquitoes indigenous to the intact coastal mangrove were mainly tree-hole breeding species as in the estuarine forest, i.e., Aedes dux and members of the Ae. niveus group. Culex sitiens was also plentiful. Only four anophelines were caught during the five nights of this study; these are considered to be strays from breeding sites outside the mangrove area.

Cutover Deforested Area (Cholburi, Thailand). The mosquito population in the cutover deforested area was distinctly different from that in the adjoining intact forest. The tree-hole breeders of the intact forest have been replaced by anophelines A. subpictus subpictus and A. subpictus malayensis. These were found to be breeding in the exposed

[a]Chigger index in R. rattus = 3/5 = 0.60

Table XIX.

Number and species of chigger mites and lice found on the rodents caught from Area a (around the Muddy Mangrove Forest Control Station).

Species of ectoparasites	Number of ectoparasites collected from		
	High mangrove		
	11 R.rattus	2 R.losea	1 R.norvegicus
L.deliense	8	0	0
G. d.disparangue	1	0	0
Lau.indica	14	0	0
Lau.audyi	1	0	0
Laelaps spp.	35	0	0
Hemogamasidae	1	0	0
Anoplura	10	0	0
Total	70	0	0

Table XX.

Number and species of chigger mites and lice found on the rodents caught from Area b (Ban-krob Hamlet).

Species of ectoparasites	Number of ectoparasites collected from					
	Short mangrove		Cut-down mangrove	In houses		
	4 R.rattus	33 R.losea	8 R.losea	5 R.rattus	2 R.losea	2R.exulan
L.deliense	0	1	0	3	0	0
Lau.indica	0	2	0	10	0	0
Laelaps spp.	4	78	3	1	1	0
Hemogamasidae	0	3	0	0	0	0
Anoplura	4	12	1	0	0	0
Unidentified Arthropods	0	4	0	0	0	0
Total	8	100	4	14	1	0

Table XXI.

Number and species of chigger mites and lice found in the rodents caught from Area c (Ban-bangchan).

Species of ectoparasites	Number of ectoparasites collected from					
	High mangrove		Short mangrove			In houses
	2 *R. rattus*	1 *R.norvegicus* 5 *R.losea* 1 *R.exulan* 1 *C.ferruginens*	12 *R. rattus*	5 *R. losea*	1 *Tupaia glis*	1 *R.rattus* 5 *R.norvegicus* 2 *R.losea* 3 *R.exulan*
Lau.indica	0	0	0	10	0	0
Lau.audyi	0	0	5	7	0	0
Lau.roluis	2	0	15	14	0	0
Anoplura	0	0	1	4	0	0
Total	2	0	21	35	0	0

Table XXII.

Number and species of chigger mites and lice found in the rodents caught from Area d (at shrimp farm near Ban-bangchan).

Species of ectoparasites	Number of ectoparasites collected from							
	High mangrove		Short mangrove			In houses		
	1 *R.rattus*	3 *R.losea*	7 *R.rattus*	2 *R.losea*	1 *C. ferruginens*	1 *R. rattus*	1 *R. norvegicus*	1 *R. losea*
Lau.indica	0	0	15	0	0	0	1	0
Lau.audyi	0	0	18	0	0	0	0	0
Lau.roluis	0	0	9	0	0	0	0	0
Laelaps spp	0	0	3	2	0	0	4	0
Hemogamasidae	0	0	0	0	0	1	1	0
Anoplura	0	1	0	0	0	0	0	0
Total	0	1	45	2	0	1	6	0

Table XXIII.

Number and species of chigger mites and lice found in the rodents caught from Area e (in Ban-ta-bayang Hamlet).

Species of ectoparasites	Number of ectoparasites collected from		
	Short mangrove		
	42 *R.rattus*	50 *R.losea*	2 *T.glis*
Lau.indica	1	0	0
Laelaps spp.	134	77	0
Hemogamasidae	9	6	0
Anoplura	52	15	0
Unidentified arthropods	2	3	14
Total	198	101	14

marshy brackish pools created by deforestation.

The results of mosquito collections in the intact and deforested areas are summarized in Table XXIV. Table XXV indicates the peak biting times of the mosquitoes collected.

Coastal Mangrove: Rodents and Ectoparasites

Intact and Deforested Areas (Cholburi, Thailand). In all, 175 traps were set during the five-day collection period in the Cholburi coastal mangrove. Only *R. rattus* was collected. Of the 55 rats trapped, only 4 (7.2%) were taken in the intact high forest, while the other 51 (92.8%) were captured in either the cutover area or short "scrub" mangrove. Almost all the ectoparasites of medical significance collected--*Laurentella indica* and *Lau. audyi* (potential vectors of scrub typhus)--were found on rats trapped in the short mangrove and deforested areas. These results are summarized in Table XXVI.

DISCUSSION

Despite the obvious limitations of this study, there are persuasive indications that deforestation of the mangrove, by whatever means, results--directly or indirectly--in adverse changes in the populations of the vectors and reservoirs of infectious diseases, particularly with respect to the anopheline vectors of malaria.

The intact estuarine and coastal mangrove forests provide few, if any, suitable breeding habitats for anopheline mosquitoes. The species of mosquitoes inhabiting the mangrove forest are mainly tree-hole breeders such as *Aedes dux* and *Ficalbia hybrida*. Deforestation, by whatever means,

Table XXIV.

Number and species of mosquitoes caught by Bare Leg Catch (BLC) method in Cholburi Province (5 nights).

Species	Mosquitoes caught by BLC			
	Cutover area		Intact area	
	Number	Species	Number	Species
<u>Aedes aegypti</u>	2		9	
<u>Ae. dux</u>	3		128	
<u>Ae. lineatopennis</u>	2		0	
<u>Ae. longirostris</u>	0	5	1	5
<u>Ae. mediolineatus</u>	1		0	
<u>Ae. taenorhynchoides</u>	88		127	
<u>Ae. vallistris</u>	0		8	
<u>Anopheles campestris</u>	1		1	
<u>An. hyrcanus nigerrimus</u>	6		0	
<u>An. philippinensis</u>	1	6	0	4
<u>An. subpictus malayensis</u>	65		1	
<u>An. subpictus subpictus</u>	158		4	
<u>An. vagus</u>	1		1	
<u>Armigeres subalbatus</u>	0		3	
<u>Culex bitaeniorhynchus</u>	2		2	
<u>C. fatigans</u>	9		954	
<u>C. fuscocephalus</u>	2	5	0	4
<u>C. sitiens</u>	108		1,960	
<u>C. tritaeniorhynchus</u>	15		10	
<u>Ficalbia hybrida</u>	0		0	
<u>F. minima</u>	0		0	
<u>Mansonia uniformis</u>	43	1	13	1
<u>Udaya argyrurus</u>	0	1	1	1
Total	507		3,223	

Table XXV.

Results of all-night mosquito capture by BLC method at intact and cutover areas in Cholburi Province.

Species	18.00-19.00	19.00-20.00	20.00-21.00	21.00-22.00	22.00-23.00	23.00-24.00	24.00-01.00	01.00-02.00	02.00-03.00	03.00-04.00	04.00-05.00	05.00-06.00	06.00-07.00
Aedes aegypti	2	0	0	0	0	0	0	0	0	0	0	0	0
Ae. dux	6	5	4	4	5	7	0	0	1	1	0	0	1
Ae. lineatopennis	0	0	1	1	0	0	0	0	0	0	0	0	0
Ae. longirostris	0	0	0	0	0	0	1	0	0	0	0	0	0
Ae. mediolineatus	0	0	1	0	0	0	0	0	0	0	0	0	0
Ae. taenorhynchoides	14	14	7	14	13	8	8	2	2	1	1	1	0
Ae. vallistris	0	0	1	0	0	2	0	0	0	0	0	0	0
Anopheles campestris	0	0	0	1	0	0	0	0	0	0	0	0	0
An. h. nigerrimus	0	0	0	0	0	1	0	0	0	0	0	0	0
An. s. malayensis	9	6	3	8	1	2	0	1	1	0	0	0	0
An. s. subpictus	24	13	3	13	3	3	0	0	1	0	0	0	0
An. vagus	2	0	0	0	0	0	0	0	0	0	0	0	0
Armigeres subalbatus	1	0	0	0	0	0	1	0	0	0	0	0	0
Culex bitaeniorhynchus	0	0	0	0	0	1	0	0	0	0	0	0	0
C. fatigans	20	26	22	24	17	55	46	29	50	42	23	8	1
C. fuscocephalus	0	0	0	1	0	0	0	0	0	0	0	0	0
C. sitiens	132	97	75	83	64	101	60	28	38	20	4	1	1
C. tritaeniorhychus	1	0	0	4	4	2	0	0	0	0	0	0	0
Mansonia uniformis	2	5	3	2	3	1	3	0	1	0	0	1	0
Total	213	166	120	155	110	183	119	60	94	64	28	11	3

Table XXVI.

Rats trapped in the high mangrove (intact forest) and the cutover and scrub mangrove of Cholburi Province, and the number and species of their ectoparasites.

Species of ectoparasites	Number of ectoparasites collected from		
	Cut - down mangrove	High mangrove	Short mangrove
No. rats trapped	23 R. rattus	4 R. rattus	28 R. rattus
Lau. indica	109	36	358
Lau. audyi	-	-	35
G. (W) micropelta	-	-	5
Laelaps spp.	5	4	32
Anoplura	3	6	18
Total	117	46	448

eliminates breeding sites and in the two situations studied the indigenous mosquitoes have been replaced with anophelines, the vectors of malaria. The events that led to anophelinism and thence to malaria transmission in the Rung-Sat study area seem to be indirectly related to deforestation by defoliants, as follows. With denudation of the forest, the area became relatively secure from Viet Cong attack. This led to the migration of people from threatened areas into the Rung-Sat settlements. Many of these people were farmers. Since woodcutting and increased pressure on fish population did not allow a livelihood to be made from these occupations, they turned to rice culture, which is marginally feasible in the Rung-Sat during monsoon season. Rice paddies and/or their irrigation ditches are believed to provide suitable breeding sites for _Anopheles sinensis_ and _A. lesteri_, species that are now abundant during the rainy season. Malaria was probably introduced by the migrants and the Viet Cong, who came into hamlets at night seeking food. The latter case was the presumed cause of the 1969-70 malaria outbreak in the Can-Gio District.

Deforestation of the coastal mangrove in Thailand, on the other hand, seems to have directly provided a suitable habitat for _Anopheles subpictus_. In view of this, it would be of interest and importance to determine whether this species, or any other brackish water breeding anopheline species, is now present in the deforested mangrove areas of the delta and other areas of the Rung-Sat where rice farming has not been undertaken.

Our studies do not include sufficient observations to permit firm conclusions regarding the effect of mangrove deforestation on rodent populations. Trapping results indicate that rodent populations are not high in intact estuarine and coastal mangrove forests. The predominant species in the estuarine mangrove was *Rattus losea*. Little is known regarding the role of this species as a reservoir of disease, but very few ectoparasite vectors, such as the chigger mite (transmitter of scrub typhus) were found on the trapped animals. The population of rodents, predominately *R. rattus* (a known potential reservoir of plague and other infectious diseases) was four times higher, as estimated by trapping results, in the deforested coastal mangrove than in the adjoining intact forest. Additional evidence that deforestation of the mangrove leads to greatly increased rodent populations has come from information, albeit somewhat anecdotal, of the Rung-Sat farmers. If this fact is true, there exists a serious potential health hazard and in view of this, it is extremely important to confirm or disprove these initial observations.

Recommendations for Rehabilitation and Future Studies

The limitations imposed by the military conditions in SVN, and the inadequacies of time, personnel, and resources have not allowed these investigations to conform to the exacting demands of scientific inquiry. Despite the deficiencies and the relatively narrow scope of this investigation, we have experienced a growing disquiet, as the data have been analyzed, about the possibility that ecological alterations caused by defoliation may result in a new set of environmental conditions highly suitable for breeding and propagation of insect vectors of disease. In this case we have focused upon malaria and its vectors not only because it was the infection most readily accessible for study, but also because malaria has a tragically long history in Southeast Asia of debilitating large population groups. The potential danger of the situation is further compounded by the fact that in recent years strains of malignant tertian malaria (Plasmodium falciparum) resistant to the mainstay chemotherapeutic agents have emerged and become widespread in Southeast Asia. Other vector-borne diseases have not been similarly investigated by us, but there is a suggestion that rats, potential reservoirs of plague, typhus, and leptospirosis, have proliferated in deforested mangrove ecosystems. Thus, on the basis of our observations, we make the strongest recommendation that the ecological-epidemiological studies begun by this Committee be continued and expanded. Not to do so may well invite disaster for a significant sector of the rehabilitation program contemplated by our government. For example, to resettle dislocated peoples unprotected by their own immune defenses or by the existence of adequate medical services into an area where the ecological effects have "seeded" vectors and reservoirs of disease can result in epidemics that would negate all the beneficial intent of the rehabilitation program. Equally important would be the introduction by planners of restorative agricultural and water impoundment schemes that could also provide new habitats for disease vectors. The lessons from other resettlement and engineering programs in the tropics which have left epidemic-endemic infectious diseases in their wake cannot be ignored.

At the very minimum, the studies of mangrove epidemiology-ecology should be continued for another year in order to confirm (or disprove) the preliminary observations made. Dry and wet season mosquito population analyses and malaria surveys should be made in the Rung-Sat. Rodent collections should be carried out and their blood and tissues tested for infectious organisms, i.e., plague, typhus, and leptospirosis.

If continued studies are to be confined to the effects of herbicides only, then a more desirable program would be to expand the investigation to ecological-epidemiological studies of mountain, delta, and farmland affected ecologies that have been subjected to defoliants. The methodology and scope of these studies should follow the original protocol outlined in the section "Design of Field Studies." It is estimated that an investigation of this magnitude would take two years to complete.

The final recommendation represents the Committee's belief as to the optimal medical ecology-epidemiology program that should be undertaken. It is apparent to us that the effects of herbicides cannot, and should not, be isolated from all the other war-created potential and possible hazards to the health of the Vietnamese people. Bomb craters (are they breeding habitats for mosquito vectors?), dislocation and resettlement of populations, breakdown of waste disposal systems, denudation of the forest by Rome-plowing are a few examples from this tragic compendium of war's effect and its aftermaths.

A multidisciplinary group of medical scientists, experienced and expert in the medical problems of Southeast Asia, should be established to identify and to advise on the management of health problems, particularly in respect to vector-borne infectious diseases. It will also be necessary to establish laboratory support in the fields of diagnostic parasitology, bacteriology, and virology for the field investigatory team. The activities of this epidemiologic investigation group should be coordinated with plans for rehabilitation. Indeed, it is our recommendation that no rehabilitation activity should be undertaken without the counsel of expert medical ecologists and epidemiologists.

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