Zeitschrift: Acta Tropica

Band: 20 (1963)

Heft: 1

Artikel: The bionomics, ecology and distribution of some mosquitoes (Diptera: Culicidae) in the territory of Papua and New Guinea

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DOI: https://doi.org/10.5169/seals-311101

The Bionomics, Ecology and Distribution of some Mosquitoes (Diptera: Culicidae) in the Territory of Papua and New Guinea.

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Foreword.

Between the years 1956 and 1961 nearly half a million adult and uncounted larval mosquitoes were collected by the staff of the Malaria Section of the Department of Public Health, Territory of Papua and New Guinea. The majority of these specimens, as in any such collections, belonged to a few common species while a minority only were of other than routine interest as regards their bionomics, ecology or distribution. In an area such as the New Guinea highlands, however, so little has been recorded of these aspects of the mosquito fauna, with the exception of the malaria-carrying Anophelines, that a detailed treatment of this highland fauna, including the common species, is called for. The fauna of the coastal (and, to a lesser degree, the subcoastal) areas are somewhat better known. They are therefore dealt with in a more summary fashion below although the following account will make it quite apparent that, in spite of the large quantity of material handled by the present writers, there exist still more lacunae in our knowledge of this group of insects than there are data to fill them.

The highland mosquito fauna differ in many respects from those of the lower lying areas and of the numerous islands and atolls, large and small, that form, in addition to the mainland of Papua and New Guinea, the remainder of the administrative area known as the Territory of Papua and New Guinea. It was therefore deemed advisable to divide the present paper into two main parts, the first of which gives an account of the highlands fauna and the second of the coastal, subcoastal, island and atoll fauna.

I. Notes on some Highland Species.

By W. PETERS and S. H. CHRISTIAN.

1. Introduction.

The New Guinea highlands, here defined as the area above 5,000 feet altitude, were practically unexplored until shortly before the second world war. LEE (1946a) and BONNE-WEPSTER (1948) published brief reports on collections

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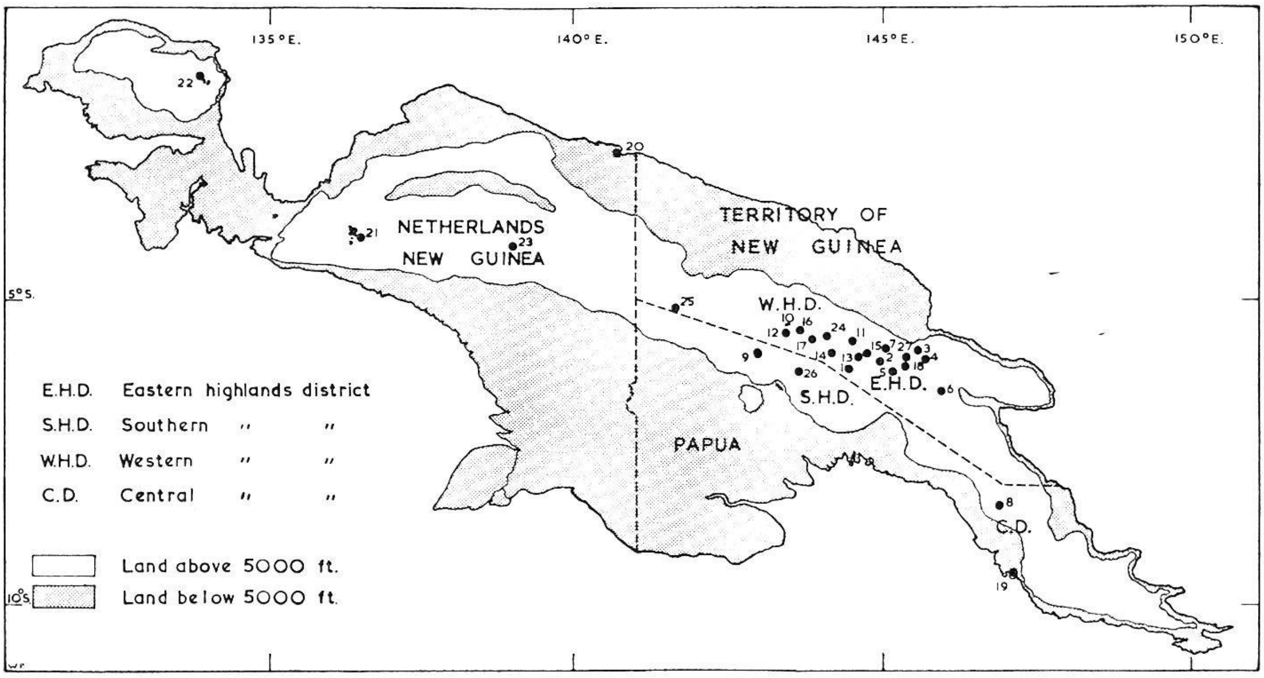

Fig. 1. Sketch map of the New Guinea mainland (excluding the island groups) to show the area above and below an altitude of approximately 5,000 feet and localities mentioned in the text (Key at foot of Table 2).

made in the Australian and Netherlands New Guinea highlands respectively. VAN DEN ASSEM and VAN DIJK (1958) reported on Anopheline distribution. One of the writers (S. H. C.) has made frequent surveys of most of the Wahgi and other highlands valleys since 1947 and has maintained constant entomological and malariological observations in the area around Minj (Fig. 1) since 1953. Malaria is highly endemic and of a seasonal epidemic nature in the Wahgi Valley (PETERS & CHRISTIAN 1960). HEYDON (1940) showed that filariasis was absent from its western end. WISSEMANN, GAJDUSEK & SCHOFIELD have found antibodies to group A arbor viruses in human sera from various localities above 6,500 feet (SCHOFIELD, 1962).

2. Description of the area.

General descriptions of the Wahgi Valley and its human inhabitants have been given by GILLIARD (1953), BLACK (1954) and PETERS & CHRISTIAN (1960).

(a) Climate.

The climate is subtropical with a marked diurnal temperature variation (Fig. 2). Rainfall averages 96 inches per year (range 79-110 between 1951 and 1960) with maximum precipitation in December to April (Northwest Monsoon) and a short rainy period in September. Some rain falls in every month but May to August may be very dry with cold winds while heavy mountain mists are the rule during the main rain months. The daily rainfall pattern is very variable. Clouds frequently shroud the high mountains lining the Wahgi Valley whose floor, several miles wide, lies at an altitude of 5,000 to 5,500 feet. The valley walls range in altitude up to about 11,000 feet and support moss forest above about 8,500 feet.

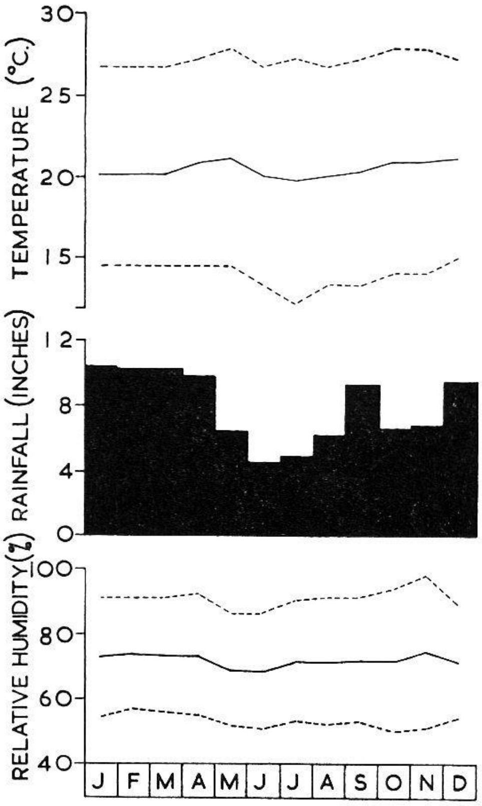

Fig. 2. Maximum mean and minimum temperatures and relative humidity and monthly rainfall. Figures from Minj, mean values for 1951 to 1960 inclusive.

(b) Topography.

The gravelly Minj and Wahgi rivers and their tributaries occupy the centre of the valley floor and are responsible for the seasonal formation of many extensive swampy areas. Mountain streams flowing into the valley are marked by rocky waterfalls in their steeper portions and swampy backwaters where they approach the main rivers. Towards the Minj (eastern) end of the Wahgi valley a series of plateaux is formed on which standing water tends to accumulate when the water table is high. Generally speaking the soils are a heavy, black, rich loam which permits rapid drainage of surface water. Clay soils are the exception so that it is only in seasons when the daily rainfall pattern is particularly favourable that there is an abundance of small transitory puddles. The majority of these are, in fact, man-made artefacts.

(c) Indigenes.

The Wahgi people of whom about 25,000 live in the Minj area and who, until recent years, led a primitive, stone-age existence, are energetic agriculturists practicing a shifting cultivation. Gardens are divided into patchworks of earth mounds about 1 yard square on which are planted mainly sweet potatoes (*Ipomaea* spp.) and other vegetables. Pawpaw trees, bananas and various species of taro are generally planted alongside the walls of the long, low, grass houses. Social life is based on the hamlets which consist of widely scattered groups of two or three houses only. Coffee is being introduced as a cash crop for both European settlers and indigenes and an extensive network of unmetalled roads has been developed. Agricultural and road building activities have resulted in a great deal of disturbance of the earth's surface and the formation of many potential sites for the accumulation of water in transient pools and semi-permanent drains and ditches. Rooting pigs also are responsible for numerous, small, ground pools.

(d) Fauna and Flora.

The Minj area is not abundant in animal life of the higher orders. Domestic pigs and dogs are common around habitations. Wild animals are few, mainly rats and opossums. Amphibians are fairly numerous but reptiles are scarce. Bird life is abundant in the forested areas but not so in the valley itself. The valley floor is mainly savannah covered with patches of relict highland forest and introduced trees such as pines, casuarinas and coffee. The mountain slopes are more extensively aforested and bamboo brakes are a common feature. Above about 8,500 feet numerous *Pandanus* spp., *Nepenthes* spp. and tree ferns occur in the moss forest.

3. Methods.

The following methods have been employed regularly:

(i) Window trap collections (from December 1957).

The human and animal occupants of a varying number of indigenous houses, usually about 30, fitted with outlet window traps with a slit-type entrance, provided the bait for the window trap collections. The average population of a house was: men and women 2.2, children 0.4, pigs 7.5, dogs 0.2. The window traps were emptied daily by native collectors who brought the catches to the central laboratory for identification and dissection. Window trap collections are essentially restricted to those species that (a) enter the trap houses and (b) leave via the traps.

(ii) Daily random larval collections (from January 1957).

Native collectors visited random larval sites daily. The catches were identified and recorded in the central laboratory where larvae were reared to the adult stage where necessary for the confirmation of species. In the laboratory, pH values were estimated on the water contained in the bottles in which individual collections were placed, using a Lovibond comparator. Note was kept also of whether the water was clear or contained clay or humus in suspension.

(iii) Meteorological data (from January 1951).

A standard cylindrical rain gauge, maximum-minimum and wet-dry bulb thermometers were read and recorded daily by one of the writers (S. H. CHRISTIAN) or a responsible subordinate .

Irregular collections have been made by the following methods:

(iv) Light trap collections.

A New Jersey-type light trap operated by a 12 volt battery was run from dusk to dawn in a number of localities. This, unfortunately, was a late acquisition and was only run on a total of 13 nights.

(v) Special larval breeding sites.

Occasional searches for rare and new species or for species not obtained otherwise were made in tree holes, bamboo stumps, leaf axils, *Nepenthes* and other container habitats. The majority of such collections are not included in the quantitative data from routine collections which follow.

(vi) All-night biting catches on human bait.

Mosquitoes were collected on random nights, biting outdoors from dusk to dawn and indoors in native houses from about 9 p.m. to dawn.

(vii) House searches for resting mosquitoes.

Early morning collections were made occasionally to ascertain the proportion of house-visiting mosquitoes that neither left the house via the window traps nor at dawn by other exits.

The quantitative data reviewed below underline the observation, frequently ignored, that no single method of collection can give an accurate picture of the overall mosquito population of a given area. The studies made at Minj have been heavily biased towards the study of Anophelines and malaria so that the frequency of larval collections in different types of breeding site is only a partial reflection of the true frequency with which these sites occur.

4. Species and distribution records.

In the following list (Table 1) are summarised all the species captured by the writers or sent from highland areas for identification. Unless otherwise specified, all these species have been collected in and around Minj. The taxonomic classification employed is that of STONE et al. (1959) and STONE (1961) (see also checklist in Appendix).

5. Species biting man.

The important man-biting species are *Anopheles farauti, An. punctulatus, Mansonia uniformis, Aëdes nocturnus* and *Culex quinquefasciatus* while other species recorded biting occasionally are shown in Table 1.

In October 1958 precipitin tests performed on the blood meals of 616 *An. farauti* taken from window traps yielded the following positive reactions:

71.3% against human serum
28.1% against pig serum
0.7% against dog serum.

This species at Minj shows a peak of biting activity from dusk to 10 p.m., the maximum biting taking place between 8 and 10 p.m. This is in marked contrast to *An. farauti* breeding in brackish coastal waters that bite mainly around and after midnight. *An. punctulatus* in the Minj area shows a peak of biting activity around midnight and a second peak shortly before dawn.

TABLE 1.

List of highland species and distribution, records of man-biting and methods of capture (all species taken at Minj unless otherwise stated).

(Sub)Genus	Species	Localities (See key below)	Biting man	Larvae and/or pupae	Method of caputre = Imagines		
					Window trap	House resting	Light trap
Anoph. (*Anoph.*)	*bancroftii*		+	+	+	.	+
	pseudobarbirostris		+	+	+	.	.
	papuensis	7, 16	.	+	.	.	.
Anoph. (*Cellia*)	*annulipes*	3, 9	.	+	+	.	+
	farauti	12, 16	+	+	+	+	+
	koliensis°		+	+	+	+	.
	punctulatus	8	+	+	+	+	.
Trip. (*Rach.*)	*bisquamatus*		.	+	.	.	.
	brevirhynchus		+	+	+°°	.	.
	filipes		.	+	.	.	.
	? *flabelliger*		.	.	.	+°°	.
	? *pallidus*		.	.	.	+°°	.
	vanleeuweni	5	.	+	.	.	.
	sp. 58 (E.N.M.)	2	.	+	.	.	.
Trip. (*Polylep.*)	*microlepis*	1, 5, 6	+	+	.	.	.
	sp. 57 (E.N.M.)	2, 26	.	+	.	.	.
Ficalbia (*Fic.*)	n. sp.		.	+	.	.	+
Ficalbia (*Mim.*)	*metallica*		.	+	+°°	.	+
Ficalbia (*Eterlept.*)	*elegans*		.	+	.	.	+
Mans. (*Coqu.*)	*crassipes*		+	+	+	.	+
	nr. *linealis*	11	+	.	+	.	+
Mans. (*Mans.*)	*uniformis*		+	+	+	.	+
Uranotaenia	*nov. alticola*		?	+	+	.	+
Aëdomyia	*catastica*		.	+	.	.	+
Aëdes (*Fin.*)	*stanleyi*		.	+	.	.	.
	sp. 59 (E.N.M.)	4, 5	.	+	.	.	.
	anggiensis	4, 5	.	+	.	.	.
	novalbitarsis		.	+	.	.	.
	subalbitarsis		.	+	.	.	.
	n. sp. *papuensis* gp. *A*	4	.	+	.	.	.
	B		.	+	.	.	.

° Present seasonally in small numbers and counted routinely with *An. farauti*.
°° A single occasion only.

Table 1 (continued).

(Sub)Genus	Species	Localities (See key below)	Biting man	Larvae and/or pupae	Method of capture = Imagines: Window trap	House resting	Light trap
Aëdes (Fin.)	n. sp. *kochi* gp.						
	A		.	+	.	.	.
	B	9, 11	.	+	.	.	+
	C	11	?	.	.	.	+
	notoscriptus	18	?	+	+°°	.	.
Aëdes (Ochlero.)	*inexpectatus*	18	.	+	.	.	.
Aëdes (Aëdi-morph.)	*nocturnus*		+	+	+	.	+
Aëdes (Aëdes)	? *lineatus*		?	+	.	.	.
	? *funereus*		+	+	+	.	.
	n. sp. *A*		+	.	.	.	.
Aëdes (Lepto.)	nr. *variepictus*		.	+	.	.	.
Culex (Lutzia)	*halifaxii*	16, 9	?	+	+	.	.
Culex (Lopho.)	*christiani*		.	+	+	.	.
	petersi		.	+	.	.	+
	pseudornatus	5	?	+	+°°	.	.
Culex (Culicio.)	*bailyi*	18	?	+	.	.	+
Culex (Acall.)	nr. *pallidiceps*	9	.	+	.	.	.
Culex (Culex)	*bitaeniorhynchus*		?	+	.	.	+
	edwardsi		?	+	.	.	+
	miraculosus	4, 6, 9, 16	?	+	+	.	+
	quinquefasciatus	3, 12, 26	+	+	+	.	.
	pseudovishnui	16, 18	?	+	.	.	+
	solitarius	3, 4, 7, 10, 16	?	+	.	.	.
	squamosus	16	?	+	+°°	.	.
	whitmorei	9	?	+	.	.	.

1. The following species have been recorded by BONNE-WEPSTER (1948) and VAN DEN ASSEM (1959) from highland localities in Netherlands New Guinea:—

Trip. (*Rachisoura*) *fuscipleura*, *T.* (*Rach.*) *flabelliger*, *T.* (*Rach.*) *cuttsi*, *T.* (*Rach.*) *felicitatis*, *T.* (*Rach.*) *exnebulis*, *T.* (*Rach.*) *confusus*, *T.* (*Polylepidomyia*) *altivallis*, *Aëdes* (*Finlaya*) *toxopeusi*, *Aë.* (*Fin.*) *alticola* and (a doubtful record) *Armigeres* (*Armigeres*) *malayi*. The altitude record appears to be for *Aë.* (*Fin.*) *alticola* and *Aë.* (*Fin.*) *toxopeusi* which were found by the Third Archbold Expedition at 11,400 ft. (3.800 m).

2. The numbered localities below refer also to the numbers on fig. 1. WHD = Western Highlands District, EHD = Eastern Highlands District, SHD = Southern Highlands District, NNG = Netherlands New Guinea, CD = Central District, SD = Sepik District.

1. Nona River, 8,250 ft. WHD
2. Kundiawa, 5,000 ft. EHD
3. Kemenaui, 7,300 ft. EHD
4. Gomenigu River, Kotuni, 7,000 ft. EHD
5. Daulo Pass, 8,000 ft. EHD

6. Benaga, 6,000 ft. EHD
7. Al Valley, 6,000 ft. WHD
8. Goilala, 5,000 ft. CD
9. Tari, 5,250 ft. SHD
10. Lake Sirunki, 8,000 ft. WHD
11. Kweina, 6,000 ft.; Mt. Miminsku, 8,500 ft. WHD
12. Laiagam, 6,950 ft. WHD
13. Minj, 5,140 ft. WHD
14. Mt. Hagen, circa 5,500 ft. WHD
15. Nondugl, 5,200 ft. WHD
16. Wabag, Miraimunda, Kumas, Tsari, Rakamanda, Tarumbais, *circa* 6,500 ft. WHD
17. Wapenamanda, 5,500 ft. WHD
18. Goroka, 5,140 ft. EHD
19. Port Moresby, 50 ft. CD
20. Hollandia, 200 ft. NNG
21. Wissel Lakes, *circa* 5,400 ft. NNG
22. Anggi Lakes, 6,500 ft. NNG
23. Baliem Valley, *circa* 4,800 ft. NNG
24. Baiyer River, 3,900 ft. WHD
25. Telefolmin, 5,000 ft. SD
26. Mendi, 5,490 ft. SHD
27. Megabu, *circa* 5,000 ft. EHD

6. Seasonal variations in adult population densities.

The data obtained from continuous window trap observations over the period December 1957 to November 1960 are summarised in Table 2.

In addition the following were collected from the window traps over the same period (total numbers collected in brackets):
An. punctulatus (179), *An. annulipes* (214), *T. brevirhynchus* (1), *Ficalbia metallica* (1), *M. crassipes* (323), *M.* nr. *linealis* (93), *Uranotaenia* spp. (812), *Aë. funereus* (533), *Aë. notoscriptus* (1), *Culex halifaxii* (12), *C. miraculosus* (93), *C. pullus* (357), *C. squamosus* (1) and *Culex (Lophoceraomyia)* spp. (3).

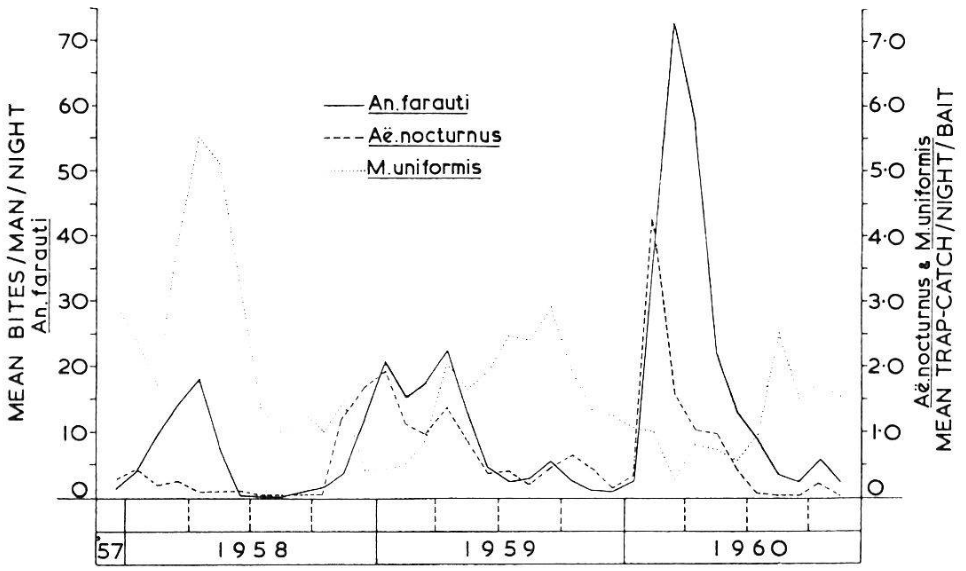

Fig. 3. Mean monthly population densities of adult mosquitoes collected in window traps, Minj, December 1957 to November 1960 inclusive (Note different scales).

TABLE 2.

Summary of window trap collections, Minj, December 1957–November 1960

Date		Mean monthly density				
		Biting 1 man per night		Trap catch per man-bait per night		
		An. farauti	*An. bancroftii s. l.*	*M. uniformis*	*Aë. nocturnus*	*C. quinquefasciatus*
1957	Dec.	1.54	0.40	2.95	0.27	0.12
1958	Jan.	3.78	1.20	2.39	0.40	0.26
	Feb.	8.54	3.20	1.71	0.19	0.22
	Mar.	13.58	4.20	3.86	0.21	0.13
	Apr.	18.20	3.00	5.49	0.12	0.06
	May	6.86	1.40	5.12	0.12	0.04
	Jun.	0.84	0.40	3.37	0.12	0.02
	Jul.	0.70	0.20	1.39	0.02	0.03
	Aug.	0.28	0.10	1.02	<0.01	<0.01
	Sep.	0.98	0.20	1.37	0.07	0.01
	Oct.	1.68	0.20	1.00	0.07	0.05
	Nov.	3.64	0.20	1.45	1.20	0.12
	Dec.	11.76	0.65	0.40	1.69	0.15
1959	Jan.	20.58	2.40	0.41	1.94	0.09
	Feb.	14.98	0.80	0.49	1.14	0.09
	Mar.	17.50	0.10	0.86	0.96	0.16
	Apr.	22.26	2.00	1.98	1.37	0.28
	May	12.88	1.40	1.68	0.82	0.14
	Jun.	4.34	0.20	1.91	0.40	0.14
	Jul.	2.52	0.40	2.47	0.41	0.13
	Aug.	3.10	0.28	2.41	0.22	0.12
	Sep.	5.88	0.26	2.90	0.44	0.25
	Oct.	2.94	0.42	1.93	0.69	0.10
	Nov.	1.32	0.27	1.34	0.42	0.09
	Dec.	1.02	0.15	1.25	0.14	0.05
1960	Jan.	2.62	0.42	1.06	0.31	0.14
	Feb.	38.57	3.54	0.97	4.29	0.49
	Mar.	72.94	2.92	0.29	1.58	0.17
	Apr.	57.26	4.32	0.81	1.05	0.11
	May	20.16	0.76	0.74	0.99	0.05
	Jun.	13.10	0.90	0.59	0.43	0.02
	Jul.	8.88	0.20	0.94	0.10	0.02
	Aug.	3.99	0.30	2.53	0.04	0.01
	Sep.	2.52	0.20	1.54	0.03	0.01
	Oct.	5.66	0.28	1.72	0.22	0.02
	Nov.	2.42	0.23	1.60	0.03	0.01
Total Nos. collected		67,343	4,366	146,081	54,084	9,087

There is a marked contrast between the relative frequency of species as seen in window trap and in larval collections. *An. punctulatus* is known to remain at rest in the houses throughout the day and it is certain that the population density, while very restricted other than in particularly favourable months, is greater than suggested by the figure given above.

7. Light trap collections.

The following material was collected in a limited number of light trap studies made in the Minj area (numbers in brackets):

An. bancroftii s.l. (6), *An. annulipes* (3), *An. farauti* (9), *Ficalbia (Fic.)* sp. (1), *Fic. metallica* (34), *Fic. elegans* (54), *M. crassipes* (84), *M.* nr. *linealis* (4), *M. uniformis* (20), *U. novaguinensis alticola* (18), *Aëdomyia catastica* (11), *Aëdes (Fin.) kochi* gp. (3), *Aë. nocturnus* (5), *C. halifaxii* (1), *C. petersi* (25), *C. bailyi* (11), *C. bitaeniorhynchus* (1), *C. edwardsi* (90), *C. miraculosus* (12), *C. pseudovishnui* (4), *C. squamosus* (1).

It is our general experience with light traps that species of certain genera or species groups (e.g. *Uranotaenia* and the *Aëdes (Finlaya) kochi* group) are taken only if the traps are set close to their breeding grounds.

8. Larval collections.

(A) Classification of breeding sites.

A modification of Bates' (1949) classification of breeding sites is employed in this paper. The sites are tabulated as follows:

I Permanent or semi-permanent standing water
- i Large marshes or marshy zones in lakes
- * ii Swamps
- * iii Small ponds or marshy areas in the open (grassy pools, stream backwaters, fish ponds, bomb holes etc.)
- iv Forest ponds or pools
- * v Freshwater springs
- vi Special plant associations
- * vii Irrigation and road drains (main roadside and house drains)

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* The full classification has been given here as it will be referred to also in the second part of this paper. Only the types of habitat marked * have been collected from in the highlands.

II Brackish water

- i Brackish marshes and swamps
- ii Small accumulations of brackish water

III Running water

- i Open streams in association with vegetation
- ii Open gravel stream beds
- iii Forest streams

IV Transient ground pools

- * i Transient ground pools in the open (cooking holes, coffee holes, small garden drains, pig wallows, roadside puddles, borrow pits, small field drains, foot and hoof prints, wheelruts etc.)
- ii Transient forest pools

V Container habitats

Natural

- * i Rock holes
- ii Crab holes
- * iii Tree holes
- * iv Bamboos
- * v Plant axils (taros, bananas, sago, pineapple etc.)
- vi Fallen spathes and leaves
- * vii *Nepenthes* pitchers
- viii Coconut shells and husks

Artificial

- * ix Drums, tins etc.

(B) Species ecotypes.

In summarising larval collections by sites the work of BICK (1951) has been taken both as a guide and to facilitate a comparison with his and our own data from lowlands areas. The following tables (Tables 3 to 5) are based on the analysis of 21,460 larval collections over the period January 1957 to October 1960 which produced 21,627 batches of 31 species.

As indicated by BICK (1951), the species can be grouped according to their general class of habitat. *Mansonia* spp., *F. metallica* and *Aëdomyia catastica* frequent natural[1] ground water in swamps and pools with clean water of pH 6.8-7.0 (Table 4).

An. bancroftii s.l., *C. squamosus, C. bitaeniorhynchus, C. solitarius, C. pseudovishnui, C. christiani* and *Uranotaenia* spp. can

[1] For definition see notes to Table 3.

TABLE 3.

Species habitat summary. Figures show percentage of all collections in given larval ecotypes (totals below 4 are summarised as "others"). New Guinea highlands.*

	Surface water: Natural: Springs	Surface water: Natural: Pools, Back-waters	Surface water: Natural: Swamps	Surface water: Artificial: Drains	Surface water: Artificial: Trans-ient pools	Containers: Rock holes	Containers: Tree holes	Containers: Bamboos	Containers: Plant axils	Containers: Artificial containers	Others	Total collections
SURFACE WATER												
Natural collections												
An. papuensis		98									2	84
M. uniformis / *M. crassipes*		11	83	6								18
F. metallica			97								3	34
Aëdo. catastica			100									22
Natural & artificial												
An. bancroftii s. l.		4	53		39						8	670
C. squamosus		4		27	65						4	1053
C. bitaeniorhynchus		4		29	64						3	374
C. solitarius	4	7		27	65						2	357
C. pseudovishnui			9	14	73						4	367
C. (Loph.) christiani			5	12	77						6	241
Uranotaenia sp.			20	20	60							5
Artificial collections												
An. punctulatus				25	70						5	670
Aë. nocturnus				15	79						6	334
An. farauti				23	71						6	3326
An. annulipes				22	72						6	8452
C. miraculosus				20	71						9	1165
C. whitmorei				14	82						4	412
C. halifaxii				19	72						1	414
C. pullus				12	84						4	57
C. quinquefasciatus				19	71					6	4	3751
Aë. funereus & *lineatus*				14	83						3	106
Aë. notoscriptus		23			33	17	23				4	30
Aë. nr. alticola (sp. 59)		59			6	35						34
Aë. novalbitarsis / *Aë. subalbitarsis*		32				68						55
CONTAINERS												
Natural & artificial												
T. filipes								100				1**
T. bisquamatus									100			1**
C. (Acallyntrum) sp.									100			2**

* Natural collections—numbered Iii, Iiii and Iv in table on p. 44 Artificial collections—numbered Ivii and IVi in table on p. 44 and 45.

** Always collected in these sites but in special collections not included in this summary.

TABLE 4.

Summary of pH and water type of different habitat groups.

	pH		Type of water*		
	Range of pH	Mean	Clear	With clay	With humus
Species selecting:—					
Surface water — natural	6.8–7.0	6.93	99	1	0
— natural and artificial	6.7–6.9	6.71	95	4	1
— artificial	6.7–6.8	6.68	92	6	1
Intermediate group	6.7–6.9	6.75	94	2	4
Container habitats	Not ascertained				

colonise natural clear surface waters or water containing clay or humus in suspension in artificial[1] ground pools and drains.

From 1.0-4.6% of sites supporting these species contained clay in suspension and from 0-1.8% contained humus. *An. punctulatus, Aë. nocturnus, An. farauti, An. annulipes, C. miraculosus, C. whitmorei, C. halifaxii, C. pullus, C. quinquefasciatus* and *Aëdes (Aëdes)* spp. inhabited collections of surface water almost invariably. The pH of these waters varied from 6.7-6.8. For most species, clay was in suspension in 4.9-6.6% of all waters but for *C. halifaxii* 8.1% and *An. punctulatus* 10.6% of all waters contained clay. Humus was present in 1.1-2.1% of all waters for species other than *C. whitmorei* and *An. punctulatus* for which the figures were 2.7% and 3.8%. The marked preference of *An. punctulatus* for small transient puddles in a clay-bearing soil noted by many authors is borne out by these observations.

A small group of *Aëdes* spp. forms a link between the surface water and container habitat groups. This group had the highest humus index observed, up to 10% of all waters, and a pH from 6.7-6.9. The clay index was 0-2.9%.

The vast majority of semi-permanent and transient collections of surface water are made by man or his domestic animals. Almost all breeding of *An. farauti* and *An. punctulatus* is in such sites and these are the main vectors of malaria in the Wahgi Valley.

(C) *Larval associations.*

The method described by Bick (1951) to calculate a larval association index has been employed to produce the data summarised in Table 5 which is laid out with the same groupings as in Table 3.

* % of all collections.

	An. papuensis	M. uniformis / M. crassipes	F. metallica	Aëdo. catastica	An. bancroftii s.l.	C. squamosus	C. bitaeniorhynchus	C. solitarius	C. pseudovishnui	C.(Loph.) christiani	An. punctulatus	Aë. nocturnus	An. farauti	An. annulipes	C. miraculosus	C. whitmorei	C. halifaxii	C. pullus	C. quinquefasciatus	Aë. funereus & lineatus	Aë. notoscriptus	Aë. nr. alticola (sp.59)	Aë. novalbitarsis / Aë. subalbitarsis	T. filipes	T. bisquamatus	C.(Acallyntrum) sp.	Others
An. papuensis	76							4						4	4								4				8
M. uniformis / *M. crassipes*		28	20		23				5																		24
F. metallica		14		11	49				6				11														9
Aëdo. catastica			17	5	52				14				10														2
An. bancroftii s. l.			8	6	18				15	11			18	9													15
C. squamosus						13	6						17	40	4				9								11
C. bitaeniorhynchus						15	5						15	37	4				9								15
C. solitarius						6		4						45	7				14								24
C. pseudovishnui					8	4			5				22	27		6			8								20
C. (Loph.) christiani					9				5				19	31	4		5		15								12
An. punctulatus											29		14	27	4				15								11
Aë. nocturnus												23	13	30	6				11								17
An. farauti						5							13	41	6				16								19
An. annulipes						6							18	32	8				20								16
C. miraculosus													17	46	13				9								15
C. whitmorei									6		4		19	38	6	5			11								11
C. halifaxii						4							9	29	6		8		31								13
C. pullus					7				4				26	27			4	4	15								13
C. quinquefasciatus													16	44			4		19								17
Aë. funereus & lineatus												4	15	30	4				15	12							20
Aë. notoscriptus	6												8	24					8		37	6					11
Aë. nr. alticola (sp. 59)	9													9	9				9		9	47					8
Aë. novalbitarsis / *Aë. subalbitarsis*	4													6					4				80				6
T. filipes																								100			
T. bisquamatus																									100		
T. (Acallyntrum) sp.																										100	

The frequency with which pure collections of any species occur is maximum in the container breeders and fairly high in the intermediate group but the other surface water breeders are conspicuous by the frequency with which mixed cultures occur. *An. punctulatus* has the second highest index for pure culture (29) within its own group, *An. annulipes* being the commonest of this group (32) to be found alone but the latter is by far the commonest species found in the larval stage in these studies (40% of all species-batches collected). The high association indices suggest that larval competition must be an important factor in maintaining the population balance of highland species. The writers feel that the emphasis on breeding in man-made sites together with the high association indices of the species involved is an indication of a dearth of other, natural breeding sites in this locality.

9. Causes of variations in population densities.

The species for which most data are available is *An. farauti* which will be discussed at some length as an example. The main and interacting factors influencing the population density of any mosquito species are as follows:

(A) Climate and potential breeding area.

Emphasis was laid earlier in this paper on the good natural drainage of much of the area studied. A quarter of all *An. farauti* collections were found in semi-permanent sites. As the water table rises with the seasonal onset of the heavy rains these sites fill up and larval breeding can increase. When the level is at a peak many transient sites are also filled so that there is an extension of the potential breeding area and consequent rise in the population density of larvae and adults.

Heavy downpours limit breeding in the transitory sites by flushing them out but may extend the breeding grounds by flooding larvae to fresh sites. Gentle continuous rainfall keeps transient sites topped up and provides optimal conditions for a time (also for *An. punctulatus*) but sites maintained for too long are invaded by predatory aquatic insects including *C. halifaxii* which again tend to diminish the numbers of *An. farauti* larvae. In the case of *An. punctulatus* which has been shown to favour small open puddles of this type, extensive breeding does not depend simply on the water table level or total rainfall at any period but occurs only in seasons when the daily rainfall pattern is favourable.

Swamp breeding species such as *Mansonia* spp. are influenced almost exclusively by the rise or fall of the water table level. Container breeders naturally depend on the topping up of water by rainfall except in the case of some rock pools.

The relative humidity influences population densities through its influence on the microclimate of adult resting sites and hence the longevity of the adults. Temperature and wind also influence the microclimate and in addition, temperature influences the duration of the aquatic stages. The gonotrophic cycle of *An. farauti* at Minj is probably 96 hours compared with 24 hours at coastal temperatures, and its daily mortality is about 10% compared with 17% on the coast.

It has been indicated already that man-made sites form a very important part of the potential breeding area for *An. farauti* and indeed for the majority of surface water breeding species in this area. It seems likely that the high association indices of most surface water breeders in this area are a reflection of this natural paucity of breeding sites in general which has resulted in the accumulation of these species in whatever sites are available. It so happens that most of such sites in the Minj area are man-made. In the Wahgi Valley this has no doubt been responsible for an extension of malaria geographically and an enhancement of the seasonal epidemics.

It is noteworthy that the higher one searches the greater becomes the proportion of container breeders so that, for example, in the moss forest, *Nepenthes, Pandanus* axil, tree hole and rock pool breeders are probably the dominant species.

(B) Other factors.

Predation appears to be of relatively minor importance in swamp breeding species such as *Mansonia* spp. which can remain buried in the muddy bottom of the swamp for long periods, when danger threatens. In small ground pools active larvae of *Culicini* are attacked by *C. halifaxii* more readily than larvae of *Anophelini*. Furthermore, the prolonged period required for the completion of the larval stages at the relatively cool Minj temperature increases the exposure to predation of any surface water species.

The duration of the aquatic stages in an area where rainfall is inconstant is a matter of major importance. When sites are liable to drying out, species requiring only a short period for larval and pupal development are most favoured. By the same token, if the eggs can support a certain degree of dessication by stranding, the species stands a better chance of surviving. *Aë. nocturnus* falls into this last category, but it is probable that *An. farauti* eggs and larvae can withstand only minimal periods of dessication.

It appears that the preponderance of *An. annulipes* in surface waters is a limiting factor in the increase of larval density of other associated species in this area where, as we have already suggested, breeding sites are at something of a premium.

It will be of great interest to establish what effect residual insecticide spraying of houses with its selective activity against house-resting mosquitoes will have on the natural balance of populations of the non house-visiting species.

II. Notes on some Species of the Coastal and Subcoastal Mainland, Islands and Atolls.

By W. Peters

1. Introduction.

Bonne-Wepster & Swellengrebel (1953), Lee & Wooodhill (1944), Belkin, Knight & Rozeboom (1946) and Van den Assem and Van Dijk (1958) give good accounts of the *Anophelini*.

Important general references to non-Anopheline fauna are those of Edwards (1924), Bonne-Wepster (1938, 1954), Lee (1944, 1946b), Belkin (1950, 1953, 1962), Bick (1951), Horsfall (1955), Laird (1956), Iyengar (1960a), Marks (1961) and Van den Assem (1961).

Most of the material described below was collected in the region of:

Maprik (Sepik District), September 1957 to February 1959
Wewak (Sepik District), July 1956 to May 1957
Port Moresby (Central District), April 1956 to January 1957 and April 1959 to February 1961

In addition short visits were made by the writer to the following areas:

Fly River and Lake Murray (Western District), November 1956
Trobriand Islands, October 1956
D'Entrecastaux Islands and Milne Bay, October 1956
Admiralty Islands, November 1958
Bougainville District mainland, May 1959 and January 1960
Bougainville District atolls, May 1959
Nissan Island and New Hanover, January 1960
New Britain, May 1959
New Ireland, November 1958 and June 1959
Lae (Morobe District), June 1956 and May 1959

2. Description of the area.

(A) Climate.

In this paper it is impossible to give a full account of the climate of a heterogenous area of approximately 190,000 sq.mls. of land surface (about 140,000 excluding the highlands) nor of the topography, general fauna and flora. While the nature and size of this area entail considerable local variation in local climate it can be stated in general that the New Guinea lowlands and islands fall within the tropical rainfall belt characterised by heavy rainfall (from 80 to over 200 inches per year) which falls in the northwest, southeast or both monsoons, depending on the exact locality, perennially high temperatures (minimum 70°F. to maximum 100°F. approximately) and relative humidity (approximately 70 to 95%). A general account of the climate is given in an official publication of the COMMONWEALTH OF AUSTRALIA (1951) and individual areas are described by BELKIN (1950, Bougainville), BICK (1951, Milne Bay), PETERS (1957, Fly River area) and PETERS & STANDFAST (1960, Maprik).

(B) Topography.

The New Guinea mainland is formed of a central mountainous spine running approximately from west to east which descends somewhat abruptly towards the ocean to the north and in the south-eastern half but falls to an extensive swampland, the Fly River area, to the south-west. The whole south-west coast is a maze of swampy deltas where the Fly, Turama, Kikori, Purari and other important rivers and their tributaries enter the Coral Sea. Apart from this region, the mainland coastal belt is a very narrow to narrow strip and in some sections the mountains descend sharply almost to the ocean. To the north and northeast of the mainland are the chain of flat islands forming the Admiralty group and New Ireland and the large mountainous island of New Britain. The two main islands of Bougainville (extending further south-eastwards as the Solomon Islands) are also mountainous with rather narrow coastal plains. From the eastern tip of Papua run the islands of the Louisiade Archipelago and the D'Entrecastaux group, geologically old and volcanic islands with narrow coastal strips. North of the latter group are the coralline islands of the Trobriand and other, smaller groups. Numerous small volcanic and coralline islands and atolls lie at various distances from the mainland and the other larger islands.

(C) *Flora.*

There are extensive mangrove swamps on most of the coasts of the mainland and larger islands giving way inland to sago stands and coconut plantations. Inland from the cultivated coastal land, rain forest of various types extends towards and into the hills until a more montane type of growth takes over with increasing altitude. The smaller and more recent islands and atolls support only coconuts and a limited growth of small, scrubby bushes, trees and flowering plants that can survive on sandy and coralline soil. Further details of the flora should be sought in the above-mentioned publication of the COMMONWEALTH OF AUSTRALIA (1951).

(D) Fauna.

Apart from man, there is a relative dearth of mammals in New Guinea, even domestic mammals being comparatively few. Marsupials such as the Wallaby are common in Papua but few are found north of the central mountains. Smaller mammals and marsupials such as rodents and opossums are fairly common in most areas. Insectivora and fruit bats, especially *Pteropus* and species of allied genera are common in most of the lowlands. Birds are numerous, reptiles relatively prolific and Amphibia are abundant everywhere.

3. Methods.

Essentially the same basic methods of collecting were employed as were described in the first part of this paper.

4. Species and distribution records.

A complete checklist of the material studied by the writers is presented in the Appendix.

The following Table 6 which is designed to give an overall picture of the distribution of the various species and does not include records published by other workers, reflects the fact established by others and well illustrated by IYENGAR (1960a) that the further east and north one looks the less species are found. In the most extensively collected area, the Maprik subdistrict of the Sepik, 95 species were collected in 29 genera or subgenera.

5. Anthropophily and endophagy.

The following records of Culicines biting man are based on personal observation by the writer or his collaborators (Table 7).

Of the 35 species in the table recorded as biting man, 5 were taken rarely (+), 8 occasionally (++) while the rest were very ready man-biters. The remaining 22 anthropophilic species include 3 *Anopheles (Cellia),* 4 *Mansonia,* 2 *Hodgesia,* 6 *Aëdes* (in 5 subgenera), 3 *Armigeres (Armigeres)* and 3 *Culex (Culex).* While the non-anophelines have been shown to feed on man readily no information is available from precipitin testing or direct observation to show on what other species they feed and with what frequency. The three species of *Anopheles (Cellia)* are the well-known malaria vectors *An. farauti, punctulatus* and *koliensis* (METSELAAR, 1957; PETERS and STANDFAST, 1960) which also transmit the microfilaria of *W. bancrofti* (see later).

Species of *Mansonia (Mansonioides)* are among the most persistent and brutal man-biting species wherever they occur and their population densities reach forbidding proportions in such areas as the Fly and Sepik Rivers. Brackish swamps support *M. papuensis* which attacks in hoards at dusk and throughout the night either indoors or outdoors.

Hodgesia cairnsensis on the Sepik and *H. quasisanguinea* on the Fly River attack during daytime. They bite the lower extremities up to about the knees when the victim stands in moist grass near the river edge.

Among the most vicious man-biting species are several species of *Aëdes (Aëdes)* the females of which, apart from those of *Aëdes lineatus,* are very difficult to identify. They attack by day in the shelter of bush adjoining the footpaths and in shade on the paths themselves. They rarely attack in open sunlight. On the south Papuan coast, *Aëdes (Ochlerotatus) vigilax* is a vicious man-biter

TABLE 6. *Summary of distribution.*

Genera & subgenera	Number of species per locality															
	Mortlock & Tasman atolls	Carteret atoll	Bougainville mainland	Nissan atoll	New Ireland offshore islands	New Hanover	New Ireland mainland	New Britain	Manus group	Mainland N. coast	E. Papuan islands	Mainland E. & S. coasts	Fly River	Sepik area	Mainland highlands	Total of these localities for each subgenus
Bironella (*Bironella*)	.	.	.	.	.	.	.	.	.	.	1	.	.	3	.	2
Bironella (*Brugella*)	.	.	.	.	.	.	.	.	.	1	.	.	.	1	.	2
Anopheles (*Anopheles*)	.	.	.	.	.	.	.	.	.	1	1	1	2	2	3	6
Anopheles (*Cellia*)	.	.	1	1	1	1	1	1	2	5	4	5	3	6	4	13
Toxorhynchites	.	.	.	.	.	.	1	.	.	1	1	1	.	1	.	5
Tripteroides (*Tripteroides*)	.	.	1	1	.	1	1	1	1	2	2	3	.	3	.	10
Tripteroides (*Rachisoura*)	.	.	3	.	.	.	2	2	.	3	3	3	.	7	7	8
Tripteroides (*Polylepidomyia*)	.	.	1	1	.	.	1	.	.	1	.	1	.	3	2	7
Malaya	.	.	.	.	.	.	.	.	1	1	.	1	.	1	.	4
Ficalbia (*Ficalbia*)	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	2
Ficalbia (*Mimomyia*)	.	.	.	.	.	.	.	.	.	1	.	.	1	.	1	3
Ficalbia (*Etorleptiomyia*)	.	.	.	.	.	.	.	.	.	.	.	1	.	1	1	3
Mansonia (*Coquilletidia*)	.	.	1	.	.	.	1	.	.	1	.	3	1	2	2	7
Mansonia (*Mansonioides*)	.	.	.	.	.	.	1	1	.	3	.	3	3	3	1	7
Uranotaenia	.	.	4	1	.	.	3	.	1	5	6	10	1	14	1	10
Hodgesia	.	.	.	.	.	.	1	.	.	2	1	.	1	1	.	5
Aëdomyia	.	.	.	.	.	.	.	.	.	1	.	.	.	1	1	3
Aëdes (*Mucidus*)	.	.	.	.	.	.	.	.	.	1	.	1	.	1	.	3
Aëdes (*Ochlerotatus*)	.	.	1	.	.	.	.	.	.	.	1	1	.	.	1	4
Aëdes (*Finlaya*)	.	2	3	2	1	3	3	1	1	3	4	3	.	4	11	13
Aëdes (*Macleaya*)	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	1
Aëdes (*Skusea*)	.	.	.	.	.	.	1	.	.	1	.	.	.	.	.	2
Aëdes (*Geoskusea*)	.	1	2	1	.	.	1	.	.	2	2	2	.	.	.	7
Aëdes (*Rhinoskusea*)	.	.	.	.	.	.	1	.	.	1	.	.	.	.	.	2
Aëdes (*Stegomyia*)	2	3	4	4	2	2	3	4	2	3	3	3	.	2	.	13
Aëdes (*Aëdimorphus*)	.	.	1	.	.	.	2	.	.	1	2	2	.	2	1	7
Aëdes (*Neomelanoconion*)	.	.	1	.	.	.	.	1	.	1	.	1	.	1	.	5
Aëdes (*Aëdes*)	1	.	1	.	.	.	4	1	1	3	1	3	?	7	3	11
Aëdes (*Leptosomatomyia*)	.	.	.	.	.	.	.	.	.	.	.	.	.	2	1	2
Armigeres (*Armigeres*)	.	1	1	1	.	1	1	1	1	3	1	3	1	3	.	12
Culex (*Lutzia*)	.	.	1	.	.	.	1	1	1	1	1	1	.	1	1	9
Culex (*Neoculex*)	.	.	.	.	.	.	.	1	.	1	.	.	.	3	.	3
Culex (*Lophoceraomyia*)	.	.	1	.	.	.	2	1	.	3	1	3	2	6	3	9
Culex (*Culiciomyia*)	.	.	.	.	.	1	1	1	2	2	2	3	.	5	1	9
Culex (*Acallyntrum*)	.	.	.	.	.	.	.	.	.	1	1	.	.	1	1	4
Culex (*Culex*)	1	1	3	1	.	1	3	2	1	7	4	9	2	8	8	14
Genera & subgenera per locality	3	5	17	9	3	7	21	14	11	31	21	26	12	29	21	
Species per locality	4	8	30	13	4	10	35	19	14	62	42	68	18	95	55	

TABLE 7.

Summary of species captured on human bait. (Where the locality is not recorded the species is widely distributed.)

(Sub)Genus	Species	Biting indoors	Biting outdoors	Localities	Notes
Anoph.					
(*Anoph.*)	*bancroftii*		+ N	Fly River	
Anoph.(*Cellia*)	*farauti*	+++ N	+++ ND		Only recorded biting by day near Sepik River
	koliensis	+++ N	+++ ND		
	longirostris		++ N	Wewak	
	punctulatus	+++ N	+ D		,, ,, ,, ,,
	subpictus	+ N		Wewak	
Trip. (*Trip.*)	*magnesianus*		+ D	Port Moresby	Biting in wooded shade
Mans. (*Coqu.*)	*crassipes*	+++ N			
Mans.(*Mans.*)	*papuensis*	+++ N	+++ N	Wewak, Milne Bay, Fly River	
	septempunctata	+++ N	+++ N	Maprik area	
	uniformis	+++ DN	+++ DN		
Hodgesia	*cairnsensis*	+ N	+++ D	Kavieng, Sepik River	Single spec. biting in room, Kavieng, others along river.
	quasisanguinae		+++ D	Fly River (Totoma)	Biting along river edge.
Aë. (*Och.*)	*vigilax*	+++ DN	+++ DN	S. Papua coast.	
Aë. (*Fin.*)	*kochi*		++ N	Trobriand Isles	
	notoscriptus	++ N		Maprik	
Aë. (*Skusea*)	*dasyorrhus*		++ N	Wewak	
Aë. (*Geosk.*)	*near longiforceps*		++ N	Wewak	(Identific. unconfirmed)
	near becki		+++ N	Wewak	,,
Aë. (*Steg.*)	*scutellaris*		+++ D		
	n. sp.		++ D	New Ireland	,,
Aë. (*Aëdim.*)	*nocturnus*	+++ N			
Aë. (*Aëdes*)	*carmenti*		++ D	Maprik	
	funereus		+ N	Wewak	
	lineatus	+++ DN	+++ DN		
	reesi	++ N	++ N	Maprik	
	sp. indet.	+++ DN	+++ DN		Females are among commonest anthropophilic species but often unidentifiable
Arm. (*Arm.*)	*brienli*		+++ D		Common biters in part-shade
	milnensis		+++ D		,,
	papuensis		+++ D		,,
Cul. (*Culicio.*)	*pullus*	++ N			
Cul. (*Culex*)	*annulirostris*	+++ N	+++ N		
	quinquefasciatus	+++ N	++ N		
	sinensis	+ N		Fly River	
	sitiens	+++ N	+++ N	Wewak	

D = in daytime N = at night + = single record ++ = several records +++ = numerous records

TABLE 8.

Summary of species visiting houses as reflected by window trap catches (Maprik) and indoor collections of resting mosquitoes. (Where the locality is not recorded the species is widely distributed.)

(Sub)Genus	Species	Window traps 06.00 hrs.	Resting indoors 07.00 hrs.	Locality	Notes
Anoph. (Anoph.)	*bancroftii*	+++	+++		
	pseudobarbirostris	++	++		
Anoph. (Cellia)	*annulipes*		+	Port Moresby	
	farauti	+++	+++		
	karwari		+	Maprik area	
	koliensis	+++	+++		
	punctulatus	+++	+++		
	subpictus		++	Wewak	
Toxorhynchites	*inornatus*		++	Port Moresby, Wewak	Probably attracted to light
Trip. (Trip.)	*alboscutellatus*		++	Maprik	
	bimaculipes		++	Maprik	
	elegans	+		Maprik	
Mans. (Coqu.)	*crassipes*	+++		Maprik	
Mans. (Mans.)	*papuensis*		+++	Wewak	
	septempunctata	+++		Maprik	
	uniformis	+++	+++		
Uranotaenia	*albescens*	++		Maprik	Probably attracted to light
Aëdes (Muc.)	*alternans*		++	P. Moresby	
Aëdes (Och.)	*vigilax*		+++	P. Moresby	
Aëdes (Fin.)	*kochi*		++	Maprik	
	notoscriptus	+++	+++	Maprik, Wewak	
Aëdes (Steg.)	*scutellaris*	+++	+++	Maprik, Wewak	
Aëdes (Aëdim.)	*nocturnus*	+++		Maprik	
Arm. (Arm.)	*brienli*		++	Wewak, Maprik	
	milnensis	++	++	Maprik	
	papuensis	++	++	Mapiik	
Cul. (Neo.)	*brevipalpis*	++		Maprik	
Cul. (Loph.)	*digoelensis*	+		Maprik	
	fraudratrix	+++		Maprik, Wewak	
	ornatus	+		Maprik, P. Moresby	
	n. sp.	++		Maprik	
Cul. (Culicio.)	*papuensis*		++	Maprik	
	pullus	+++	++	Maprik	
Cul. (Culex)	*annulirostris*	+++	+++		
	quinquefasciatus	+++	+++		
	sitiens		++	P. Moresby	
	whitmorei		++	Maprik	

\+ = single record ++ = several records +++ = numerous records by day or night, indoors or outdoors, in shade or broad sunlight. *Aëdes (Finlaya) kochi* has been captured on human bait outdoors after dusk and *Aëdes (Fin.) notoscriptus* has occasionally been captured indoors biting man in the Maprik area. *Aëdes (Geoskusea)* spp. near *becki* and *longiforceps* and *Aëdes (Skusea) dasyorrhus,* all brackish water breeders, are commonly taken biting man at night outdoors on the Sepik coast. *Aëdes (Stegomyia) aegypti queenslandensis* and *Aë. (Steg.) scutellaris* bite man indoors or outdoors in half shade during the day (the former is not included in Table 9 as it was not taken by the writer). *Aë. (Aëdimorphus) nocturnus* is an endophagic nocturnal biter.

Armigeres (Armigeres) species are frequently found together with species of *Aëdes (Aëdes)* and bite under the same conditions.

Culex annulirostris and (in coastal areas) *C. sitiens* are markedly anthropophilic while *C. quinquefasciatus* is somewhat catholic in its tastes. All three species will feed indoors or outdoors at night.

There is a marked similarity between the lists in Tables 7 and 8 suggesting that few species enter human dwellings that do not feed on man.

6. Potential disease vectors.

(A) Virus diseases.

It is now known that, in addition to the well-known arthropod borne virus diseases of man such as Dengue and Murray Valley Encephalitis (MVE), other arbor viruses exist in New Guinea. Recent work has indicated that as yet incompletely identified group A arbor viruses are endemic in the Maprik area (PETERS, 1960 and SCHOFIELD, 1961). Species of mosquito found in New Guinea which have been incriminated elsewhere as vectors of arbor viruses are shown in the following Table 9.

(B) Malaria.

The epidemiology and vectors of malaria in the New Guinea lowlands have been well documented by METSELAAR (1957) and PETERS and STANDFAST (1960). The main vectors are *An. punctulatus, An. farauti, An. koliensis* and *An. bancroftii* s.l. while *An. subpictus, An. karwari* and possibly other rarer species may occasionally act as secondary vectors in specific localities.

(C) Filariasis.

IYENGAR (1960b) has listed the main species of mosquitoes incriminated as vectors of human Bancroftian filariasis in New Guinea. In addition to these SLOOF and VAN DIJK (1961) suggest that

Culex (Culiciomyia) spathifurca (Edw.) 1915 may be a vector on Pam Island in Netherlands New Guinea. The role of Anopheline mosquitoes as vectors of filariasis was reviewed by DE ROOK and VAN DIJK (1959). We have made a limited number of dissections of wild-caught mosquitoes in and around Maprik and have found the following infection rates with *Wuchereria bancrofti:*

An. farauti	4.8%	(105 dissections)
An. koliensis	0	(286 dissections)
An. punctulatus	3.8%	(546 dissections)
C. annulirostris	0	(304 dissections)
C. (Lophoceraomyia) spp.	0	(44 dissections)
C. (Culiciomyia) pullus	0	(218 dissections)

7. Light trap collections.

The species listed in Table 10 below were captured in a New Jersey-type light trap operated from car batteries on 13 nights in the Maprik area and 1 night each in Port Moresby, Kavieng, Buin,

TABLE 9.

otential vectors of arbor viruses infecting man, based on recorded virus isolations in related species and high of anthropophily.

(Sub)Genus	Species	Anthropophily	Recorded virus isolations	
			Viruses	Species & locality
Anoph. (Anoph.)	*bancroftii*	++	M.V.E.	*An. bancroftii* Gulf of Carpentaria°
Anoph. (Cellia)	*punctulatus*	+++		None isolated from this group so far
	farauti	+++		
	koliensis	+++		
Mans. (Mans.)	*uniformis*	+++		None isolated from this group so far
Aë. (Och.)	*vigilax*	+++	M.V.E.	*Aë. normanensis* Gulf of Carpentaria
Aë. (Aëdim.)	*nocturnus*	+++	Jap. B	*Aë. vexans* Guam & U.S.A.°°
Aë. (Steg.)	*scutellaris*	+++	Dengue	*Aë. scutellaris* New Guinea°°
Aë. (Aëdes)	spp.	+++		None isolated from this group so far
Arm. (Arm.)	spp.	+++	Jap. B	*"Arm. obturbans"* Japan°°
Culex (Culex)	*annulirostris*	+++	MRM 16, MRM 32, M.V.E.	*C. annulirostris* Gulf of Carpentaria°
			Jap. B	*C. annulirostris* Caroline Islands°°
			Jap. B	*C. tritaeniorhynchus* Japan°°
Culex (Culex)	*quinquefasciatus*	++	Jap. B	*"C. fatigans"* Guam, Caroline Island

DOHERTY et al. (1961). °° Data summarised by HORSFALL (1955).

TABLE 10.

List of specimens taken in light traps (various localities).

(Sub)Genus	Species	No. taken
Bir. (Bir.)	*bironelli*	2
Bir. (Brug.)	? *travestita*	2
Anoph. (Anoph.)	*bancroftii*	16
Anoph. (Cellia)	*farauti*	12
	koliensis	16
	longirostris	25
	punctulatus	23
Trip. (Trip.)	*elegans*	1
	novohanoverae	1
Trip. (Rach.)	*mathesoni*	1
Fic. (Eterl.)	*elegans*	2
Mans. (Coqu.)	*crassipes*	5
	ochraceus	3
Mans. (Mans.)	*papuensis*	8
	septempunctata	51
	uniformis	14
Uranotaenia	*albescens*	84
	albosternopleura	16
	sp. nr. *antennalis*	49
	argyrotarsis	2
	barnesi	?
	diagonalis	9
	lateralis	?
	novaguinensis gp.	59
	papua	4
	paralateralis	7
	quadrimaculata	?
	setosa	?
	sexauri	?
	solomonis	?
	tibioclada	1

(Sub)Genus	Species	No. taken
Aëd. (Och.)	*vigilax*	31
Aëd. (Fin.)	*kochi*	3
	wallacei	6
Aëd. (Aëdim.)	*alboscutellatus*	25
Aëd. (Neo.)	*imprimens*	9
Aëd. (Aëdes)	*carmenti*	?
	foliformis	1
	lineatus	2
	neomacrodixoa	?
	reesi	1
	sentanius	?
	? spp.	108
Arm. (Arm.)	*brienli*	1
	milnensis	?
	papuensis	1
Cul. (Neo.)	*brevipalpis*	1
	crassistylus	2
Cul. (Loph.)	*digoelensis*	1
	fraudratrix	113
	leei	?
	ornatus	27
	sp. indet.	104
Cul. (Culicio.)	*fragilis*	1
	fuscicinctus	2
	nailoni	10
	papuensis	?
	pullus	158
Cul. (Culex)	*annulirostris*	134
	bitaeniorhynchus	1
	quinquefasciatus	1
	vicinus	2
	whitmorei	6

? = total number captured not recorded.

Inis and Lae. This list excludes 1 night on the Mortlock atoll where several hundred *C. annulirostris* and a significant number of *Aë. (Aë.) lineatus* were taken.

Mainly night-flying mosquitoes were taken (as would be anticipated) of which certain species and genera were dominant. Of the 1167 specimens collected, the commonest were as shown in Table 11 below.

TABLE 11.

Summary of light trap collections to show groups most commonly collected.

Sub)Genus	Species	No. collected	% of recorded total
Culex (Lophoceraomyia)		245	21.0
	fraudratrix	113	9.7
	sp. indet.	104	8.9
Uranotaenia		231	19.9
	albescens	84	7.2
	novaguinensis gp.	59	5.1
Culex (Culiciomyia)		171	13.8
	pullus	158	13.5
Culex (Culex)		144	12.3
	annulirostris	134	11.5
Aëdes (Aëdes)		112	9.6
	sp. indet.	108	9.2
Anopheles (Cellia)		92	7.9
	longirostris	25	2.1
	punctulatus	23	2.0
Mansonia (Mansonioides)		73	6.3
	septempunctata	51	4.4
	Total specimens recorded		1167

It is probable that these collections are biased by the heliotrophic tendency of the various species rather than their relative frequency in the collecting sites.

8. Larval collections.

(A) Classification.

The same classification is employed here as in Part I of this paper.

(B) Species ecotypes.

In Table 12 are summarised and analysed the data obtained from 1019 separate collections made at various times and sites. No record of the numbers of larvae collected was maintained and the following data include only a fraction of the routine larval collections aimed at the study of Anopheline larval densities in the

TABLE 12.

Species habitat summary. Figures show percentage of collections in given larval ecotypes. (Totals below 10 are summarised as "others". Species represented by less than 10 collections are not included.) New Guinea lowlands.

	Surface water						Containers						
	Natural			Artificial									
	Streams	Pools, Backwaters	Swamps	Drains	Transient pools	Brackish water	Tree holes	Plant axils	Coconuts	Bamboos	Nepenthes	Artificial containers	Others
SURFACE WATER													
Natural collections													
Bironella spp.	86												14
Natural & artificial													
An. bancroftii			53		31								16
C. squamosus	18	18		12	28								24
C. n. sp. nr. *vishnui*		12	12	12	52								12
U. argyrotarsis		15			65			10					10
C. fraudratrix gp.	10				54								36
C. annulirostris		10			57								33
Fresh or brackish													
An. annulipes		30		31		15							24
An. farauti			16		43	21							20
U. sp. indet. ? *tibialis* gp.			17		64	19							0
C. sitiens			12		24	37							27
An. subpictus		18				64							18
Artificial													
An. punctulatus					69								31
U. albescens				25	69								6
Aë. nocturnus					83								17
Aë. lineatus					71								29
Aë. parasimilis					93								7
Aë. (*Aë.*) sp. indet.					72								28
C. mimulus				13	71								16
C. pullus					56							14	30
Aë. aegypti				10								90	0
Aë. scutellaris					11		22		14			30	23
Armigeres spp.				17			33		17			21	12
C. halifaxii					32		22					27	19
C. quinquefasciatus					18							41	41

Table 12 (continued).

	Surface water						Containers						
	Natural			Artificial									
	Streams	Pools, Backwaters	Swamps	Drains	Transient pools	Brackish water	Tree holes	Plant axils	Coconuts	Bamboos	Nepenthes	Artificial containers	Others
CONTAINERS													
Natural													
Trip. filipes							30	10		10	50		0
Trip. fuscipleura								100					0
Trip. standfasti							17	58	17				8
H. leei								90					10
U. papua								64					36
Aë. kochi								86					14
Arm. brienli									79				21
C. brevipalpis							77						23
Natural & artificial													
Tox. inornatus							28	13		13		33	13
Trip. bimaculipes							74					14	12
Trip. elegans								90				10	0
Trip. bisquamatus gp.							15			37	28	10	10
U. diagonalis								50	17			17	16
U. nigerrima							23	18	23			18	18
Aë. notoscriptus							43					32	25
Aë. albolineatus							41			13		19	27
Aë. (*Steg.*) n. sp. nr. *gurneyi*							35			15		40	10
Arm. lacuum							40		30	10		20	0

Maprik area. It is, however, a relatively random sample of the available larval sites in the areas collected.

Altogether over 5000 batches including 112 species were collected.

The frequency with which collections were made in different types of site is shown in Table 13. The data in this table are discussed further below.

(C) *Larval associations.*

The species can be grouped roughly according to their general preference for surface water or container sites. These can be further divided into natural and artificial (see definition in Part I)

TABLE 13.

Frequencies of collecting in different types of larval ecotypes in lowland and highland areas (% of all collections).

Habitat	Lowlands		Highlands
	Peters	Based on Bick (1951)	Peters & Christian
Surface water, permanent or semi-permanent			
Natural	7.3	10.4	5.8
Artificial	4.0	2.0	20.9
Brackish water	6.5	8.1	–
Running water	4.1	3.9	–
Transient pools			
Artificial	25.9	26.1	70.2
Containers			
Natural	39.0	27.3	1.3
Artificial	13.2	21.9	1.8
Total number of sites recorded	1019	1508	14,630

and fresh or brackish water-containing. Roughly the same species groups recur in Table 14 in which the species associations of the commoner species are summarised.

An interesting feature of this table is the demonstration of the frequency with which individual species are found alone. The highest frequencies are found among the predaceous species such as *Armigeres* spp., certain of the "intermediate" group which occur commonly in artificial containers but also in surface water, such as *C. quinquefasciatus* and *Aë. (Steg.) aegypti* and *Uranotaenia* spp. such as *U. papua* which are found in natural containers.

9. Variations in population densities.

(A) Man-made factors.

By the time of writing, nature has gone far towards re-establishing a semblance of order and restoring the normal balance of mosquito species and population densities that was disturbed considerably in certain areas by the ravages of World War II. Modern insecticide campaigns which are based on widescale spraying of

TABLE 14. *Association indices of the various species. Totals under 5 have been summarised under "others".*

	Bironella spp.	*An. bancroftii*	*C. squamosus*	*C.* n. sp. nr. *vishnui*	*U. argyrotarsis*	*C. fraudratrix* gp.	*C. annulirostris*	*An. annulipes*	*An. farauti*	*U.*sp. indet.? *tibialis* gp.	*C. sitiens*	*An. subpictus*	*An. punctulatus*	*U. albescens*	*Aë. nocturnus*	*Aë. lineatus*	*Aë. parasimilis*	*Aë.* (*Aë.*) sp. indet.	*C. mimulus*	*C. pullus*
Bironella spp.	73												10							5
An. bancroftii		23		5		7			10	23										
C. squamosus			29	6		6	9			6									9	6
C. n. sp. nr. *vishnui*		9	6			24	6		6	9										6
U. argyrotarsis					25	5		5						8				5		16
C. fraudratrix gp.						20				9			7					7		9
C. annulirostris						5	18		15		8		6							9
An. annulipes					6	6		39	9			6	6							
An. farauti							10		28		10		15							
U. sp. indet.? *tibialis* gp.		8				10				61										
C. sitiens							11		23		20		10							
An. subpictus							15	10	25		15	10	10							
An. punctulatus						7	5		20		6		31							7
U. albescens					7	14	9		5	7			5	6						12
Aë. nocturnus						8			8						17				12	20
Aë. lineatus							13									21				7
Aë. parasimilis						11							11				20	27		13
Aë. (*Aë.*) sp. indet.						8											8	45		8
C. mimulus						6	6											6	33	15
C. pullus						9	6						5					7		24
Aë. aegypti						6								6						
C. quinquefasciatus											5									
Aë. scutellaris																				
Armigeres milnensis gp.																				
C. halifaxii						5														15
Trip. filipes																				
Trip. fuscipleura																				
Trip. standfasti																				
H. leei																				
U. papua																				
Aë. kochi																				
Arm. brienli																				5
C. brevipalpis																				
Tox. inornatus																				
Trip. bimaculipes																				
Trip. elegans																				
Trip. bisquamatus gp.																				
U. diagonalis																				
U. nigerrima																				
Aë. notoscriptus																				5
Aë. albolineatus																				
Aë. (*Steg.*) n. sp. nr. *gurneyi*																				6
Arm. lacuum																				

Read from left to right. New Guinea lowlands. (Species represented by less than 10 collections are not included).

Aë. aegypti	*C. quinquefasciatus*	*Aë. scutellaris*	*Armigeres milnensis* gp.	*C. halifaxii*	*Trip. filipes*	*Trip. fuscipleura*	*Trip. standfasti*	*H. leei*	*U. papua*	*Aë. kochi*	*Arm. brienli*	*C. brevipalpis*	*Tox. inornatus*	*Trip. bimaculipes*	*Trip. elegans*	*Trip. bisquamatus* gp.	*U. diagonalis*	*U. nigerrima*	*Aë. notoscriptus*	*Aë. albolineatus*	*Aë. (Steg.)* n. sp. nr. *gurneyi*	*Arm. lacuum*	Others
				5																			7
																							32
				6																			23
																							34
																							36
																							48
																							39
																							28
																							37
																							21
																							36
																							15
																							34
																							35
																							35
		10		7																			42
																							18
																							31
				6																			28
																							42
50	6	6																	11	6			9
	47																						48
		33																	6	8			53
			63															5					32
		5		22																			53
		5			0					5			5			33			5				47
						20		43	6	31													0
		10					9			7						7	23	7					37
						11		45		23						5							16
									50					6				6					38
		5				6		17		27													45
		11									27							5		5	5		37
												42		14									44
		5											41	11		10			5				28
		7										10	5	28		7				8			35
		8							8			8			68		8						0
													7	8		42							43
		10					17										28			5			40
		14	10													6		32					38
		15																	20	9			51
		14							8										8	13	8		49
		9		5															5	12	15		48
		17																			8	50	25

TABLE 15.

Influence of anti-Anopheline insecticide campaign on numbers and ratio of Anopheline and Culicine mosquitoes—Maprik area, Sepik District, April 1958—November 1960. Biannual DDT spraying.

(Numbers of mosquitoes captured in an outlet window trap attached to an unsprayed house—remaining houses first sprayed with DDT during first half of April 1959. "No. of inhabitants" = sum of nightly total of human inhabitants for the month.)

Date		*An. punctulatus*	Culicines	No. of inhabitants
1958	April	542	18	8
	May	585	185	32
	June	390	95	28
	July	500	63	30
	August	1906	13	27
	September	2043	34	30
	October	266	72	31
	November	1300	74	30
	December	1083	186	30
1959	January	1036	38	29
	February	1013	100	28
	March	739	42	28
	April	187	36	25
	May	45	192	28
	June	9	58	20
	July	6	203	25
	August	66	439	29
	September	246	407	30
	October	119	52	14
	November	0	1333	0
	December	0	1388	24
1960	January	11	1361	65
	February	0	528	31
	March	0	160	0
	April	3	225	32
	May	0	253	56
	June	2	933	40
	July	1	581	37
	August	19	134	34
	September	56	98	38
	October	29	129	48
	November	1	123	48

potent insecticides such as DDT are a new factor which may disturb this equilibrium.

Prior to residual spraying with Dieldrin against malaria vectors in the Maprik area, the commonest species of Culicines taken in window traps were *C. quinquefasciatus, C. annulirostris* and members of the *C. fraudratrix* group, all of which in that area breed in the same type of sites as those selected by the local Anophelines. There was little change in the proportions of these Culicine species following spraying but the proportions and numbers of Anophelines and Culicines changed greatly and there was an alarming increase in the population density of the latter.

The danger of this situation is clear when the potential vectorial capacity of such species as *C. annulirostris* for certain of the arbor viruses is realised.

(B) Natural.

i. Climate.

The same underlying principles as those mentioned in Part I can be applied to the relationship between climate and mosquito population density in other areas.

Total rainfall—changes in water table level.

Particularly susceptible are those species such as *M. uniformis* that depend on the flooding of alluvial plains for their major breeding areas. By the Sepik and Fly rivers *M. uniformis* is found in enormous numbers at the time when the level of the rivers is falling, leaving large areas of lagoon and swampland on each side.

Daily rainfall pattern.

This has been discussed in detail in Part I. In the Maprik area the species particularly affected by the daily rainfall pattern are *An. punctulatus, C. pullus* and *Aë. vexans nocturnus.*

Relative humidity.

It is doubtful whether seasonal variations in relative humidity play a significant part in the population density of any coastal or subcoastal mosquito species except around the particularly dry Port Moresby coastal strip.

Temperature.

The relatively constant and high temperature that prevails in the tropical coastal and subcoastal areas is such that the rate of development of the aquatic stages and hence the number of generations per year is at a maximum. However, the increased rate of development may be offset by the smaller size attained by the individuals.

Wind.

Wind direction is an important factor as regards adult population densities and distribution of such species as the brackish water breeding *Aë. vigilax* on the south Papuan coast. In the town of Port Moresby itself the biting rate during the NW monsoon reaches proportions that make this species a serious public health problem. With the onset of the SE monsoon vast numbers are carried out to sea where they perish and the population density decreases considerably. Its distribution extends along the chain of islands forming the Louisiade Archipelago east of Papua and is continued far to the east in the New Caledonia area. It is almost never found along the coast northwest beyond the Milne Bay area.

ii. Tidal variations.

In Wewak regular collections of Anophelines on human bait revealed a seasonal variation that is illustrated in Table 16.

The highest population densities of *An. farauti* (essentially a brackish water breeder in this area) appeared to coincide with a period shortly after the highest spring tides.

TABLE 16.

Monthly data collected at Wewak, Sepik coast, September 1956–June 1957 (Highest spring tide 19th December 1956.)

Date	Mean anopheline population density (Bites per man per night)	Rainfall (Inches)
1956 September	24.54	Not recorded
October	67.47	Not recorded
November	71.11	5.29
December	159.80	4.85
1957 January	78.27	1.80
February	76.30	3.23
March	Monthly mean 34.70 (March–June)	4.45
April		6.88
May		10.32
June		6.26

Total specimens recorded: *Anopheles farauti* 18,896; *An. punctulatus* 550; *An. koliensis* 749.

iii. Container sites.

Artificial containers in many coastal areas are readily available and the frequency with which collections were made from these is shown in Table 13. *C. quinquefasciatus* is a notorious breeder wherever rainwater is collected in tins and drums. Natural breeding sites, particularly coconut husks and shells and bamboos provide abundant breeding sites for such species as those of the *Aë. scutellaris* group, *Armigeres (Armigeres)* spp. and *Tripteroides* spp.

The other factors considered in Part I also play their respective roles in determining the variations and levels of mosquito population densities in the lower lying areas. Unfortunately almost no quantitative data is available on the population dynamics beyond that recorded by such workers as LAIRD (1956) and the exigencies of our own work prohibited the collection of such data during the present study.

10. Small islands and atolls.

The distribution of species of mosquitoes on a number of the New Guinea islands and atolls has been discussed above and is summarised in Table 6. Such localities are generally notable for the small number of species they support but no less for the presence of very localised species, especially those of the *Aë. scutellaris* group and the high population densities that some of the species attain. In the Mortlock and Tasman atolls for example *C. annulirostris* attains unbelievable adult densities that at times make life for the few inhabitants of these atolls almost intolerable. How such large numbers survive the enormous competition for food which must result from this population pressure is an interesting ecological problem which would repay further detailed study. It is interesting to record the presence on the Mortlock and Tasman atolls of *Aë. (Steg.) hebrideus* (which we originally misidentified as *Aë. scutellaris*). Presumably transported during human migrations, this species occurs also on Ontong Java, Nuguria and Wuvulu islands (BELKIN, 1962).

11. Endoparasites and exoparasites.

LAIRD (1956) has recorded a number of parasites from various species of mosquitoes in the southwest Pacific. During the course of the present studies several endoparasites were found but, unfortunately most were not preserved and identified. The species identified were *Plasmodium* spp. (*falciparum, vivax* and *malariae*) and *Wuchereria bancrofti.*

Unidentified were:
Mermethidae in *An. farauti* (Minj).
Coelomomyces in *An. punctulatus* and *An. farauti* (Maprik).
Metacercariae of *Plagiorchiidae* or *Lecithodendriidae* *(Trematoda)* in *An. punctulatus* (Maprik).

12. Comparison of highland and lowland fauna.

(A) Larval ecology.

It is evident that the physical conditions of topography, flora, and climate govern the distribution of mosquito species through their effects on insect ecology. Most species of mosquitoes have fairly restricted ecological niches with the exception of a few of the more adaptable groups which tend to occur in several distinct ecotypes.

BICK's and our own lowlands collections (Table 13) show a marked similarity in the frequency with which collections were made from different habitat types and the contrast between these and the highlands collections. In the lowlands nearly a half of all the collections were from container habitats. The wartime ones from artificial containers were almost twice as frequent as those found by the present writer but nevertheless even in recent times 13.2% of all collections were from artificial containers. This is a reflection of the frequency with which such containers are still to be found in lowland areas where such items as 44 gallon drums are still extensively used for the collection and storage of rain water. In the highlands only 1.8% of all collections were from artificial containers.

In recent collections 25.9% were made from transient artificial pools and 4.0% from ditches and drains in lowlands areas. By contrast, in the highlands 70.2% of all collections were from artificial transient pools and 20.9% from drains, ditches and other essentially artificial semi-permanent sites. This again emphasises the part played by man in the propagation of mosquitoes in the highlands.

(B) Adult ecology.

There is apparently little basic difference between the ecology of those species of mosquitoes found in common both in the highlands and lower lying areas other than factors such as longevity imposed by differences in the local climate. Much the same species are anthropophilic and endophilic e.g. the malaria-carrying Anophelines, *Mansonia* spp. and *C. quinquefasciatus*.

(C) Distribution.

IYENGAR (1960a) listed 253 species of mosquitoes in 40 subgenera for the whole Papuan faunistic zone of the South Pacific. To this number can be added about 14 new species in the highlands and about 21 in the other areas, bringing the total number of species to about 288. The New Guinea highlands can be regarded as a subzone lying within IYENGAR's "Papuan Zone". In our collection are 55 species in 21 subgenera from the highland subzone. An additional 8 species of which 5 are *Tripteroides* have been recorded in Netherlands New Guinea (see footnote to Table 1). The 15 subgenera not found in the highland subzone utilise fresh surface water (6), brackish surface water (5) and natural or artificial containers (4) as larval ecotypes.

No subgenera are found in the highlands that are not also found in lower areas (Table 6) but, on the other hand, apart from the subgenera that utilise brackish water, the following are completely absent from the highland subzone: *Bironella (Bironella), B. (Brugella), Toxorhynchites, Tripteroides (Tripteroides), Malaya, Hodgesia, Aëdes (Mucidus), Aë. (Macleaya), Aë. (Stegomyia), Aë. (Neomelanoconion), Armigeres* and *Culex (Neoculex).*

28 of the species we have found (plus a further 7 listed in the footnote to Table 1) are virtually endemic to the highland subzone. In a number of cases a common coastal species appears to be represented by an allied but different species in the highlands over about 5,000 feet, for example *C. pullus* and *C. bailyi, C. annulirostris* and *C. edwardsi, C.* n.sp. near *vishnui* and *C. pseudovishnui, C. fraudratrix* and *C. christiani* and *petersi.*

Another interesting feature is the predominance of *An. annulipes* in the highlands and its relative scarcity in lower areas except around Port Moresby. *C. bailyi* which almost entirely replaces *C. pullus* in the highlands is probably the same species as that described as *"C. pallidothorax"* by earlier writers.

MARKS (1960) has noted a relationship between the Oriental and Australasian species of *Culex (Culex)* with banded proboscis (group A of EDWARDS, 1924). Of the examples quoted above, all widely distributed freshwater breeders, *C. bailyi, edwardsi* and *pseudovishnui* are Oriental species whereas their coastal counterparts are also found in Australia.

Acknowledgements.

We are considerably indebted to the staff of the Malaria Control Pilot Project, Maprik, and Malaria Control School, Minj, members of the Department of Public Health and other government departments, the Australasian Petroleum Company, Dr. E. N. Marks, Mr. P. F. Mattingly, Mr. N. V. Dobrotworsky, Dr. D. Colless and other private individuals in New Guinea. This paper is published by kind permission of the Director, Department of Public Health, Territory of Papua and New Guinea.

Appendix.

Checklist of mosquito species forming the basis of the present paper. (This is *not* a complete checklist of the mosquitoes of New Guinea.) (A detailed distribution summary of the following species has been omitted for reasons of economy.) L = lowlands, H = highlands, * = Manuscript names in press, E. N. M. = Dr. E. N. Marks.

1. *Bironella (Bironella) bironelli* (Christophers) 1924 (L)
2. *B. (B.) confusa* Bonne-Wepster 1951 (L)
3. *B. (B.) soesiloi* (Strickland & Chaudhury) 1931 (L)

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4. *Bironella (Brugella)? travestita* (Brug) 1928 (L)

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5. *Anopheles (Anopheles) bancroftii* Giles 1902 (L H)
6. *A. (A.) papuensis* Dobrotworsky 1957 (H)
7. *A. (A.) pseudobarbirostris* Ludlow 1902 (L H)

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8. *Anopheles (Cellia) annulipes* Walker 1856 (L H)
9. *A. (C.) farauti* Laveran 1902 (L H)
10. *A. (C.) karwari* (James) 1903 (L)
11. *A. (C.) koliensis* Owen 1945 (L H)
12. *A. (C.) longirostris* Brug 1928 (L)
13. *A. (C.) punctulatus* Dönitz 1901 (L H)
14. *A. (C.) subpictus* Grassi 1899 (L)

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15. *Toxorhynchites (Toxorhynchites) inornatus* (Walker) 1865 (L)

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16. *Tripteroides (Tripteroides) alboscutellatus* Lee 1946 (L)
17. *T. (T.) bimaculipes* (Theobald) 1905 (L)
18. T. (T.) *binotatus* Belkin 1950 (L)
19. *T. (T.) elegans* Brug 1934 (L)
20. *T. (T.) lorengaui* Peters * (L)
21. *T. (T.) magnesianus* (Edwards) 1924 (L)
22. *T. (T.) nissanensis* Lee 1946 (L)
23. *T. (T.) novohanoverae* Peters * (L)
24. *T. (T.) quasiornatus* (Taylor) 1915 (L)

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25. *Tripteroides (Rachisoura) bisquamatus* Lee 1946 (L H)
26. *T. (R.) brevirhynchus* Brug 1934 (H)
27. *T. (R.) filipes* (Walker) 1861 (L H)
28. *T. (R.) flabelliger* Bonne-Wepster 1948 (H)
29. *T. (R.) fuscipleura* Lee 1946 (L)
30. *T. (R.) leei* Peters 1959 (L)
31. *T. (R.) longipalpatus* Lee 1946 (L)
32. *T. (R.) mathesoni* Belkin 1950 (L)
33. *T. (R.) pallidus* Lee 1946 (H)
34. *T. (R.) plumiger* Bonne-Wepster 1948 (L)
35. *T. (R.) stonei* Belkin 1950 (L)
36. *T. (R.) torokinae* Belkin 1950 (L)
37. *T. (R.) vanleeuweni* (Edwards) 1927 (L H)
38. *T. (R.) sp. 58* (E. N. M.) (H)

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39. *Tripteroides (Polylepidomyia) argenteiventris* (Theobald) 1905 (L)
40. *T. (P.) coheni* Belkin 1950 (L)
41. *T. (P.) microlepis* (Edwards) 1927 (H)
42. *T. (P.) sp. 57* (E.N.M.) (? = no. 41((H)

43. *T. (P.) perplexus* Peters * (L)
44. *T. (P.) solomonis* (Edwards) 1924 (L)
45. *T. (P.) standfasti* Peters 1959 (L)

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46. *Malaya leei* (Wharton) 1947 (L)

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47. *Ficalbia (Ficalbia) minima* (Theobald) 1901 (L)
48. *F. (F.)* n. sp. (H)

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49. *Ficalbia (Mimeteomyia) chamberlaini metallica* (Leicester) 1908 (L H)
50. *F. (M.) modesta* King & Hoogstraal 1946 (L)

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51. *Ficalbia (Eterleptiomyia) elegans* (Taylor) 1914 (L H)

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52. *Mansonia (Coquilletidia) crassipes* (Van der Wulp) 1881 (LH)
53. *M. (C.) giblini* (Taylor) 1914 (?H)
54. *M. (C.) ochracea* (Theobald) 1903 (L)
55. *M. (C.) xanthogaster* (Edwards) 1924 (L)
56. *M. (C.) lutea* Belkin 1962 (L)
57. *M. (C.)* near *linealis* (Skuse) 1889 (H)

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58. *Mansonia (Mansonioides) papuensis* (Taylor) 1914 (L)
59. *M. (M.) septempunctata* Theobald 1905 (L)
60. *M. (M.) uniformis* (Theobald) 1901 (L H)

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61. *Uranotaenia albescens* Taylor 1914 (L)
62. *U. albosternopleura* Peters * (L)
63. *U. amiensis* Peters * (L)
64. *U.* near *antennalis* Taylor 1919 (L)
65. *U. argyrotarsis* Leicester 1908 (L)
66. *U. atra* Theobald 1905 (L)
67. *U. barnesi* Belkin 1953 (L)
68. *U. diagonalis* Brug 1934 (L)
69. *U. fimbriata* King & Hoogstraal 1946 (L)
70. *U. hirsutifemora* Peters * (L)
71. *U. lateralis* Ludlow 1905 (L)
72. *U. moresbyi* Peters * (L)
73. *U. novaguinensis* Peters * (L)
74. *U. novaguinensis alticola* Peters * (H)
75. *U. papua* Brug 1924 (L)
76. *U. paralateralis* Peters * (L)
77. *U. paranovaguinensis* Peters * (L)
78. *U. quadrimaculata* Edwards 1929 (L)
79. *U. setosa* King & Hoogstraal 1946 (L)
80. *U. sexauri* Belkin 1953 (L)
81. *U. solomonis* Belkin 1953 (L)
82. *U. tibioclada* King & Hoogstraal 1946 (L)

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83. *Hodgesia cairnsensis* Taylor 1919 (L)
84. *H. quasisanguinae* Leicester 1908 (L)
85. *H. spoliata* Edwards 1923 (L)

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86. *Aëdomyia catastica* Knab 1909 (L H)

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87. *Aëdes (Mucidus) alternans* (Westwood) 1835 (L)
88. *Aë. (Muc.) aurantius chryso-gaster* (Taylor) 1927 (L)

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89. *Aë. (Ochlerotatus) inexpectatus* Bonne-Wepster 1948 (H)
90. *Aë. (Och.) vigilax* (Skuse) 1889 (L)
91. *Aë. (Och.) mcdonaldi* Belkin 1962 (L)

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92. *Aëdes (Finlaya) albilabris* Edwards 1925 (L)
93. *Aë. (Fin.)* near *alticola* Bonne-Wepster 1948 (H) = sp. 59 E. N. M.
94. *Aë. (Fin.) anggiensis* Bonne-Wepster 1937 (H)
95. *Aë. (Fin.) argenteitarsis* Brug 1932 (L)
96. *Aë. (Fin.) bougainvillensis* Marks 1947 (L)
97. *Aë. (Fin.)* near *candidoscutellum* Marks 1947 (L) (New Ireland)
98. *Aë. (Fin.) dobodurus* King & Hoogstraal 1946 (L)
99. *Aë. (Fin.) kochi* (Dönitz) 1901 (L)
100. *Aë. (Fin.) kochi* group, *A* (H)

101. *Aë. (Fin.) kochi* group, *B* (H)
102. *Aë. (Fin.) kochi* group, *C* (H)
103. *Aë. (Fin.) notoscriptus* (Skuse) 1889 (L H)
104. *Aë. (Fin.) novalbitarsis* King & Hoogstraal 1946 (H)
105. *Aë. (Fin.) papuensis* (Taylor) 1914 (L)
106. *Aë. (Fin.) papuensis* group, *A* (H)
107. *Aë. (Fin.) papuensis* group, *B* (H)
108. *Aë. (Fin.) solomonis* Stone & Bohart 1944 (L)
109. *Aë. (Fin.) stanleyi* Peters * (H)
110. *Aë. (Fin.) subalbitarsis* King & Hoogstraal 1946 (H)
111. *Aë. (Fin.) wallacei* Edwards 1926 (L)

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112. *Aëdes (Macleaya) tremulus* (Theobald) 1903 (L)

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113. *Aëdes (Skusea) dasyorrhus* King & Hoogstraal 1946 (L) [1]

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114. *Aëdes (Geoskusea)* near *becki* Belkin 1962 (L)
115. *Aë. (Geo.) perryi* Belkin 1962 (L)
116. *Aë. (Geo.) fimbripes* Edwards 1924 (L)
117. *Aë. (Geo.)* near *longiforceps* Edwards 1924 (L)

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118. *Aëdes (Rhinoskusea)* longi- *rostris* (Leicester) 1908 (L)

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119. *Aëdes (Stegomyia) aegypti* (Linnaeus) 1762 (L)
120. *Aë. (Steg.) albolineatus* (Theobald) 1904 (L)
121. *Aë. (Steg.) gurneyi* Stone & Bohart 1944 (L)
122. *Aë. (Steg.) quasiscutellaris* Farner & Bohart 1944 (L)
123. *Aë. (Steg.) scutellaris* (Walker) 1859 (L) [2]
124. *Aë. (Steg.)* (near *gurneyi*) n. sp. (L)

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125. *Aëdes (Aëdimorphus)* albo- *scutellatus* (Theobald) 1905 (L)
126. *Aë. (Aëdi.) vexans nocturnus* (Theobald) 1903 (L H)

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127. *Aëdes (Neomelanoconion) imprimens* (Walker) 1861 (L) [1]

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128. *Aëdes (Aëdes) carmenti* Edwards 1924 (L) [1]
129. *Aë. (Aë.) foliformis* King & Hoogstraal 1947 (L)
130. *Aë. (Aë.) funereus* (Theobald) 1903 (L H)
131. *Aë. (Aë.) lineatus* (Taylor) 1914 (L H)
132. *Aë. (Aë.) neomacrodixoa* King & Hoogstraal 1947 (L)
133. *Aë. (Aë.) parasimilis* King & Hoogstraal 1947 (L)
134. *Aë. (Aë.) reesi* King & Hoogstraal 1947 (L)
135. *Aë. (Aë.) sentanius* King & Hoogstraal 1947 (L)
136. *Aë. (Aë.) trispinatus* King & Hoogstraal 1947 (L)
137. *Aë. (Aë.)* sp. n. *A* (H)
138. *Aë. (Aë.)* sp. n. *B* (L) (Port Moresby)

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139. *Aëdes (Leptosomatomyia) aurimargo* Edwards 1922 (L)
140. *Aë. (Lept.) lateralis* Theobald 1905 (L)
141. *Aë. (Lept.)* near *variepictus* King & Hoogstraal 1946 (H)

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142. *Armigeres (Armigeres) brienli* (Taylor) 1914 (L)
143. *Arm. (Arm.) lacuum* Edwards 1922 (L)
144. *Arm. (Arm.) milnensis* Lee 1944 (L)
145. *Arm. (Arm.) papuensis* Peters 1962 (L)

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146. *Culex (Lutzia) halifaxii* Theobald 1903 (L H)

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[1] BELKIN (1962) has renamed subgenus *Skusea, Lorrainea; Neomelanoconion, Edwardsaëdes* and *Aëdes, Verrallina.*

[2] 123a. *Aë. (Steg.) hebrideus* Edwards 1926 (L).

147. *Culex (Neoculex) brevipalpis* (Giles) 1902 (L)
148. *C. (Neo.) caeruleus* King & Hoogstraal 1947 (L)
149. *C. (Neo.) crassistylus* Brug 1934 (L)

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150. *Culex (Lophoceraomyia) atracus* Colless 1960 (L)
151. *C. (Loph.) christiani* Colless 1960 (H)
152. *C. (Loph.) digoelensis* Brug 1932 (L)
153. *C. (Loph.) fraudratrix* (Theobald) 1905 (L)
154. *C. (Loph.) leei* King & Hoogstraal 1955 (L)
155. *C. (Loph.) ornatus* (Theobald) 1905 (L)
156. *C. (Loph.) petersi* Colless 1960 (H)
157. *C. (Loph.) pseudornatus* Colless 1960 (H)
158. *C. (Loph.)* n. sp. *A* (L) (Maprik)
159. *C. (Loph.)* n. sp. *B* (L) (Maprik and Lae)
160. *C. (Loph.) walakusi* Belkin 1962 (L)

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161. *Culex (Culiciomyia) bailyi* Barraud 1934 (H)
162. *C. (Culicio.) fragilis* Ludlow 1903 (L)
163. *C. (Culicio.) fuscicinctus* King & Hoogstraal 1946 (L)
164. *C. (Culicio.) nailoni* King & Hoogstraal 1946 (L)
165. *C. (Culicio.) papuensis* (Taylor) 1914 (L)
166. *C. (Culicio.) pullus* Theobald 1905 (L)
167. *C. (Culicio.) ruthae* Peters 1958 (L)

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168. *Culex (Acallyntrum) bicki* Stone & Penn 1947 (L)
169. *C. (Acall.) pallidiceps* (Theobald) 1905 (L)
170. *C. (Acall.)* n. sp. near *pallidiceps* (H)

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171. *Culex (Culex) annulirostris* Theobald 1901 (L)
172. *C. (C.) bitaeniorhynchus* Giles 1901 (L H)
173. *C. (C.) edwardsi* Barraud 1923 (H)
174. *C. (C.) mimulus* Edwards 1915 (L)
175. *C. (C.) miraculosus* Bonne-Wepster 1937 (H)
176. *C. (C.) pipiens quinquefasciatus* Say 1823 (L H)
177. *C. (C.) pseudovishnui* Colless 1957 (H)
178. *C. (C.) sinensis* Theobald 1903 (L)
179. *C. (C.) sitiens* Wiedemann 1828 (L)
180. *C. (C.) solitarius* Bonne-Wepster 1938 (H)
181. *C. (C.) squamosus* (Taylor) 1914 (L H)
182. *C. (C.) vicinus* (Taylor) 1916 (L)
183. *C. (C.)* n. sp. near *vishnui* Theobald 1901 (L)
184. *C. (C.) whitmorei* (Giles) 1904 (L H)

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Zusammenfassung.

Es wurden Untersuchungen über die Oekologie und Verbreitung von Stechmücken im Hochland von Neu-Guinea in einer Höhe von über 1500 m durchgeführt. Dabei wurden bei Anwendung verschiedener Fangmethoden 55 Arten (davon 14 unbeschrieben) gefunden, die 21 Untergattungen angehören.

Die wichtigsten Vertreter der menschenstechenden (anthropophilen) Arten waren *Anopheles farauti, An. punctulatus, Mansonia uniformis, Aëdes nocturnus* und *Culex quinquefasciatus* (= *C. fatigans).*

Die Populationsdichte der Imagines variiert je nach Jahreszeit, erreicht aber ein ausgesprochenes Maximum während der Hauptregenzeit, die etwa von Januar bis April dauert.

Eine Analyse von nach Fundorten gesammelten Larven ergab, daß die Mehrzahl der untersuchten Brutstätten (91,2%) aus halbpermanenten und vorübergehenden Wassertümpeln bestand, die bei landwirtschaftlichen und straßenbaulichen Tätigkeiten entstanden.

Die heterotypische Assoziation, also die Vergesellschaftung mehrerer Individuen *verschiedener* Arten, legt die Vermutung nahe, daß die Konkurrenz zwischen den Larven eine populationsdynamisch wichtige Rolle bei den in diesem Gebiet vorkommenden Oberflächenwasserarten spielt. Ferner zeigte es sich, daß natürliche Brutstätten, im Gegensatz zu den von Menschen geschaffenen, verhältnismäßig selten vorkommen.

Die Faktoren, die die Populationsdichte der verschiedenen Arten mitbestimmen, werden unter besonderer Berücksichtigung von *An. farauti* und der geographischen Ausbreitung der Malaria im Hochland besprochen.

Umfangreiche Sammlungen in einigen niedriger gelegenen Gebieten von Neu-Guinea lieferten nebst den auch im Hochland gefundenen Stechmücken noch 153 weitere Arten, die 36 Gattungen und Untergattungen angehören. Das Vorkommen der verschiedenen Mosquito-Arten nahm gegen den Norden und Osten des Festlandes ab.

Die durch Arthopoden verschleppten Krankheiten, die in gewissen Gegen-

den des Tieflandes vorkommen, werden wahrscheinlich durch die häufiger anzutreffenden anthropophilen Culicinae, wie z. B. *Culex annulirostris*, übertragen.

Die wichtigeren anthropophilen Arten waren mit den im Hochland gefundenen im großen und ganzen identisch. Hinzu kommen noch weitere Gattungen, wie *Armigeres* und *Aëdes (Stegomyia)*. Die Auswertung der an verschiedenen Stellen gesammelten Larven zeigte für die meisten Oberflächenwasserarten einen hohen Assoziationsindex. Wie im Hochland ist eine Zunahme der Stechmücken dort zu verzeichnen, wo der Mensch sich angesiedelt hat. Dies beruht aber weniger auf Eingriffen in das Land — ausgenommen in Kriegszeiten — als auf dem Aufstellen von Wasserbehältern aller Art.

Die Moskitofauna des Hochlandes läßt sich als eine «Hochland-Unterzone» der «Papua-Zone» klassieren. Mehrere Untergattungen des Tieflandes fehlen im Hochland. Dieses aber weist andererseits etwa 28 endemische Arten auf.

Im ganzen Land bearbeiteten die Autoren 185 Arten, die 36 Untergattungen angehörten. 35 dieser Arten waren noch nicht oder erst kürzlich beschrieben. Nahezu 500 000 Imagines und unzählige Larven bildeten die Grundlage dieser Studien, die im Zusammenhang mit der vom «Department of Public Health» geleiteten Malaria-Bekämpfungsaktion standen.

Résumé

Des recherches minutieuses sur l'écologie et la répartition des moustiques dans les montagnes de Nouvelle-Guinée (au-dessus de 5.000 pieds d'altitude), utilisant diverses méthodes, ont révélé un total de 55 espèces (dont 14 non décrites) appartenant à 21 sous-genres.

Les principales espèces qui s'attaquent à l'homme sont *Anopheles farauti*, *An. punctulatus*, *Mansonia uniformis*, *Aëdes nocturnus* et *Culex quinquefasciatus* (= *C. fatigans*).

Les densités de la population adulte varient selon les saisons ; il y a un maximum très net au moment de la principale saison des pluies, laquelle dure à peu près de janvier à avril.

Le groupement de récoltes de larves selon leurs écotype a montré que la grande majorité (91,2 %) des gîtes larvaires consistait en eaux de surface semi-permanentes et temporaires, résultant essentiellement de travaux d'agriculture ou de la construction de routes. L'indice d'association entre larves de différentes espèces permet de penser que la compétition entre celles-ci doit jouer un grand rôle dans la dynamique des populations pour les espèces des eaux de surface de cette région, et que les gîtes larvaires naturels sont relativement rares par rapport à ceux que crée l'activité de l'homme.

Les facteurs dont dépendent les densités de population des diverses espèces sont étudiés, notamment en ce qui concerne *An. farauti* et l'extension géographique du paludisme dans les montagnes.

D'abondantes récoltes faites dans un certain nombre de régions basses de Nouvelle-Guinée ont permis de constater la présence de 153 espèces, appartenant à 36 sous-genres, en plus des espèces également trouvées dans les montagnes. Le nombre d'espèces va en diminuant vers le nord et vers l'est de la Nouvelle-Guinée (« mainland »).

Les principales espèces anthropophiles des régions basses sont à peu près les mêmes que dans les montagnes, avec en outre les genres tels qu'*Armigeres* et *Aëdes (Stegomyia)*.

Les affections virales transmises par les arthropodes qu'on rencontre dans certaines zones des régions basses sont probablement transmises par les Culicines les plus abondants et anthropophiles, tels que *Culex annulirostris*.

Les récoltes de larves ont prouvé que pour la plupart des espèces d'eaux de surface l'indice d'association était très élevé. Comme dans les montagnes, les diverses activités humaines provoquent une augmentation des larves, mais ce phénomène est dû plutôt à l'abandon de récipients manufacturés qu'à une modification du pays (sauf en temps de guerre).

La faune des moustiques des montagnes peut être considérée comme appartenant à une « sous-zone montagneuse » de la « zone papoue ». Un certain nombre de sous-genres ne se trouvent pas dans les montagnes, où vivent par ailleurs quelque 28 espèces endémiques. Les auteurs ont étudié au total 185 espèces de tout le pays, dont environ 35 ont été décrites récemment ou sont nouvelles ; elles se répartissent entre 36 sous-genres. Le présent travail se fonde sur l'observation de près d'un demi-million d'imagines et d'innombrables larves, dans le cadre d'opérations extensives entreprises par le Départment de la Santé Publique pour venir à bout du paludisme.