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THE PHILIPPINE ANOPHELES OF THE ROSSI-LUDLOWI  
GROUP

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## THE PHILIPPINE ANOPHELES OF THE ROSSI-LUDLOWI GROUP<sup>1</sup>

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FOUR PLATES AND SIX TEXT FIGURES

### INTRODUCTION

Five species or subspecies belonging to this group (the *Pseudomyzomyia* group of the subgenus *Myzomyia* as defined by Christophers in 1924) are now known to occur in the Philippines. These consist of a local variety each of the species *Anopheles vagus* and *Anopheles subpictus* (*rossi*), two species that have previously been included under the name *ludlowi*, and *Anopheles parangensis*. The latter is known at present only from Min-

<sup>1</sup>The studies on which this paper is based were conducted with the support and under the auspices of the International Health Division of the Rockefeller Foundation, in coöperation with the Bureau of Science, the Philippine Health Service, and the United States Bureau of Entomology.

The author wishes to acknowledge his indebtedness especially to Dr. Victor G. Heiser, who arranged the present investigation of Philippine mosquitoes; to Mr. J. J. Mieldazis, whose familiarity with the territory and the breeding habits of the local *Anopheles* was of much assistance in the early part of the work; and to Mr. F. E. Baisas, who, under the writer's direct supervision, has reared and examined a large part of the mosquito material and who has made a majority of the camera-lucida drawings used as illustrations.

Some of the preliminary work on this and other groups was carried out during the first five months of 1929 and the study was resumed in November, 1930.

danao and the Celebes area but the others are generally prevalent in the Philippines and, with the possible exception of the fresh-water form of *A. ludlowi*, their near relatives are widely distributed in the Orient.

Although a great deal has been published on this group, the correct nomenclature of the Philippine species and their relationship to the forms occurring in other regions has not been satisfactorily settled. A special study of the local forms has therefore been made and comparative descriptions, with consideration of the taxonomic problems, are given in the present paper.<sup>2</sup>

The species described or discussed are shown in the following list:

- Anopheles ludlowi* Theobald (fresh-water *ludlowi*).
- Anopheles litoralis* sp. nov. (salt-water *ludlowi*).
- Anopheles sundaicus* Rodenwaldt (East Indian or Sunda Islands *ludlowi*).
- Anopheles flavescens* Swellengrebel.
- Anopheles hatorii* Koidzumi.
- Anopheles parangensis* Ludlow.
- Anopheles subpictus* var. *indefinitus* Ludlow.
- Anopheles subpictus* var. *malayensis* Hacker.

<sup>2</sup>Since this investigation was begun, a study of the group has been made by C. M. Urbino and a summary of his work has appeared in a bulletin of the Philippine Health Service. After the completion of the present article I find that his full manuscript has appeared in a local medical journal, *Rev. Fil. Med. y Farm.* 22 (1931) No. 5. It is unfortunate that the two studies were not better coordinated as a number of discrepancies have arisen, the most important of which is in the description of the leaflets of the mesosome of the male genitalia. The differences that I have given here and that have now been amply confirmed, were originally demonstrated to Mr. Urbino (for his personal information) following my preliminary work in 1929. From his published conclusions it is evident that some of his identifications, particularly of fresh-water *subpictus*, were at fault since the leaflets of the Philippine *subpictus* and *vagus* are not similar as stated by him. Other less important discrepancies have been noted as follows: (1) The average length given for the palmate hairs is greater than in my series, and it appears that the factor used in converting the ocular measurements to millimeters may have been incorrect. (2) The records of the occurrence of fringe spots between veins 5.2 and 6 are at variance, the only agreement being in fresh-water *ludlowi*. This spot also occurs in a fairly large proportion of my specimens of salt-water *ludlowi* (= *litoralis*) and I have not found it of value in distinguishing between the two species. (3) Several useful distinguishing characters in wing and leg markings are not included in the article.

*Anopheles formosaensis* II Tsuzuki.

*Anopheles subpictus* Grassi (type form).

*Anopheles subpictus* var. *indefinitus* from brackish water.

*Anopheles vagus* var. *limosus* var. nov.

At the beginning of the study in 1929, it was planned to collect and compare a large enough series of each of the commoner varieties to determine, if possible, the extent of normal variation, both in larval and adult characters. This was felt to be necessary on account of the close similarity between some of the forms and the confusion that has existed as to their relationship.

Larval breeding habits were also taken into account and, in order to become familiar with the distribution and preferred breeding places of the different species, nearly all of the collections were made in person, frequently accompanied by Mr. Mieldazis during the first four months of the work. When making the collections, the specimens from each breeding place were kept separated until identifications could be made so as to have exact records of their source and to determine the extent of association or lack of association of species.

Upon arrival at the laboratory, the fourth-stage larvæ were examined alive, counts of various hairs were recorded on a tabular form, and the specimens were then given an individual sub-number and isolated in small Petri dishes for rearing. Nearly all of the adults included in the study were from such identified and described larvæ. The cast larval skin from each individual was mounted and preserved under its proper number for reference purposes. Some of the characters are best observed in entire larvæ, but the cast skins have proven of value especially in checking the identification, in cases where some question arises later, and in looking up characters not originally noted.

The technic employed in the examination of the male genitalia differs somewhat from the usual methods. The leaflets of the mesosome (phallosome) have proven to be especially useful in the differentiation of certain members of this group, and in order to examine them under high magnification it is almost necessary to dissect off the mesosome, after the usual treatment of the genitalia with caustic soda, and to mount it under a separate cover glass. By this means the leaflets may be spread out and pressed down into one plane. If desired, the mesosome may also be split into two parts and the two halves separated in mounting so that the leaflets of one side do not overlies those

of the other. Care must be taken in the dissections that some of the leaflets are not broken off. Most of the specimens have been mounted in Gater's modification of Berlese's solution, which has a good index of refraction and with which the mesosome may be transferred directly from water.

The results of the present studies, combined with those of other workers, indicate with little question that the Philippine forms of this group are specifically distinct one from another. The recognition of Philippine varieties of the type forms of *vagus* and *subpictus* also appears warranted on the evidence available.

With reference to the use of a varietal as well as a specific name, the objection is sometimes made that the splitting of species does more to confuse than clarify the situation for the field worker. However, where the differences justify it, the practice is recognized as necessary for proper systematic treatment and, from the viewpoint of the field work, the use of varietal names is undoubtedly desirable in many cases if for no other reason than to indicate the affinities of the species and to call attention to the possibility of differences in habits. The lack of information on such differences, or the failure to recognize them, has resulted in considerable confusion as regards the connection of certain species with the transmission of malaria.

The group here dealt with is thought to be sufficiently well known so that the general characteristics may be omitted. The descriptive matter is therefore largely limited to comparative data. Tables have been added to show the occurrence of certain variable characters in the adults and larvæ and include some information not noted in the text.

Although some collecting of *Anopheles* has been done on islands other than Luzon, the comparative matter included here, with the exception of that pertaining to *Anopheles parangensis*, is restricted to Luzon material.

**ANOPHELES LUDLOWI** Theobald, 1903.

The two speckle-legged species that occur commonly on Luzon Island have been locally referred to in recent years under the names of salt-water and fresh-water *ludlowi*. Outside of the Philippines, it has not, I believe, been generally known that more than one species occur in the Islands and comparisons have been made sometimes with one and sometimes with the other of the two forms as representing typical *ludlowi*.

The original description of Theobald does not definitely show to which one of the two species the name should be applied and, according to Yamada (1925), the type specimen in the British Museum is now in poor condition. Nevertheless, the very definite statement by Miss Ludlow (1914) that the specimens on which the description was based were from an inland locality (Abra Province, Luzon), well removed from any salt-water source, would appear to settle the matter sufficiently clearly since, in numerous collections made by the members of the International Health Division and the Philippine Health Service, one of the forms has been found only in fresh-water breeding places associated with streams and the other only in salt-water ponds or pools near the coast.

Christophers (1924) called attention to the fact that the true *ludlowi* was not the species usually referred to as such but refrained from changing the name, in order to avoid confusion, and suggested that the fresh-water species be considered merely as *parangensis*. In the meantime, however, *parangensis* has been shown to be a distinct species and the East Indian form to differ from the type form. Since the latter, probably the most important member of the group, has now been renamed there is, of course, much less reason for arbitrarily retaining the name *ludlowi* to designate the salt-water species. Furthermore, it is probable that the strict application of the name would in any event be proposed sooner or later. After considerable thought, it has been decided to restrict the name to the fresh-water form in the present article and to propose a new name for the Philippine salt-water species.

The principal characters of *A. ludlowi*, based on a series of specimens from various fresh-water breeding places, are as follows:

*Female*.—Costal sector spot<sup>3</sup> of wings (Plate 1, fig. 1) invariably present in the material at hand; two white interruptions between this and the base of the wing; basal accessory dark spot without white scales on the anterior margin but a few white scales usually present over the bend near the extreme base of the wing; accessory sector spot on the subcostal vein present in about 40 per cent of the specimens, 44 per cent with three dark spots under the midcostal area, and 67 per cent with a dark patch of scales (sometimes only two or three) at the fork of vein 2; subapical dark costal spot forming from 29 to

<sup>3</sup>The terms used to designate the wing spots are shown in text fig. 1.

48 per cent of the area included in the costal measurement (see fig. 1), with an average of 37 per cent; vein 5.1 with an average of 35 per cent black to the total length of the branch; stem of vein 2 (measured from the supernumerary cross vein) about nine-tenths the length of the cell.

The fossa of the mesonotum (that is, the depressed lateral area in front of the suture) either bare of scales or with a few narrow ones similar to those on the dorsal surface—at most, one or two broad flat scales.

Legs, except for the white speckling, usually dark scaled ventrally as well as dorsally; white apical bands of mid tarsi usually slightly narrower than those on the hind feet; basal bands absent on the mid and hind feet or, if present, very indistinct.

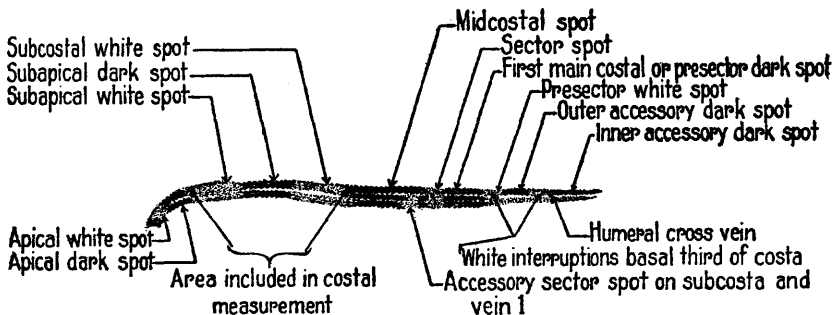


FIG. 1. Terms employed to designate the costal wing spots. Most of the names have been adapted from those used by S. R. Christophers and others.

Subapical black palpal band averages six-tenths the length of the apical white area; the latter frequently divided into two by an additional narrow band of black scales at the base of the apical segment.

*Male genitalia.*—Mesosome with three or four main leaflets (Plate 3, fig. 3, and Plate 4, fig. 3) on each side, the first one long, stout, widened near the base and S-shaped, with serrations on the outer edge of the lower curve; the next three or four leaflets also stout but progressively shorter, some of them also serrated. There are usually several short spikes at the base, or occasionally a longer slender leaflet. The long S-shaped leaflet averaged  $53 \mu$  in length in nine specimens, and the measurements for the next two in a typical group were 49 and  $30 \mu$ .

*Larva.*—Outer clypeal hairs more than half the length of inner; about three-fourths (77 per cent) of the outer occipital

hairs with four or more branches; anterior submedian thoracic hairs usually with more than nine branches each; thoracic palmate with an average of 3.6 hairlike branches; palmate of first abdominal segment with an average of 3.2 branches, not developed as leaflets (fig. 4, c); lateral hairs of abdominal segments IV to VI may or may not be irregularly branched but the first branches arise some distance from the base leaving a distinct "stalk" (fig. 5, f); the lateral hairs frequently 4-branched on

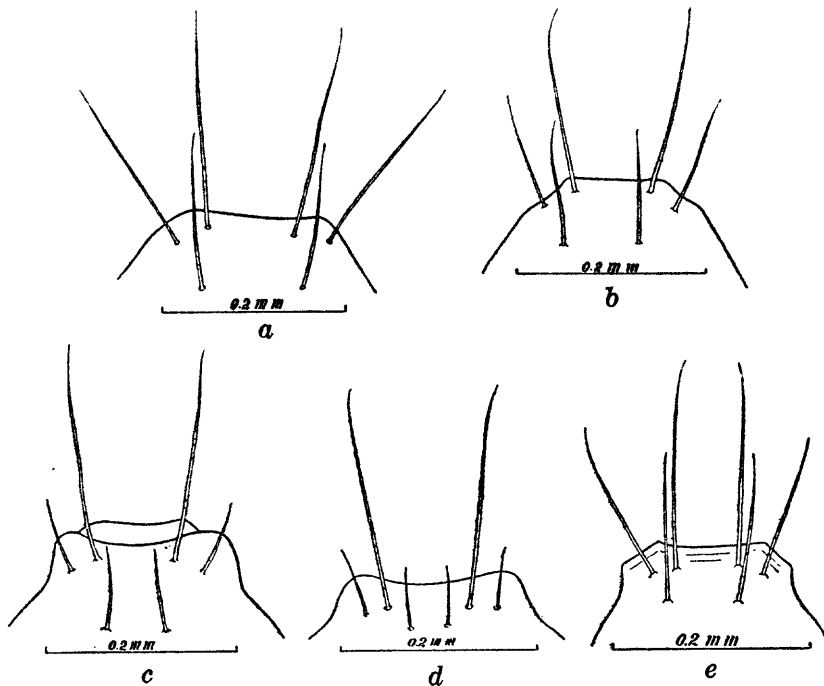


FIG. 2. Larval clypeal hairs; a, *Anopheles litoralis*; b, *Anopheles subpictus* var. *indefinitus* (also similar to *A. ludlowi*); c, *Anopheles vagus* var. *limosus*; d, *Anopheles vagus*, type form from Java; e, *Anopheles parangensis*.

segment IV and 3- or 4-branched on segments V and VI; pecten with short and long teeth of nearly equal length (fig. 6, c).

*ANOPHELES LITORALIS* sp. nov. (Salt-water *ludlowi*.)

*Female*.—Costal sector spot of wing incomplete or absent in about 30 per cent of the specimens (see Table 3 and Plate 1, fig. 2); basal third of costa with two or three white interruptions; basal accessory dark spot almost invariably with some white scaling on the anterior margin, sometimes completely interrupting the black (counted as one of the basal white spots

in the latter case); accessory sector white spot of subcostal vein present in 70 per cent of the specimens examined; vein 1 under the midcostal area with two dark spots, the basal one sometimes with only one or two dark scales separating the sector from the accessory sector spots; stem of vein 2 without a patch of dark scales at the fork, the only exceptions among eighty-eight specimens being two with one or two dark scales at this point and six in which the usual dark spot on the center of the stem extended nearly to the fork; subapical costal dark spot forming about 38 per cent of the costal measurement, with variations from 26 to 50 per cent; vein 5.1 with an average of 44 per cent black to total length; stem of vein 2 averaging about nine-tenths (0.88) the length of the cell.

Fossa of mesonotum with scattered broad flat scales, usually about six to ten in number.

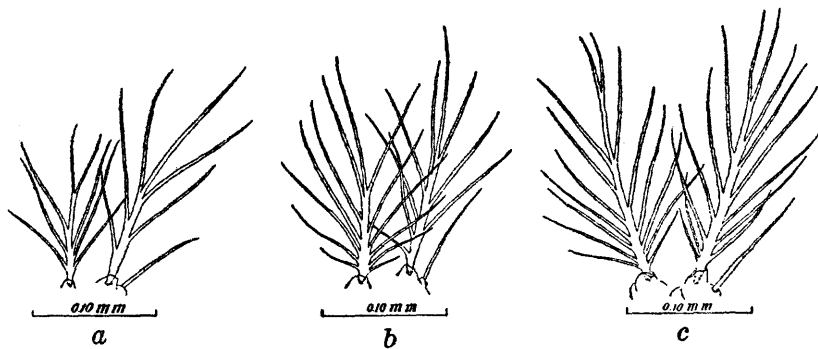


FIG. 3. Anterior submedian thoracic hairs; a, *Anopheles litoralis*; b, *Anopheles subpictus* var. *indefinitus* (also similar to *A. ludlowi* and *A. vagus* var. *limosus*; c, *Anopheles paranagensis*.

Legs well speckled but the white spots usually not quite so contrasting or so numerous as in *ludlowi*; ventral surface of legs, especially the mid and hind femora and tibiae and the fore tarsi, partly or almost completely yellowish scaled; segments 3 and 4 of the mid tarsi, frequently segment 2, with narrow though distinct basal white bands,<sup>4</sup> in addition to the apical bands of the preceding segment; segments 3 and 4 of hind legs often with very narrow basal bands also.

Palpal bands variable, the subapical black averaging slightly more than half (0.58) the length of the apical white; apical segment without an additional black band as observed in specimens of *ludlowi*.

<sup>4</sup> Noted by Yamada (1925) as differences between *A. hatorii* and what he took to be true *A. ludlowi* but were evidently the salt-water form.

*Male genitalia.*—Mesosome with from 8 to 14 leaflets on each side (Plate 3, fig. 1, and Plate 4, fig. 1), subequal in length except for short spikes at the base. In the ordinary mounts the leaflets are usually bunched so that the number and shape of the leaflets cannot be made out easily. When the mesosome is separated and mounted under a separate cover glass the longest leaflets and some of the others are found to be typically thin and flattened, with one side broadly rounded toward the tip and the other more or less straight and serrated. The longest leaflet,

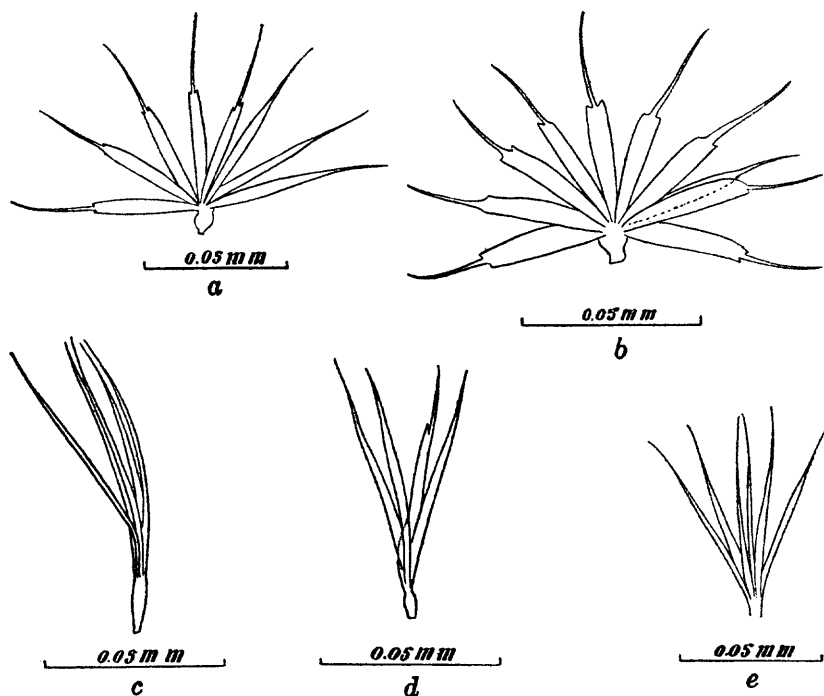


FIG. 4. Palmate hairs of first abdominal segment; a, *Anopheles subpictus* var. *indefinitus*; b, *Anopheles parangensis*; c, *Anopheles ludlowi*; d, *Anopheles vagus* var. *limosus*; e, *Anopheles litoralis*.

with an average length of about  $42 \mu$ , is much shorter than and differs in shape from that of either *ludlowi* or *vagus*. The leaflets are, however, similar to those of the Philippine *subpictus* except possibly for a slight difference in number and length.

*Larva.*—Clypeal hairs similar to those of *ludlowi* and *subpictus* except that the outer appear to be slightly longer (fig. 2, a); all clypeal hairs usually simple but occasionally forked or double;

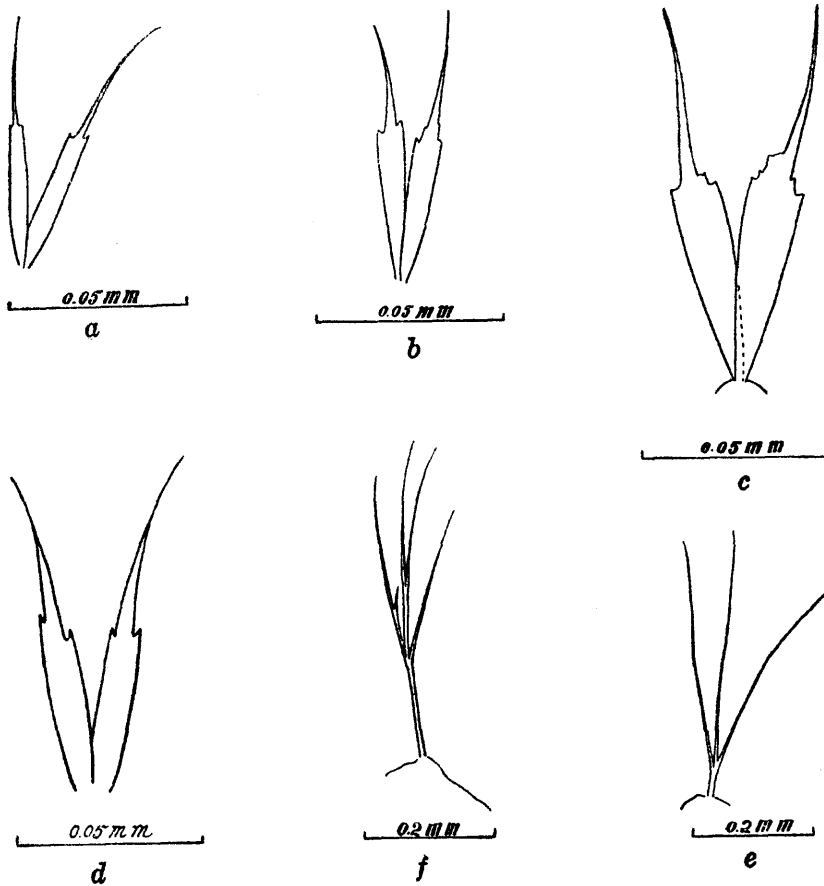


FIG. 5. Leaflets of palmate hairs from abdominal segment IV (a to d) and lateral hairs from same segment (e and f); a, *Anopheles litoralis*; b, *Anopheles vagus* var. *limosus*; c, *Anopheles parangensis*; d, *Anopheles subpictus* var. *indefinitus*; e, *Anopheles litoralis*, lateral hair; f, *Anopheles ludlowi*.

outer occipital hairs very seldom with more than three branches; anterior thoracic hairs (fig. 3, a) usually less than 9-branched;<sup>5</sup> thoracic palmate with three or two (average 2.3) hairlike branches; palmate I also undeveloped, with an average of 5.3 hairlike branches (fig. 4, e); leaflets of other palmates smaller

<sup>5</sup> Table 6 shows 91 per cent of the hairs with less than nine branches. However, in another series of larvæ recently examined (1931) only 62 per cent had less than nine and the average number was eight instead of less than seven in the previous series. There were four out of forty-seven larvæ in the second series in which all four hairs had more than eight branches.

than in *subpictus* (fig. 5, a); lateral hair of segments IV to VI usually 3-branched, the branches arising near the base, without an elongated stem as in *ludlowi* (fig. 5, e); antepalmate of segment VI 2- or 3-branched in about half (47 per cent) of the specimens; pecten with long and short teeth of nearly the same length (fig. 6, a).

*Type female*.—Rared from larva collected in a salt-water fishpond near Parañaque, Rizal, Luzon, December 24, 1930.

The form of branching of the lateral hairs is usually reliable for separating the larvæ of *ludlowi* and *litoralis*, while the num-

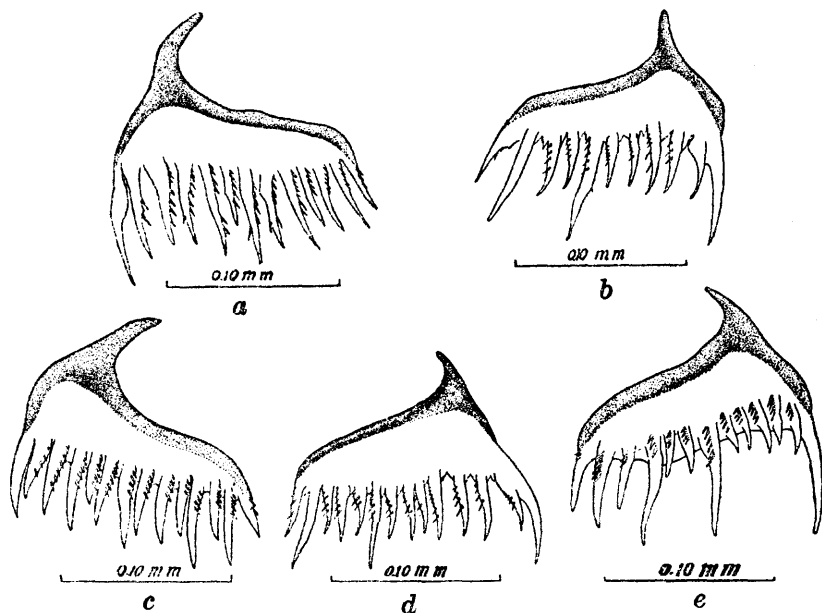


FIG. 6. Pectens of eighth abdominal segment; a, *Anopheles litoralis*; b, *Anopheles subpictus* var. *indefinitus*; c, *Anopheles ludlowi*; d, *Anopheles vagus* var. *limosus*; e, *Anopheles parangensis*.

ber of branches in the anterior thoracic hairs, the outer occipital hairs, the undeveloped thoracic palmate and palmate I, and the antepalmate hairs of segment VI may be useful for confirmation, especially in a series. The only species with which *litoralis* larvæ have been taken is the brackish-water breeding *subpictus*. The most useful characters for separating these two are the shape of the pectens and of the palmate hairs on segment I.

The first description of this form, under the name of *ludlowi*, appears to be that of Banks (1907) who described the male and

larva and gave an account of the life history. Although the characters given are not sufficient to recognize the species with certainty he states that the material was from salt-water sources.

Yamada appears to be the first to indicate specific differences in the markings of the two forms. (See remarks under *A. hatorii*.)

The breeding places of *litoralis* are discussed below in connection with those of *sundaicus*.

COMPARISON OF ANOPHELES LITORALIS AND LUDLOWI WITH  
ANOPHELES SUNDAICUS RODENWALDT, 1925

Although *litoralis* and *ludlowi* are almost certainly specifically distinct, their relation to the variety occurring in brackish-water fishponds in the Netherlands East Indies is not so clear. The East Indian form (described as *Myzomyia ludlowi* var. *sundaica*) was separated from the type species on the basis of the relative widths of certain spots on the female wing. The author gives the distribution of this variety as "The Major and Minor Sunda Islands from Roma to Sumatra, the peninsula of Malacca and surrounding islands and on the Andamans."

The specimens from the Philippines which he had for comparison were probably the true *ludlowi*. They were sent to him by Mr. Tiedeman, most of whose material was, I believe, obtained from fresh-water rivers in Pampanga Province, Luzon. The distinguishing wing characters, or at least the measurements, given by Rodenwaldt would apply almost equally well to either of the Philippine forms. In Table 1 are given comparative measurements for certain characters in *ludlowi*, *litoralis*, and a few specimens of what are presumably *sundaicus* from Singapore, obtained through the kindness of Dr. C. H. Yeager. It may be noted that the measurements of the costa and vein 5.1 agree fairly well with those given by Rodenwaldt. His averages for *sundaicus* (all specimens) were 56 per cent black in the costal measurement and 63.6 per cent black on vein 5.1, as compared with my averages of 57 and 58 per cent for the Singapore material; his averages for the Philippine *ludlowi* were 35 per cent and 31 per cent, respectively, as compared with my averages of 37 and 35 per cent for *ludlowi* and 38 and 44 per cent for *litoralis*. (Compare figs. 1, 2, and 3 of Plate 1 for the wings of the three species.)

An accessory sector white spot on the subcostal vein was found by Rodenwaldt only once in 150 specimens, while in my

TABLE 1.—Measurements of female palpal bands, wing spots, and vein 2.<sup>a</sup>  
(Speckle-legged species of *Anopheles* of the *Pseudomyzomyia* group.)

	<i>Anopheles</i> <i>litoralis</i> (Luzon).	<i>Anopheles</i> <i>ludlowi</i> <sup>b</sup> (Luzon).	<i>Anopheles</i> <i>sundaicus</i> (Singapore).	<i>Anopheles</i> <i>parangensis</i> (Mindanao).
Palpal apical bands:				
Number of measurements.....	46	25	12	11
Length of white plus dark.....mm..	0.43	0.34	0.45	0.37
Ratio of black to white.....	0.58	<sup>b</sup> 0.60	0.69	0.73
Variation in ratio.....	0.39-0.94	0.29-1.00	0.37-1.00	0.54-0.86
Costal spots (see text fig. 1):				
Number of measurements.....	46	25	22	11
Per cent of black.....	88	37	57	26
Variation in per cent of black.....	26-50	29-48	47-65	21-32
Vein 5.1:				
Number of measurements.....	44	24	17	-----
Per cent of black.....	44	35	58	-----
Variation in per cent of black.....	35-60	30-49	43-85	-----
Vein 2:				
Number of measurements.....	25	25	23	9
Length of cell (average).....mm..	0.68	0.66	0.82	0.75
Length of stem (to crossvein) .mm..	0.60	0.60	0.49	0.58
Ratio of stem to cell.....	0.88	0.90	0.58	0.77
Variation in ratio.....	0.76-1.05	0.74-1.00	0.54-0.68	0.73-0.82

<sup>a</sup> Measurements were made from one wing per specimen except in *sundaicus* and *parangensis*, in which both wings were measured in most of the specimens. The measurements were made with an ocular micrometer at magnifications of 57 and 24.

<sup>b</sup> Does not include the additional black band which occurs in some specimens of *ludlowi* at the base of the apical joint.

TABLE 2.—Measurements of palpal bands, wing spots, and vein 2. (Non-speckle-legged species of *Anopheles* of the *Pseudomyzomyia* group.)

	<i>Anopheles subpictus</i> var. <i>indefinitus</i> .		<i>Anopheles</i> <i>subpictus</i> (India).	<i>Anopheles</i> <i>vagus</i> var. <i>limosus</i> .
	Brackish water.	Fresh water.		
Palpal apical bands:				
Number of measurements.....	20	47	22	36
Average length.....mm..	0.36	0.34	0.45	0.33
Ratio of black to white.....	0.51	0.52	0.97	0.37
Variation in ratio.....	0.31-0.91	0.23-0.77	0.57-1.67	0.20-0.58
Costal spots:				
Number of measurements.....	20	20	21	20
Subapical white (length).....mm..	0.24	0.22	0.31	0.35
Subapical black.....mm..	0.42	0.40	0.35	0.28
Subcostal white.....mm..	0.19	0.19	0.38	0.40
Total length (average).....mm..	0.85	0.81	1.04	1.03
Per cent of black.....	49	48	34	27
Variation in per cent of black.....	37-65	38-57	24-42	16-37
Vein 5.1:				
Number of measurements.....	20	20	-----	19
Per cent of black.....	53	51	-----	44
Variation in per cent of black.....	44-61	39-75	-----	33-59

series it occurs in 74 out of 106 *litoralis* and in 17 out of 43 *ludlowi* (see Table 3). He states that three dark spots sometimes occur on vein 2.2, which has not been noted in the Philippine material. He also states that fringe spots between the veins are absent in *sundaicus* and this is true of all the Singapore specimens, while a light spot between veins 5.2 and 6

TABLE 3.—Variation in occurrence of spots on female wing.\* (Speckle-legged species of *Anopheles* of the *Pseudomyzomyia* group.)

	<i>Anopheles litoralis</i> .		<i>Anopheles ludlowi</i> .		<i>Anopheles sundaicus</i> .		<i>Anopheles parangensis</i> .	
	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
Specimens examined <sup>b</sup> .....	88-106		43-45		10-12		7	
White spots, basal third of costa:								
One.....	0		0		2		0	
Two.....	81		45		9		7	
Three.....	17	17	0	0	0	0	0	0
Sector spot on costa:								
Present.....	68		45		9		7	
Incomplete <sup>c</sup> .....	6	6	0	0	3	25	0	0
Absent.....	23	24	0	0	0	0	0	0
Accessory sector spot on subcosta:								
Present.....	74	70	17	40	0	0	7	100
Absent.....	32		26		12		0	
Accessory sector and sector spots on vein 1:								
Continuous.....	0	0	2	5	0	0	0	0
Slight black between <sup>d</sup> .....	27		7		2		3	
Separated.....	79		34		10		4	
Number dark spots on vein 1 under midcostal spot:								
One.....	0		2		0		0	
Two.....	106		23		12		7	
Three.....	0	0	20	44	0	0	0	0
Black spot at fork of vein 2:								
Absent.....	80	91	14	33	9	75	7	100
One to 3 dark scales.....	2		11		2		0	
Patch of scales.....	• 6		18		1		0	
Fringe spot between veins 5.2 and 6:								
Present.....	34	35	30	68	0	0	7	100
Absent.....	63		14		10		0	

\* Variations sometimes occur in the markings of the wings of the same specimens. The characters were recorded from one wing on the same side (left) unless this one was in poor condition for examination.

<sup>b</sup> Some specimens were rubbed and for this and other reasons the characters were not recorded from the same number of specimens in all cases.

<sup>c</sup> With dark scales on anterior side and white scales on posterior side of costal vein.

<sup>d</sup> One to three dark scales; counted as a dark spot in next tabulation.

<sup>e</sup> Central spot on stem extended to fork; not a separate patch of scales.

occurs in about one-third (35 per cent) of the Philippine *litoralis* and two-thirds (68 per cent) of the *ludlowi*.

In the Singapore specimens the basal black spot of the costa is without white scaling on the anterior margin as in *ludlowi* and the ventral scaling of the legs is also more like *ludlowi* than *litoralis*.

TABLE 4.—Variation in occurrence of spots on female wing. (Non-speckle-legged species.)

	<i>Anopheles subpictus</i> var. <i>indefinitus</i> .				<i>Anopheles subpictus</i> (India).		<i>Anopheles vagus</i> var. <i>limosus</i> .	
	Brackish water.		Fresh water.		Number.	Per cent.	Number.	Per cent.
	Number.	Per cent.	Number.	Per cent.				
Specimens examined.....	82-95		52-60		22		50-53	
White spots, basal third of costa:								
One spot.....	13	14	4	7	0	0	0	0
Two spots.....	82		56		* 8		50	
Three spots.....	0	0	0	0	14	64	0	0
Prehumeral white spot present.....	0		b 0		21	95	0	
Sector spot on costa:								
Present.....	88		53		21		49	
Incomplete.....	1	4	4	12	1	5	1	2
Absent.....	3		3					
Accessory sector on subcosta:								
Present.....	37	40	21	38	1	5	7	14
Absent.....	55		35		21		43	
Accessory sector and sector spots on vein 1:								
Continuous <sup>c</sup> .....	20	21	9	16	12	55	7	11
Slight black between.....	19		15		10		9	
Separated.....	56		34		0		37	
Presector dark spot on vein 1:								
Absent.....	0		0		4	55	7	68
Shortened.....	8	9	3	6	8		29	
Long <sup>d</sup> .....	78		50		10		17	
Fringe spot between veins 5.2 and 6:								
Present.....	12	13	13	25	19	90	27	54
Absent.....	80		39		2		23	

\* Prehumeral white spot absent in only one of these and the presector white spot absent in one. The others had one long spot, due to the absence of either the inner or outer accessory dark spots.

<sup>b</sup> Part of the *indefinitus* have white scales on the anterior edge of the costa near the base but not a complete white spot involving both sides of the vein.

<sup>c</sup> This is also the number with one dark spot on vein 1 under the midcostal spot except in one specimen of fresh-water *indefinitus* that had no dark spot.

<sup>d</sup> More than half the length of presector spot on costa.

A further important difference is found in the relative length of the forks and stem of vein 2. The ratio of the stem (measured from the supernumerary cross vein) to the posterior branch is 0.88 for *ludlowi*, 0.90 for *litoralis*, but only 0.58 for the Singapore *sundaicus* (see Table 1). Most of the illustrations of the wings of *sundaicus* given by Rodenwaldt also show the comparatively short stem.

The leaflets of the mesosome of the Singapore *sundaicus* are similar to those of *litoralis* and the Philippine *subpictus* so far as observed in the specimens examined, except for very slight differences in length of the longest leaflet, *sundaicus* being intermediate between these two species (Table 5).

The larvæ of the East Indian *ludlowi* and *subpictus* are said to be very similar except in the shape of the pecten, which Walch and Soesilo (1929) have recently used as a distinguishing character. Quite curiously their *ludlowi* type of pecten resembles the pectens of our *subpictus* (with short and long teeth of distinctly different length). If the character holds good it is also a distinction between *sundaicus* and *litoralis-ludlowi*.

In two mounted larval specimens from Singapore (loaned me by Doctor Yeager) both inner occipital hairs are bifid in each specimen (instead of the usual simple hair); the number of branches of the inner anterior thoracic hairs are 8-9 and 11-12 and in the middle hairs 11-10 and 13-14 (an average of 11 branches each); the antepalpmate hairs on segment VI are all simple. The pecten of one of these specimens is similar to our material and not as given by Walch and Soesilo. Unfortunately, a sufficient number of authentic *sundaicus* larvæ are not available for a detailed comparison.

On biological grounds the differences between *sundaicus* and *litoralis* appear to be quite marked in certain characteristics. Along the coast of the bay on both sides of Manila are considerable areas of salt-water fishponds with a very large output of *Anopheles litoralis*; but, so far as I am informed, no serious trouble from malaria has ever been experienced in the vicinity of these breeding places. On the other hand, the East Indian *ludlowi* (= *sundaicus*), as is well known, is considered to be the principal carrier of malaria in Java and other of the Sunda Islands.

The salt content of the water most favorable for breeding evidently differs also. The Philippine form is found in abundance in water having a salt content of sea water or higher and

may or may not occur in brackish-water pools nearby. We have found it entirely replaced by *subpictus* in slightly brackish pools. The fishponds examined during the dry season have shown a specific-gravity reading equivalent to from 3.1 to 3.6 per cent salt or about equal to that of sea water. Larvæ of *litoralis* have also been taken in large numbers in partially concentrated pools connected with salt evaporation beds and containing from 4.2 to 7.4 per cent salt.<sup>6</sup> In the highest concentration full-grown larvæ and pupæ were collected in algal mats and adults emerged normally from these specimens.

In comparison with these records, the East Indian form is reported to thrive best at a salt percentage from 1.2 to 1.8 and to disappear when the salt content goes above 3 per cent (Rodenwaldt and Essed, 1925, and van Breemen, 1930). The Java salt-water *subpictus* is said to breed at higher salt percentages and this is just the reverse of the habits of the Philippine forms since our salt-water *subpictus* is limited to brackish water.

In regard to the nomenclature of these species, the least confusing solution would probably be to designate both *litoralis* and *sundaicus* as varieties of *ludlowi*, as Rodenwaldt has done with *sundaicus*. This would not be consistent, however, in view of the fact that the genitalia of *ludlowi* (a character that Rodenwaldt did not consider) are distinct and the differences in the female and larva are at least of the same order as those separating *subpictus* and *vagus*.

The similarity in the leaflets of the mesosome of *litoralis* and *sundaicus* would indicate a closer relationship between these two but is not necessarily final since the case of the Philippine *subpictus* shows that even in this group the leaflets may be quite similar in distinct species and such similarity is known of course in other groups. On the other hand, the difference between the two forms in the relative length of the first forked cell and its stem is very possibly specific. For this reason it has not seemed desirable to designate *litoralis* as a variety of *sundaicus* until a

<sup>6</sup>The salt concentration was estimated in most cases from specific-gravity readings. The highest percentage determination (7.4) was checked with a standard specific-gravity spindle and several of the others were checked by chlorine titrations made for me by Mr. R. H. Aguilar, of the Bureau of Science. The percentages obtained by the two methods were very close, provided the specific-gravity readings were properly adjusted for the temperature at which the spindles were calibrated.

further comparative study of the latter can be made. Moreover, a slight question still exists as to the correct name of the Malasian form. Christophers (1924) made *Anopheles flavescens* Swellengrebel (1921) a synonym of *ludlowi* as he thought it probably only a flavescens form and not a true local variety. The species was described from a specimen or specimens taken at Soerabaja, Java, and so far as I can ascertain has not again been encountered. It was said to be intermediate between *ludlowi* (= *sundaicus*) and *immaculatus* and the only *ludlowi*-like character mentioned was the amount of black scaling on vein 5.1 (three-fourths dark below the cross vein). All dark scaling was said to be bleached and the legs entirely pale. Since the legs were not speckled perhaps it could be considered a synonym of *subpictus* and thus avoid the necessity of substituting the name for *sundaicus*.

Reference should also be made to *Anopheles hatorii* Koidzumi, the Formosan form, which Yamada (1925) considered to be distinct from *ludlowi* after comparison with material in the British Museum. It appears from his description, however, that the specimens examined there were probably the salt-water form and not the true *ludlowi*. He states that the type specimen was in poor condition and that the comparison was made with specimens subsequently sent to the museum and bearing the identification labels of Banks and Ludlow.

For *A. hatorii*, he describes three dark spots on vein 1 under the midcostal area, a spot of dark scales at the fork of vein 2 and the mid and hind tarsi without basal banding, which indicate *ludlowi*. The leaflets of the mesosome of a male specimen obtained from the United States National Museum and labeled "*A. hatorii*, E. Formosa, V-1918" are, I find, similar to those of *ludlowi*. The long leaflet on each side is stout and S-shaped with a length of 56  $\mu$ .

While the two forms might be geographical varieties, Yamada's detailed description does not show distinct differences on which to separate them.

**ANOPHELES PARANGENSIS** Ludlow, 1914.

This species was described from very much speckled specimens sent from Parang, Mindanao, one of the southern islands. Miss Ludlow stated that it had not been received from any other locality and her mosquito collection, now in the United States National Museum at Washington, contains only two type specimens.

On a recent collecting trip to Mindanao (March and April, 1931), *parangensis* larvæ were taken in a fresh-water pool near the coast in Oriental Misamis Province, and a few adult specimens were reared from these. The larvæ were associated with *A. pseudobarbistrotris* and *A. subpictus* var. *indefinitus* although the latter were somewhat differently distributed in the pool.

Rodenwaldt (1925 and 1926) has given a good description of the male, female, and larva from Celebes specimens. The description agrees very well with the Mindanao material with the possible exception of certain characters of the male genitalia, particularly the bulbous membrane with modified leaflets on the mesosome and the outer blunt spines on the harpagones noted in the Mindanao specimens. These were not mentioned by Rodenwaldt but may have been merely overlooked.

The principal characteristics of the species, based on the Mindanao material, are summarized below:

*Female*.—Sixth vein of wing (Plate 2, fig. 4) with three dark spots; <sup>7</sup> a wide fringe spot between veins 5.1 and 5.2 (in addition to the usual fringe spots at the tips of the longitudinal veins and between veins 5.2 and 6); subapical costal dark spot very short, averaging about one-fourth of the distal costal area and similar in this respect to the Philippine *vagus*; a prominent accessory sector spot on the subcosta in all specimens; two dark spots on vein 1 under midcostal spot, the end of the outer one even or nearly even with the distal end of the mid-costal spot; two white interruptions on basal third of costa and extreme base of costa usually white for a short distance.

Legs much speckled, the light scales forming distinct intermediate bands on the first three tarsal segments of the hind legs and usually one band in the middle of the 4th segment; tarsal segments of front legs broadly banded apically and basally; segments 1 to 4 of mid and hind tarsi with narrow apical bands and mid tarsal segments with a few basal white scales ventrally.

Palpi with the subapical dark band about three-fourths (0.73) the length of the apical white.

*Male genitalia*.—(Plate 3, fig. 5.) As noted by Rodenwaldt, who has described and figured the genitalia, these differ remarkably from the other species in the subgenus *Myzomyia*. The usual group of parabasal spines is absent and two unmodified

<sup>7</sup> The basal spot was said by Rodenwaldt to be lacking sometimes. Three dark spots on vein 6 occur very rarely in *A. ludlowi*.

hairs, one very long and one very short, occur in this area. On the inner face of the side piece near the basal ring is an expanded or spoon-shaped blade arising from a tubercle. Another short hair occurs near the base of the tubercle. In a freshly dissected specimen, examined before mounting, the spoon-shaped blade appears to be semimembranous toward the apex and the base is in the shape of a trough (Plate 3, fig. 5, *b*). It has hardly any resemblance to the stout spines found in the subgenus *Anopheles*. The principal lobe of the harpago (fig. 5, *c*) is extended into a fingerlike process bearing a flattened blade, split at the tip. A smaller outer lobe bears a short hair and a longer, stout, blunt spine, the latter double on each side in one of three specimens. The usual leaflets are lacking on the mesosome and in place of these a peculiar transparent bulbous membrane (not mentioned by Rodenwaldt) surrounds the end dorsally; that is, on the side toward the anal segment. Along each side of the membrane are a number of short, overlapping, modified leaflets, apparently fused basally. In fig. 5, *c*, Plate 3, the leaflets are shown in a single row, although after mounting and under higher magnification there appears to be a double layer of leaflets on each side.

*Larva*.—Clypeal hairs long and slender, usually simple (fig. 2, *e*); two specimens out of twenty-two with one of the inner hairs forked, one with an outer and one with a posterior hair forked;<sup>8</sup> anterior thoracic hairs more heavily branched than in *subpictus* or *ludlowi* with an average of fifteen or sixteen branches (fig. 3, *c*); thoracic palmate with an average of five hairlike branches; first abdominal palmate tuft typically developed, although small (fig. 4, *b*); those on the other segments unusually broad and often pigmented (fig. 5, *c*); tergal plates similar to *subpictus* (var. *indefinitus*), or slightly broader. Pecten (fig. 6, *e*) with about nine short and four long teeth, the short teeth at the lower end hardly more than one-third the length of the long teeth.

The long hairs in the pleural hair<sup>9</sup> group of the prothorax consist of two simple hairs and one feathered hair; the group on the mesothorax with one long simple hair and one sparsely

<sup>8</sup>The clypeal hairs of the Celebes specimens, especially the outer, appear to have more of a tendency toward branching. According to Rodenwaldt they are often bifurcated or may have from two to three side branches.

<sup>9</sup>The term used by Puri (1928) to designate the paired ventrolateral groups of hairs of the thorax, one pair on each of the three segments.

feathered; the mesothorax with two long feathered hairs. Basal tubercle on the pro- and mesothorax with a large sharp spine; a shorter one on the metathorax. Other larval characters are shown in table 6.

The larva of *parangensis* is closest to the Philippine form of *subpictus* in the characters generally employed for identification, but the two can usually be separated readily enough by the shape of the first palmate hairs and the anterior thoracic hairs, as stated by Rodenwaldt. A few specimens, however, were found to be intermediate and in these cases positive identifications could be made by the presence of feathered hairs in the pleural hair groups of the pro- and mesothorax. In *subpictus* (as well as *vagus* and *ludlowi*) one of the long hairs in each group may be 2- or 3-branched toward the tip, but none of the hairs in either group is feathered.

The differences in the larval and genitalic characters raise the question as to the affinities of this species. On the basis of the pleural hairs it would fall into Group II of Puri's classification, with *maculatus*, *philippinensis*, etc. (group *Neocellia* of Christophers), instead of Group III containing *subpictus*, *vagus*, and *ludlowi* (group *Pseudomyzomyia* of Christophers). The adults of *parangensis*, however, have narrow scales on the mesonotum and two or three large prosternal hairs, as in *Pseudomyzomyia*. Most of the other adult and larval characters are also typical of the group, and I think it probably correct to assume that it comes nearest to *Pseudomyzomyia*, in spite of the pleural hairs and the freakish male hypopygium.

**ANOPHELES SUBPICTUS var. INDEFINITUS** Ludlow 1904. (*Anopheles indefinitus*.)

It is somewhat unfortunate that the name *indefinitus* should have to be resurrected since it has been used in the literature to designate both *subpictus* and *vagus*. Nevertheless, a recent examination of the type material in the United States National Museum leaves little doubt that at least two of the four specimens bearing the type label are of the *subpictus* form; the other two are too badly damaged to be identified. In the two better specimens the palpal subapical black bands are from 0.6 to 0.8 as long as the apical white, while the subapical black costal spots of the wings are wider than the white spots on either side. Measurements of the two specimens made for me by Mr. C. T. Green gave 50 per cent and 47 per cent as the proportion of black in the total length of the three costal spots. These percentages fall outside the range of variability for *vagus* variety

(Table 2) but are very close to the average for the Philippine *subpictus* specimens. This confirms the synonymy previously given by Christophers (1916 and 1924).

Through the kindness of Maj. G. Covell who has sent me a good series of *subpictus* from Larkana, India, I have been able to compare the Philippine form with the type form. As noted in connection with the descriptions below, the differences in the palpal, wing, and especially the genitalic characters are of about the same order as those distinguishing the Philippine *subpictus* and *vagus*. While I believe that *indefinitus* is a distinct species and should be so treated, I have retained it as a variety for the present in order to avoid the confusion resulting from the previous misapplication of the name.

*Female (var. indefinitus from fresh water).*—Palpal bands variable (see Table 2), the subapical dark averages about one-half (0.52) the length of the apical white; subapical dark spot on costa of wing (Plate 2, fig. 2) as wide as and usually distinctly wider than the white spot on either side; subcostal white spot usually shorter than subapical white; dark presector spot on vein 1 usually more than half as wide as the costal spot above it; two, sometimes one, white interruptions on the basal third of the costa, formed by the humeral white spot which is invariably present and the presector white spot which is usually present; scattered white scales frequently occur along the anterior edge of the base of the costa but no specimens noted with a complete prehumeral white spot similar to that in the type form; fringe spot between veins 5.2 and 6 present in 25 per cent of the specimens. Hind tarsal segments with apical but not basal white banding; mid tarsi with narrow apical bands on segments 1 to 3 and usually with a few basal pale scales ventrally on segments 2 to 4.

Fore tarsi of male with a narrow though usually fairly distinct basal and apical band at tarsal joint 3-4.

*Male genitalia.*—Mesosome with from 6 to 13 leaflets on each side (Plate 3, fig. 2, and Plate 4, fig. 2), much shorter than in *vagus*<sup>10</sup> and with less difference in length between the indi-

<sup>10</sup> Not similar to those of *vagus* as stated by C. M. Urbino (see footnote 2). He also states that fresh-water *subpictus* as well as salt-water *ludlowi* and *vagus* have non-serrated leaflets and differ from salt-water *subpictus* in this respect. However, when properly mounted, serrated leaflets are to be seen in all of these forms.

vidual leaflets, as in *litoralis*; most of the leaflets flattened and bladelike, and with serrations on the straight side.

*Larva*.—Clypeal hairs (fig. 2, *b*) usually simple but occasionally forked (as occurs in nearly all species of this group), the outer and posterior hairs from one-half to three-fourths the length of the inner and the posterior extend about half their length beyond the base of the inner; thoracic palmate undeveloped; palmate of abdominal segment I (fig. 4, *a*) with an average of 7.6 leaflets, partly developed, the leaflets spread, somewhat broadened, and with a terminal filament; leaflets of other palmate tufts (fig. 5, *d*) usually wider and longer than in the Philippine *vagus* (noted by C. M. Urbino); ratio of filament to branch (leaflets of palmate IV) about 0.85, total length about 0.1 millimeter; lateral hairs of abdominal segment IV usually 3-branched, seldom two as in *vagus*; pecten (fig. 6, *b*) with four or five long teeth and eight or so short teeth, the latter about one-half the length of the former, especially on the lower end.

The Philippine species has sometimes been identified as *Anopheles subpictus* var. *malayensis* Hacker, 1921, a variety originally separated from the type form on the basis of a greater variability in the palpal banding. The two may be distinct but in any event the name *indefinitus* antedates this and should be applied to the local species.

I have recently had an opportunity to examine fourteen larvæ of var. *malayensis* from the Federated Malay States, for which I am indebted to Dr. A. N. Kingsbury and Mr. E. P. Hodge, of the Institute for Medical Research, Kuala Lumpur. Certain slight differences in comparison with *indefinitus* were observed, as follows:

Anterior submedian thoracic hairs somewhat more branched, the inner with an average of 17.5 branches compared with 13.2 in *indefinitus* and the middle hairs with an average of 15.8 compared with 12.2. The range for the inner was from 11 to 21 and for the middle hair, from 11 to 20. Palmate I more typically developed than in *indefinitus* and similar to *parangensis* in this respect; average number of leaflets 10.5 (range 8 to 13) compared with the average of 7.6 in *indefinitus*. The leaflets of palmate IV appear to be somewhat larger, with a total length of filament and blade of about 0.12 millimeter and the filament approximately equal to the blade in length.

Other larval characters are similar to those of *indefinitus* as given in Table 6 and the pecten has long and short teeth of distinctly different lengths.

The leaflets of the male mesosome, in two specimens, are more nearly similar to *indefinitus* than to the type form; the apical leaflet slightly longer (42  $\mu$  long) and narrower than in *indefinitus*.

Yamada (1925) considered both *indefinitus* and *vagus* to be synonymous with *Anopheles formosaensis II* Tsuzuki, 1902. The name *formosaensis*, however, is preoccupied and the combination "*formosaensis II*" appears to be invalid. Judging from some of the characters given by Yamada for the Formosan specimens it is probable that they were of the *indefinitus* type (as defined here), rather than *vagus*.<sup>11</sup> The characters that indicate *indefinitus* are: Subapical dark band on the female palpi from one-half to two-thirds the width of the apical white, subcostal white spot of the wing slightly shorter than the subapical dark spot, presector dark spot on vein 1 three-fifths the length of the costal spot above it and the basal dark spot on the costa (inner accessory dark spot) with white scales on the anterior margin. The banding of the hind tarsi may also indicate *indefinitus*, in which basal white bands are absent as noted by Yamada for *formosaensis II*. Their occurrence on *vagus*, however, is very irregular.

**ANOPHELES SUBPICTUS** Grassi, 1899. (Type form.)

The series of specimens from Larkana, Sind, India, furnished by Major Covell, show a number of differences from the Philippine material as follows: Palpal black bands wider, about equal in width to the apical white; subapical black costal spot of wing (Plate 2, fig. 3) shorter, usually less than the length of the white on either side; basal third of costa mostly white scaled, usually divided into three white areas consisting of presector, humeral, and prehumeral white spots, the latter sometimes continuous with the humeral spot. The prehumeral white spot is absent in only one of twenty-two specimens and the presector white spot absent in one. A fringe spot between veins 5.2 and 6 is present in all except two specimens and is sometimes continuous with the fringe spot opposite 5.2.

<sup>11</sup> Dönitz (1903, p. 234) thought that a specimen of *formosaensis II*, received from Tsuzuki, also had a greater likeness to *A. rossi* than to *A. vagus*.

TABLE 5.—Measurements of the longest leaflet of the mesosome in several species of *Anopheles*.<sup>a</sup>

Species.	Locality.	Number measured.	Average length (microns) and standard deviation.	Variation (microns).
<i>Anopheles litoralis</i> .....	Philippine Islands...	19	42 ± 1.0	31-47
<i>Anopheles ludlowi</i> .....	do.....	9	53 ± 1.7	47-64
<i>Anopheles sundaicus</i> .....	Singapore.....	5	39	37-42
<i>Anopheles subpictus</i> .....	India.....	7	57	51-59
<i>Anopheles subpictus</i> var. <i>indefinitus</i> :				
Brackish water.....	Philippine Islands...	18	36 ± 0.6	31-40
Fresh water.....	do.....	21	36 ± 0.7	28-40
<i>Anopheles vagus</i> .....	Java.....	3	72	71-75
<i>Anopheles vagus</i> var. <i>limosus</i> .....	Philippine Islands...	15	68 ± 1.0	61-75

<sup>a</sup> Measured with an ocular micrometer at a magnification of × 425.

*Male genitalia*.—The leaflets of the mesosome (Plate 4, fig. 5) are somewhat intermediate between *vagus* and *indefinitus* but nearer to those of *vagus*. The first leaflet is long, stout, and tapered, with an average length of 57  $\mu$  compared with 68  $\mu$  in the Philippine *vagus* and 36  $\mu$  in *indefinitus*. As shown by the illustration, it differs slightly in shape from that of *vagus* and quite decidedly from that of *indefinitus*. There may also be more short leaflets than in *vagus*. As in all the other members of the group some of the leaflets are serrated, the long one on the basal half. Although the two Philippine species are readily identified by the shape and length of the leaflets, I should expect more difficulty in distinguishing *vagus* from the type form of *subpictus*, except possibly by actual measurement.

#### ANOPHELES SUBPICTUS FROM BRACKISH WATER

In two places near Manila are certain brackish-water ponds in which *subpictus* type of larvæ giving rise to adults with unspotted legs can usually be found. The water in these ponds appears to be seep water or overflow water from nearby fishponds and salt beds, diluted by rain water, and there is considerable fluctuation in the salt content. Occasionally, a mixture of *subpictus* and *litoralis* larvæ have been taken in one of the ponds, but at other times "pure cultures" of *subpictus* larvæ occur in the brackish water and only *litoralis* larvæ just across a dike or embankment in more salty water.<sup>12</sup>

<sup>12</sup> These records apply to the dry season. During the rainy season the fishponds and salt ponds become much diluted. Breeding of *litoralis* appears to be reduced and that of *subpictus* becomes more general.

*Subpictus* larvæ have not as yet been taken in water with a salt content as high as sea water, the highest salt percentage recorded for them being 2.8. This was in a slowly drying pool and the larvæ were much less abundant than they had been three weeks previously when the water showed only 1.4 per cent salt.

In fresh-water breeding places *indefinitus* larvæ are found in association with one or more of several other common species such as *fuliginosus*, *barbistrotris*, or *ludlowi*. Its occurrence in pure cultures in a different type of breeding place therefore gives the impression of a possibly distinct biological race. In the present study the material from the two sources has been considered separately, and the comparative tabulation of larval and adult characters shows certain variations between the two forms, several of which are at least of statistical significance and others that might be so in larger series.

It may be noted in Table 4 that the fresh-water form gave a larger proportion of specimens with a fringe spot between veins 5.2 and 6 and a slightly larger proportion with incomplete or absent costal sector spots. Statistically significant differences (as shown by the relation to the standard deviation) were found in certain of the larval characters (Table 6) as follows:

Outer occipital hair; 32 per cent 5-branched in the salt-water larvæ compared with 48 per cent in the fresh-water larvæ—a difference of  $0.16 \pm 0.062$ .

Thoracic palmate hair; 71 per cent 3-branched compared with 38 per cent in the fresh-water larvæ—a difference of  $0.33 \pm 0.084$ .

Palmate I; 15 per cent with 5 or fewer branches compared with 3 per cent—a difference of  $0.12 \pm 0.032$ .

Antepalmate VII; 3 per cent 4-branched compared with 13 per cent—a difference of  $0.10 \pm 0.03$ .

The measurements of certain characters shown in Tables 2 and 5 are, however, almost identical and no decided characteristics that would justify their separation have as yet been noted. Variations somewhat comparable to those given above may sometimes occur in different broods or lots of what are clearly the same species.

**ANOPHELES VAGUS var. LIMOSUS var. nov.**

The separation of the Philippine form of this species as a variety of the type form from Java seems justified on the differences in the posterior clypeal hairs of the larvæ. The description and illustrations of Swellengrebel (1919) and others

show these hairs to be much closer together than the inner anterior clypeals and placed well forward on the clypeus. Two or three larval specimens recently received from Java through the kindness of Doctor Soesilo show this placement clearly. The illustration (fig. 2, *d*) was drawn from one of these. In variety *limosus* the postclypeal hairs arise much farther back and are nearly in line with or sometimes slightly closer together than the inner anterior clypeals. Sufficient material for a more detailed comparison of the larvæ or adults of the type form is not available at the present time.

*Female*.—Palpal black band narrower than in var. *indefinitus* in the majority of specimens but is variable and not by itself a dependable diagnostic character; proboscis without the white spot just back of the flabella that is said to occur in the type form; subapical black costal spot of wing (Plate 2, fig. 1) almost always shorter than one, usually both, of the adjoining white spots and frequently very much reduced, averaging only slightly more than one-fourth of the total area of the three spots; subcostal white spot usually as long as or longer than subapical white; accessory sector spot on subcosta sometimes present; sector spot and accessory sector spots on vein 1 continuous in 11 per cent of the specimens; presector black spot on vein 1 less than half as long as the costal spot above it in two-thirds (68 per cent) of the specimens, sometimes entirely absent, as compared with var. *indefinitus* in which this spot is very seldom less than half as long as the costal spot; two white basal costal interruptions present in all specimens; basal dark spot seldom with white scales on anterior margin; fringe spot between veins 5.2 and 6 in 54 per cent of the specimens.

Fore tarsi of male usually without a basal white band on segment 4 and sometimes without apical band on segment 3 (similar in this respect to the banding in the type form as shown by Rodenwaldt, 1922).

*Male genitalia*.—Leaflets of the mesosome (Plate 3, fig. 4, and Plate 4, fig. 4) differ in size and shape from any of the other Philippine species in this group but appear to be similar to those of the type form of *vagus* from Java and as described by Christophers (1915) for Indian specimens. The group on each side consists usually of four stout, straight leaflets, the first one very long, the others progressively much shorter. In addition there are usually one or two, sometimes more, short irregular spikes at the base and occasionally a longer slender leaflet. The longest leaflet averaged 68  $\mu$  in length and the

TABLE 6.—Comparative branching of larval hairs and measurements of palmate leaflets in several species of *Anopheles*.

	<i>Anopheles titorakis</i> .		<i>Anopheles ludlowi</i> .		<i>Anopheles parangensis</i> .		<i>Anopheles subpictus</i> var. <i>indefinitus</i> .				<i>Anopheles vagus</i> var. <i>limosus</i> .	
	Number.	Per-cent.	Number.	Per-cent.	Number.	Per-cent.	Brackish water.		Fresh water.		Number.	Per-cent.
							Number.	Per-cent.	Number.	Per-cent.		
Larval specimens examined <sup>a</sup> .....	129		99		22		68		66		96	
Inner occipital hair:												
Variation (in branching) <sup>b</sup> .....	1-3		1-3		1-2		1-4		1-3		1-3	
Usual.....	1	96	1	96	1	88	1	98	1	96	1	95
Outer occipital hair:												
Variation.....	1-5		2-7		3-5		3-6		3-7		3-9	
Usual.....	3-2	89	4-5-3	91	4-5-3	100	4	46	5	48	5	39
{ 3 or less	97		4 or more	77			5	32	4	31	6	36
Anterior thoracic hairs:												
Inner.....	2-11		8-16		12-20		7-16		9-16		10-18	
Average.....	6.7		12.3		16.7		11.5		13.2		13.4	
Usual.....	8 or less	91	10 or more	92	15 or more	85	9-14	88	10-15	88	11-17	92
Middle.....	2-10		8-14		12-19		6-15		9-16		9-17	
Average.....	6.0		10.1		15.4		11.3		12.2		12.4	
Usual.....	8 or less	91	9 or more	94	14 or more	84						
Thoracic "palmate" hair:												
Variation.....	1-4		2-5		3-7		2-5		2-5		1-6	
Average.....	2.3		3.6		5.0		3.2		3.7		2.9	
Usual.....	3-2	83	4-3	67			3	71	4	43	3	63
{ 3 or less	99		4 or more	52			4	19	3	38	2	25
Abdominal palmate, segment I:												
Variation.....	3-9		2-5		8-12		4-11		5-11		2-8	
Average.....	5.3		3.2		10.5		7.0		7.6		5.0	
Usual.....	5-6-4	77	3-4-2	93	11-10	68	7-8-6	72	8-7-6	74	5-6-4	80
{ 6 or more	43		5 or less	99			6 or more	85	6 or more	97	5 or less	71

Antepalpmate hairs:											
Segment II.....	2-5										
Usual.....	3	76	2-6	88	8-4	76	3-6	80	3-6	81	2-5
Segment III.....	2-4										
Usual.....	3	98	3-4	89	3	95	4-5	84	4-5	81	3
Segments IV and V.....	1-3										
Usual.....	1	98	1-2	99	1	100	3	96	1-2	99	3
Segment VI.....	1-3										
Usual.....	1	53	1-2	94	1-3	98	1-3	81	1-3	90	1
	2	34	1		1		1		1		2
Segment VII.....	2-5										
Usual.....	3	92	1-4	80	3-5	88	1-4	90	2-4	84	3
Lateral abdominal hairs:											
Segment IV.....	2-6										
Usual.....	3	85	3	50	2-4	95	3	87	3	85	2
Segments V and VI.....	2-5										
Usual.....	3	9	2-5	44	2-4	90	2-4	9	2-4	8	3
Measurements of leaflets of pal- mate IV:											
Number of measurements.....	50		50	74	3	90	3	83	3	88	3
Filament, average length.....mm.	0.036		0.031		30		50		50		50
Blade, average length.....mm.	0.039		0.035		0.053		0.047		0.047		0.023
Total, average length.....mm.	0.075		0.066		0.041		0.051		0.055		0.041
					0.094		0.098		0.102		0.064

<sup>a</sup> Both hairs in each pair were counted in the majority of specimens, except the anterior thoracic hairs and the thoracic palpmate hairs which were recorded for only a part of the specimens.

<sup>b</sup> Simple hairs indicated by figure "1."

measurements made of the four main leaflets in a typical group were 67-51-36-21  $\mu$ .

When the mesosome is separated from the hypopygium and mounted separately the leaflets frequently show fine serrations along the sides as in fig. 4, Plate 4. (See footnote 10.)

*Larva*.—Clypeal hairs (fig. 2, *c*) usually simple, sometimes forked, the outer short, about one-third the length of the inner; the posterior slightly longer than the outer and normally extend only a short distance beyond the base of the inner but not beyond the front margin of the clypeus; they are placed well back on the clypeus and are as widely or nearly as widely separated as the inner hairs. In the type form the posterior hairs are only about one-third their own length back of the inner and their bases are much closer together (fig. 2, *d*). Anterior submedian thoracic hairs and antepalpmate hairs of segments III, IV, and V similar to var. *indefinitus*; thoracic palpmate with an average of about three (2.9) hairlike branches; palpmate I with an average of five hairlike or slightly broadened branches (fig. 4, *d*); antepalpmate hairs of segment II usually 3-branched; those of segment VI usually 2- or 3-branched instead of simple as in other members of the group; about half (55 per cent) of the lateral abdominal hairs of segment IV 2-branched (instead of the normal three)—one or both of the hairs 2-branched in 74 per cent of the individual specimens; average ratio of filament to blade of the leaflets of palpmate IV about 0.56; leaflets (fig. 5, *b*) narrower than and about two-thirds (64 per cent) the total length of those in var. *indefinitus*; pecten with short and long teeth of distinctly different lengths (fig. 6, *d*).

*Type female*.—Reared from larva collected at Balintawak, Rizal, Luzon, January 15, 1929.

The typical breeding place of the species is a small muddy unshaded pool without aquatic vegetation.

*Summary of the principal distinguishing characters of the Philippine species of the Pseudomyzomyia group.*

#### ADULTS

- |   |    |
|---|----|
| 1. Legs speckled .....  | 2. |
| Legs not speckled .....   | 4. |
| 2. Female; sixth vein of wing with two dark spots, no pale fringe spot between forks of vein 5, subapical black costal spot of about the same length as the white areas on either side. |    |
| Male genitalia of normal <i>Myzomyia</i> type with a group of four or five spines in the parbasal area of the side piece.....   | 3. |

Vein 6 with three dark spots; pale fringe spot between forks of vein 5; subapical costal black spot very short.

Side piece of male genitalia without the normal group of parabasals; a long and a short unmodified hair in this area and internally a large spoon-shaped organ arising from a tubercle; mesosome with a bulbous membrane bearing modified leaflets; claspette (harpago) with a long fingerlike extension..... *A. parangensis*.

3. Sector spot of wing costa frequently absent or incomplete; basal dark spot of costa usually with white scaling on anterior margin, sometimes forming a complete prehumeral white spot; two dark spots on vein 1 under mid-costal area; vein 2 without a separate patch of dark scales at fork; legs usually yellowish scaled ventrally and segments 3 and 4 of mid tarsi, often segment 2, with narrow basal as well as apical pale bands. Fossa of mesonotum with scattered broad flat scales (about six to ten in number).

Mesosome with eight to fourteen leaflets, subequal in length, some of them flattened and blade-shaped, the longest about  $42\mu$ .... *A. litoralis*. Costal sector spot present; basal dark spot of costa without white scaling on anterior margin; three dark spots on vein 1 under the midcostal area and a dark patch of scales at fork of vein 2 frequently present; legs, except for speckling, mostly dark scaled ventrally as well as dorsally; segments of mid and hind tarsi usually without basal pale bands. Apical white palpal band frequently divided into two by an additional narrow black band at the base of the apical segment.

Mesosome with three or four main leaflets on each side besides a few short spikes; the first leaflet stout, S-shaped and broadest near base with prominent serrations, the next two or three leaflets progressively shorter; length of longest about  $53\mu$ ..... *A. ludlowi*.

4. Female wing with subapical costal black spot usually distinctly shorter than the white spots on either side, particularly the subcostal spot; presector dark spot on vein 1 usually less than half as long as the costal spot above, sometimes absent; costal dark spot at base of wing without white scales on anterior margin; preapical palpal black band narrow, averaging about one-third the length of the apical white.

Mesosome with four or five stout leaflets and one or more short spikes on each side; the first leaflet straight and very long, the next three or four progressively shorter; length of long leaflet about  $68\mu$ .

*A. vagus* var. *limosus*.

Subapical costal black spot usually as long as or longer than the white spot on either side; presector dark spot on vein 1 usually more than half the length of the costal spot above costal dark spot at base of wing often with white scaling on anterior margin; preapical palpal black band averaging about one-half the length of the apical white.

Mesosome with six to thirteen leaflets on each side, short and similar to *litoralis* in shape; length of longest about  $36\mu$ .

*A. subpictus* var. *indefinitus*.

## LARVÆ

1. Outer clypeal hairs one-half or more, the length of the inner..... 2.  
Outer clypeal hairs short, about one-third the length of the inner; palmate of first abdominal segment hairlike; one or both lateral hairs of segment IV 2-branched and antepalmate hair of segment VI, 2- or 3-branched in many of the specimens; pecten usually with short and long teeth of distinctly different lengths.  
*A. vagus* var. *limosus*.
2. Palmate of segment I with more- or less-developed leaflets terminating in filaments; short teeth of pecten usually about one-half, or less, the length of the long teeth..... 3.  
Palmate I hairlike or, if the hairs are slightly broadened, without differentiated filaments; short and long teeth of pecten of about the same length ..... 4.
3. Palmate I usually not fully developed; anterior thoracic hairs usually with less than fifteen branches; pleural hair groups on pro- and mesothorax without feathered hairs..... *A. subpictus* var. *indefinitus*.  
Palmate I small but typically developed; anterior thoracic hairs usually with fifteen or more branches; pleural hair groups on pro- and mesothorax each with one feathered hair..... *A. parangensis*.
4. Lateral hairs of abdominal segments IV to VI with the first branches arising some distance from the base, the hair on segment IV frequently 4-branched. In the majority of specimens the outer occipital hair has four or more branches, the anterior thoracic hair more than nine branches and the antepalmate hair of segment VI is simple ..... *A. ludlowi*.  
Lateral hairs of abdominal segments IV to VI branched near the base, usually with three branches. The outer occipital hair has less than four branches and the anterior thoracic hairs less than nine branches in the majority of specimens while the antepalmate hair of segment VI is bi- or tri-fid about half the time..... *A. litoralis*.

## GENERAL SUMMARY

Five anopheline species of the *Pseudomyzomyia* group, commonly referred to as the *rossi-ludlowi* group, occur in the Philippines. Their principal distinguishing characters are given, together with comparative observations on related species and the conclusions reached in regard to questions of nomenclature.

Two speckle-legged forms that have formerly been included under the name *Anopheles ludlowi* Theobald, are shown to be specifically distinct and to differ from the important East Indian species, *Anopheles sunndaicus* (also called *ludlowi*). The name *ludlowi* is restricted to the form that, in the Philippines, appears to breed exclusively in fresh water and a new name, *Anopheles litoralis*, is proposed for the local salt-water breeder.

The leaflets of the mesosome of *A. ludlowi* are distinct from those of the other members of the group, while the leaflets of *sundaicus* and *litoralis* (as well as the Philippine *subpictus*) are more nearly alike. *Anopheles sunndaicus* differs from both *ludlowi* and *litoralis* in the relative lengths of the stem and forks of wing vein 2, and, as shown by Rodenwaldt for *ludlowi*, in the proportion of black- to white-scaled areas on the costa and vein 5.1, as well as in certain other wing markings.

Although *sundaicus* is an important carrier of malaria in Java and elsewhere, the salt-water form in the Philippines is not known to be of any importance in this respect. These two species evidently differ also in regard to the concentration of salt required to produce the most favorable breeding conditions. *Anopheles sunndaicus* is said to thrive best in water containing less than 2 per cent salt, while *litoralis* is found breeding most prolifically in water of about the salinity of sea water (from 3 to 4 per cent) or higher. They have been collected in water containing as high as 7.4 per cent salt (about 27 per cent of saturation).

The Philippine form of *Anopheles subpictus* Grassi differs from the type form from India in the leaflets of the mesosome as well as in certain wing characters. While the evidence indicates that it is a distinct species, it is retained for the present as a variety, *Anopheles subpictus* var. *indefinitus* Ludlow, to avoid the confusion that might otherwise arise due to the previous misapplication of the name to *Anopheles vagus*.

Larvæ of var. *indefinitus* are found in brackish as well as fresh water. Although minor variations occur in material from the two sources, no distinctive differences sufficient to justify their separation have been observed.

The Philippine form of *Anopheles vagus* is separable from the East Indian type form on the position of the posterior clypeal hairs of the larva. It is therefore described under a new varietal name, *A. vagus* var. *limosus*. The leaflets of the mesosome of this variety are distinct from those of the other Philippine species.

*Anopheles parangensis*, a very much speckled species with a southern distribution, differs from the other members of the group, especially in the thoracic pleural hairs of the larva and in the male genitalia. The latter, as shown by Rodenwaldt, are unique in that they lack the typical parabasal spines but possess

a large spoon-shaped organ on the side pieces and a fingerlike extension of the claspettes (harpagones). A peculiar membrane with modified leaflets, that has not previously been described, is found to be attached to the mesosome.

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## ERRATA

In a previous article on the "Philippine varieties of *Anopheles gigas* and *Anopheles lindesayi*," Philip. Journ. Sci. 46 (1931) 751-757, the figure numbers for the illustrations of the leaflets of the mesosome (Plate 2) have been reversed. As now numbered, fig. 3 should read "*Anopheles lindesayi* var. *benguetensis*" and fig. 4, "*Anopheles gigas* var. *formosus*."

For "antipalmate" on pp. 752 and 755 read antepalmate.

Attention may also be called to the fact that, in the illustrations of the wings of the two species, some of the white spots have not been reproduced clearly, especially the fringe spot between veins 5.2 and 6 in fig. 1 (var. *formosus*), the long white spot on the apical half of vein 6 and the small spot in the center of vein 2.1. Vein 5.2, which appears to be somewhat pale is actually dark.

In fig. 2 (var. *benguetensis*) all of the white spots with the exception of the fringe spots at the ends of veins 4.2 and 6 are considerably more contrasting in the original than they appear in the illustration.



## ILLUSTRATIONS

### PLATE 1. FEMALE WINGS

- FIG. 1. *Anopheles ludlowi*, with costa of another specimen showing two spots on vein 1 under the midcostal spot and an accessory sector spot on the subcosta.
2. *Anopheles litoralis*, with costa of another specimen showing an accessory sector spot on the subcosta, a complete sector spot and a patch of white scales on the anterior margin of the basal black spot.
  3. *Anopheles sundaicus*.

### PLATE 2. FEMALE WINGS

- FIG. 1. *Anopheles vagus* var. *limosus*, with costa of another specimen showing a very short subapical dark spot, one dark spot on vein 1 under the midcosta, and a short presector dark spot on vein 1.
2. *Anopheles subpictus* var. *indefinitus*.
  3. *Anopheles subpictus*; type form from India. (This specimen lacks the fringe spot usually present between veins 5.2 and 6.)
  4. *Anopheles parangensis*.

### PLATE 3

- FIG. 1. *Anopheles litoralis*; leaflets of mesosome (ædeagus).
2. *Anopheles subpictus* var. *indefinitus*; leaflets of mesosome.
  3. *Anopheles ludlowi*; leaflets of mesosome, showing on the right side the typical shape of the long leaflet.
  4. *Anopheles vagus* var. *limosus*; leaflets of mesosome.
  5. *Anopheles parangensis*; a, base of side piece; b, expanded organ on the side piece, drawn from an unmounted specimen; c, mesosome and claspette.

### PLATE 4

Leaflets from one side of mesosome, at higher magnification, to show shape and serrations. (Originally drawn at a magnification of  $\times 2,500$ .)

- FIG. 1. *Anopheles litoralis*.
2. *Anopheles subpictus* var. *indefinitus*.
  3. *Anopheles ludlowi*.
  4. *Anopheles vagus* var. *limosus*.
  5. *Anopheles subpictus*; type form from India.

## TEXT FIGURES

- FIG. 1. Terms employed to designate the costal wing spots. Most of the names have been adapted from those used by S. R. Christophers and others.
2. Larval clypeal hairs; *a*, *Anopheles litoralis*; *b*, *Anopheles subpictus* var. *indefinitus* (also similar to *A. ludlowi*); *c*, *Anopheles vagus* var. *limosus*; *d*, *Anopheles vagus*, type form from Java; *e*, *Anopheles parangensis*.
  3. Anterior submedian thoracic hairs; *a*, *Anopheles litoralis*; *b*, *Anopheles subpictus* var. *indefinitus* (also similar to *A. ludlowi* and *A. vagus* var. *limosus*); *c*, *Anopheles parangensis*.
  4. Palmate hairs of first abdominal segment; *a*, *Anopheles subpictus* var. *indefinitus*; *b*, *Anopheles parangensis*; *c*, *Anopheles ludlowi*; *d*, *Anopheles vagus* var. *limosus*; *e*, *Anopheles litoralis*.
  5. Leaflets of palmate hairs from abdominal segment IV (*a* to *d*) and lateral hairs from same segment (*e* and *f*); *a*, *Anopheles litoralis*; *b*, *Anopheles vagus* var. *limosus*; *c*, *Anopheles parangensis*; *d*, *Anopheles subpictus* var. *indefinitus*; *e*, *Anopheles litoralis*, lateral hair; *f*, *Anopheles ludlowi*.
  6. Pectens of eighth abdominal segment; *a*, *Anopheles litoralis*; *b*, *Anopheles subpictus* var. *indefinitus*; *c*, *Anopheles ludlowi*; *d*, *Anopheles vagus* var. *limosus*; *e*, *Anopheles parangensis*.

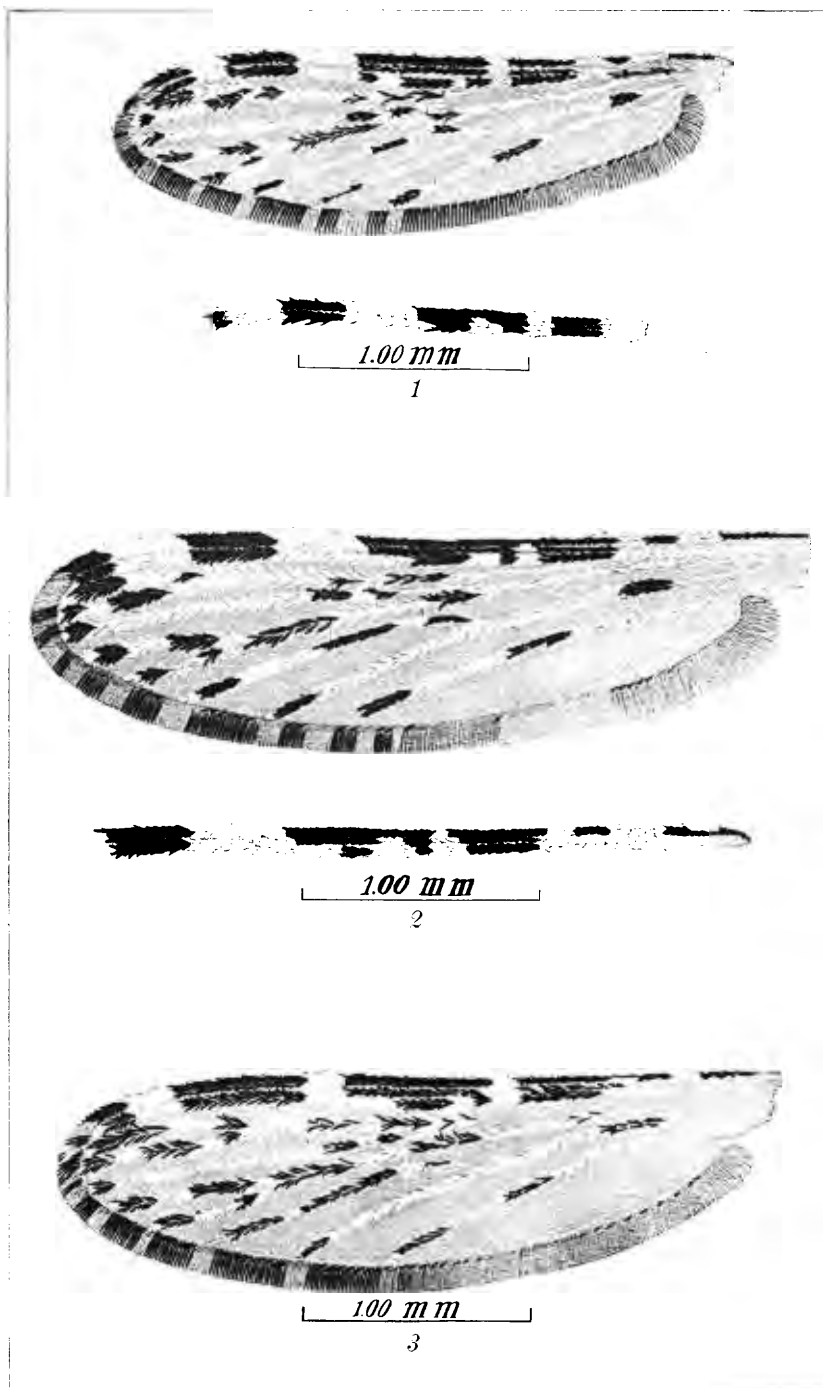


PLATE 1.

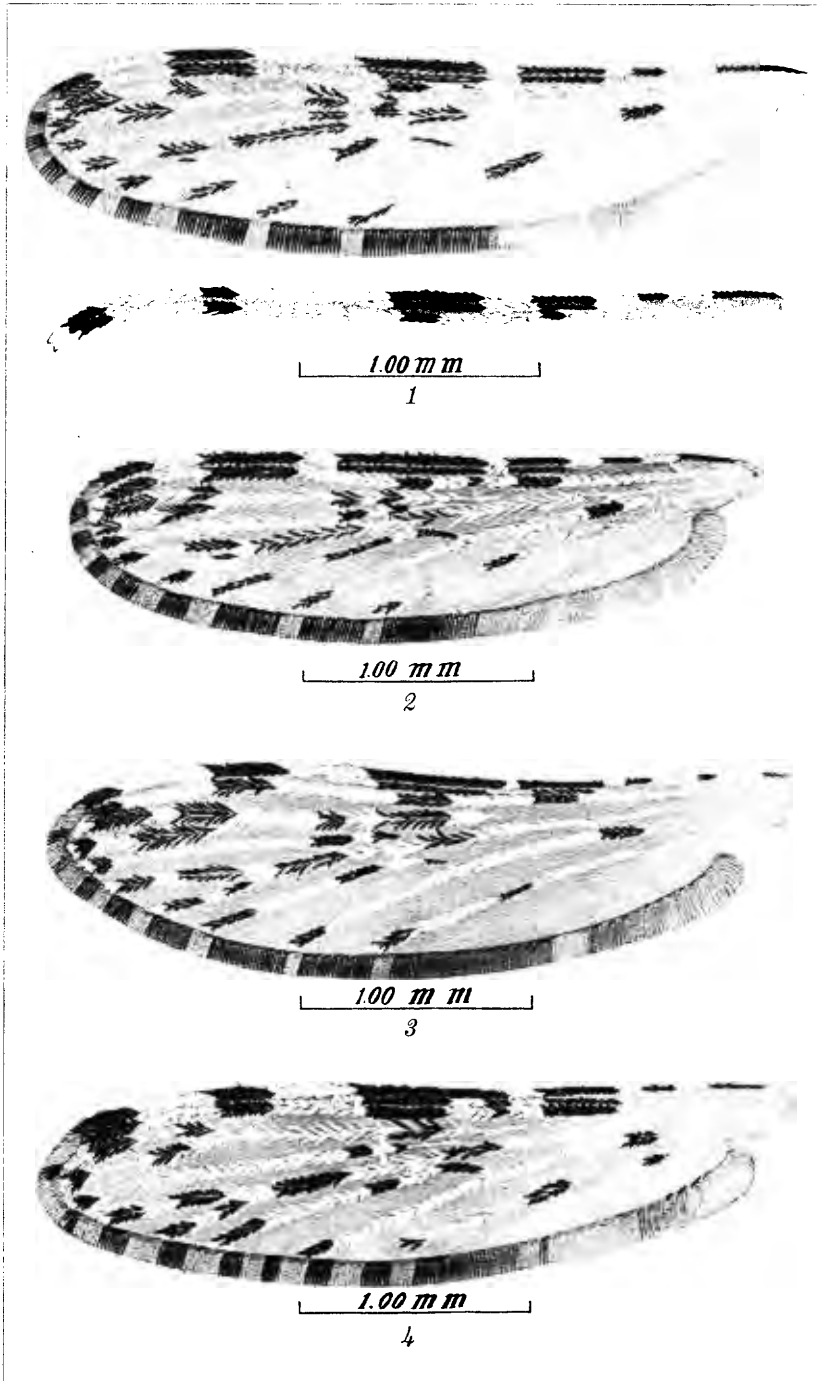


PLATE 2.

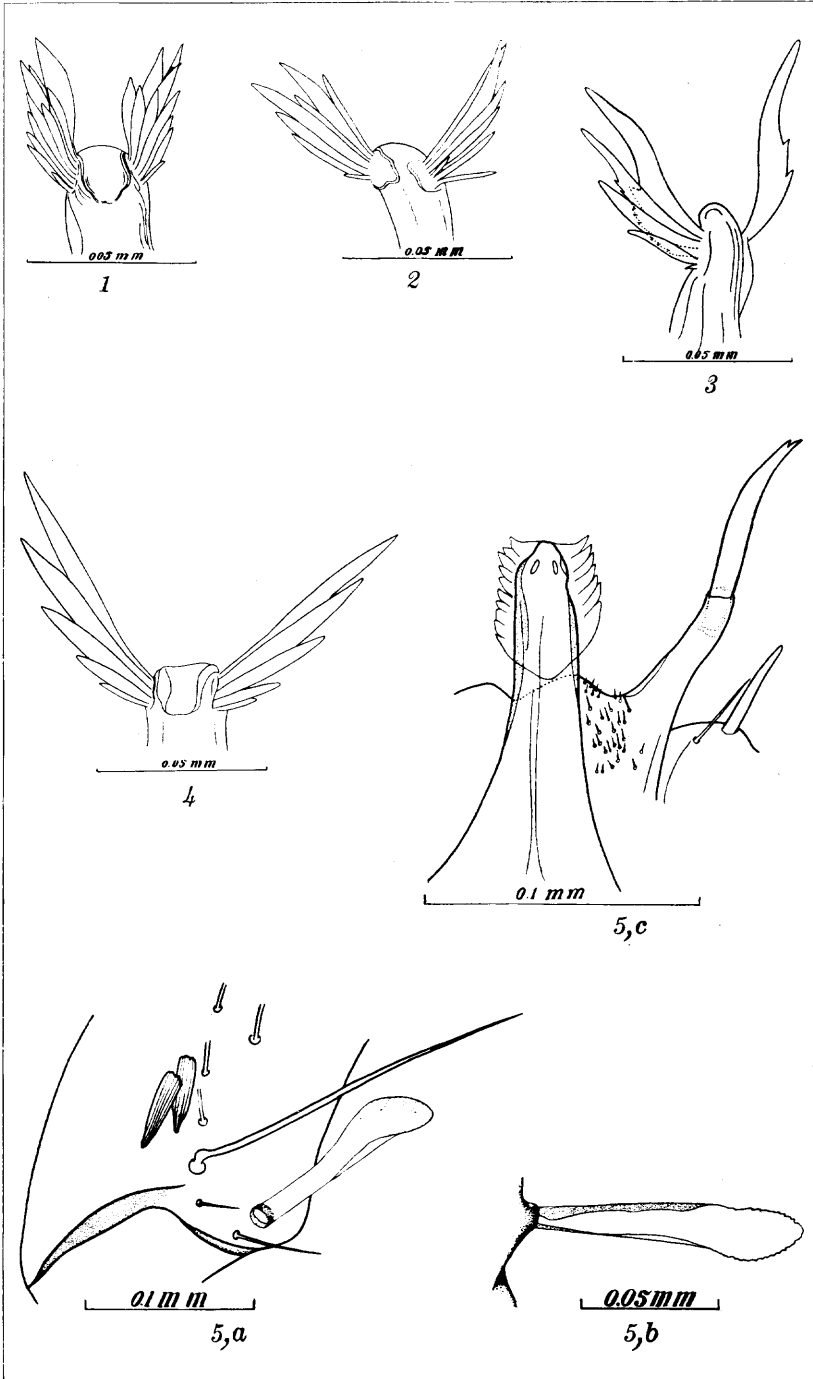


PLATE 3.

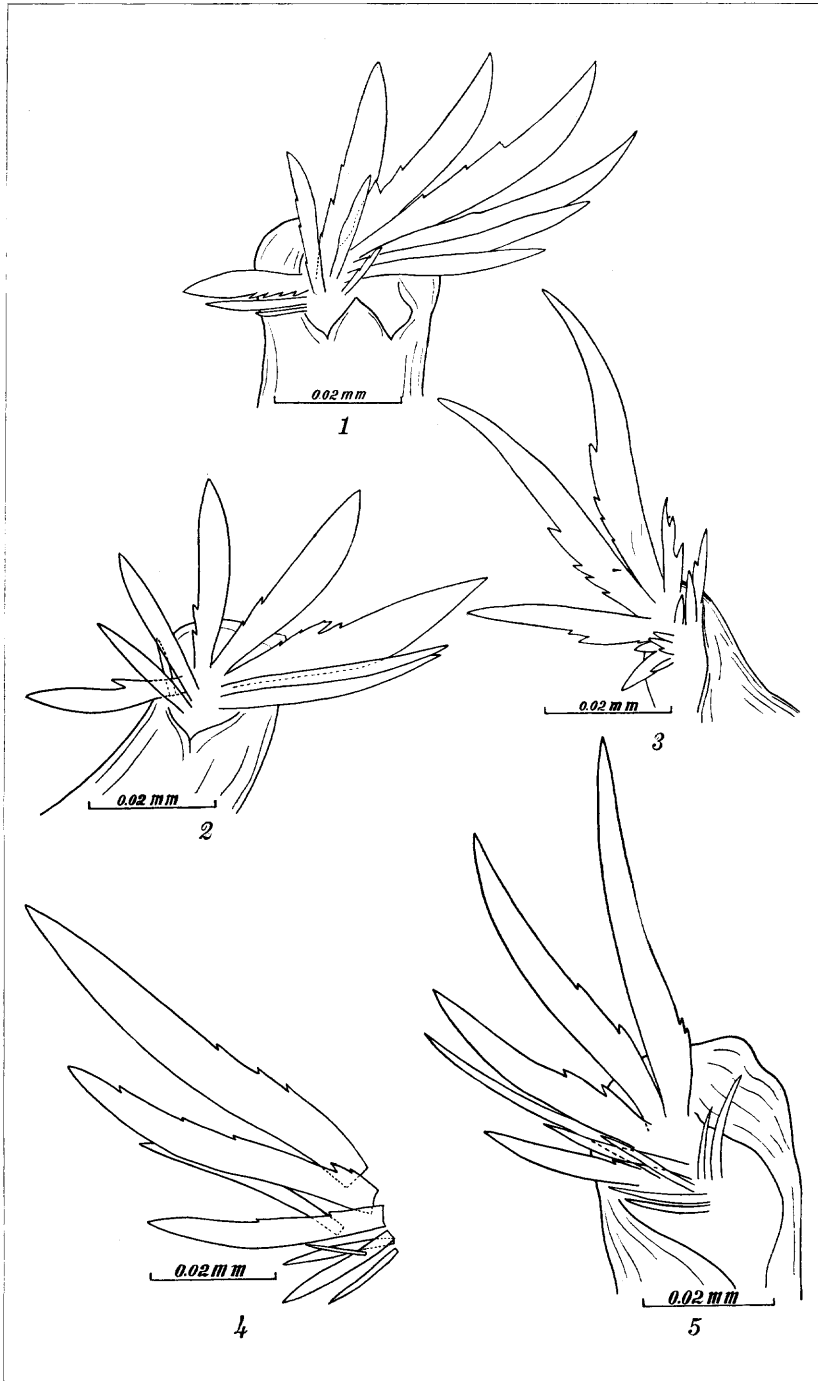


PLATE 4.

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