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THE IDENTITY OF THE MALARIA VECTOR, *A. LEUCOSPHYRUS.*

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INTRODUCTION.

A. leucosphyrus, a species widely distributed throughout the oriental region, has only comparatively recently been recognized as a malaria vector of any great importance. Earlier workers occasionally suspected it on epidemiological grounds and a few natural infections were reported, but since the published findings of Clark and Choudhury (1941) in Assam, McArthur (1947) in Borneo, and Kuitert and Hitchcock (1948) and Macan (1948) in Burma, it has become clear that this species is a dangerous, if not the principal, vector over quite large areas.

In all the above publications the vector is recorded simply as '*A. leucosphyrus*'. It is now known, however, that this name has been used in the past to include a number of different forms. The most recent review of the group (Reid, 1949) lists six forms and more recent work by Reid and the writer, as yet unpublished, makes it necessary to add a seventh. Of these, at least three have a wide distribution and are morphologically rather similar, which leaves a considerable element of doubt as to the exact identity of the incriminated vectors.

Reid (*loc. cit.*) reviewed the small amount of evidence available at the time and concluded that the vector was most probably the type form, under which designation he included *A. leucosphyrus balabacensis* Baisas. This latter form is now known to be a distinct sub-species or species and its importance as a vector has been amply demonstrated by investigations made in North Borneo during 1948-49. It is the purpose of this paper to set out the results of these investigations and to show that, for British Borneo at least, *A. leucosphyrus balabacensis* is almost certainly the only member of the group involved in malaria transmission.

Note.—Throughout this paper, the name in quotes refers to records which do not distinguish between members of the complex.

SYSTEMATIC.

The present knowledge of the *leucosphyrus* group shows it to consist of the following forms :—

1. *A. leucosphyrus leucosphyrus* Dönitz, 1901.
2. *A. leucosphyrus balabacensis* Baisas, 1936.
3. *A. leucosphyrus elegans* James, 1903.
4. *A. leucosphyrus riparis* King and Baisas, 1936.
5. *A. leucosphyrus pujutensis* Colless, 1948.
6. *A. leucosphyrus hackeri* Edwards, 1921.
7. *A. cristatus* King and Baisas, 1936.

There are also other forms, notably the *hackeri*-like form of Celebes, whose exact status is not yet established.

The above list is substantially the same as that given by Reid (*loc. cit.*) although the nomenclature differs slightly since the writer prefers to recognize most of the forms as good species; *balabacensis* was included by Reid under the synonomy of the type form but, as already mentioned above, subsequent work has shown it to be a distinct form; it is here given as a sub-species since its actual status is still under investigation.

Of these forms, three have so far been found in North Borneo—*A. leucosphyrus balabacensis*, *A. pujutensis* and *A. hackeri*. The related *A. riparis* which occurs in Malaya and Mindanao as a rather common species is apparently absent from North Borneo, if not the entire island; there is no obvious reason for this surprising omission from the Borneo fauna. *A. leucosphyrus balabacensis* occurs as a common species, widely distributed throughout Borneo; *A. pujutensis* is less common though it appears to be rather widely distributed; *A. hackeri* is a very rare species of specialized breeding habits. The Borneo *balabacensis* appears to be identical with that originally described by Baisas (1936) and has been described under that name by Colless (1948).

A. LEUCOSPHYRUS BALABACENSIS AS A MALARIA VECTOR.

Over a period of several years, a large number of dissections have been carried out on Labuan Island, British North Borneo, including 1,840 specimens of *balabacensis*. The figures for 1948-49 are given in Table I and show a high natural infection rate in this form (1·6 per cent gland infections).

Material for dissection came from the Bukit Kuda, Lajau-Batu Manikar areas at the northern end of the island, comprising some five to six square miles of hilly country, mostly covered with secondary jungle or rubber, and with a high malaria endemicity; spleen rates in native children are of the order of 60 to 100 per cent. Almost all specimens were taken by hand trapping at night, the bulk being taken while attempting to feed on the collector. A very small number were also taken from outdoor resting places.

TABLE I.

Total dissections in 1948-49.

Species.	Guts examined.	Glands examined.	Total dissected.	Positives.		
				Gut only.	Gland only.	Gut and gland.
A. leucosphyrus balabacensis	1,227	1,815	1,840	15	24	6
A. sundaicus	916	1,106	1,126	2	2	0
A. philippinensis ...	1,086	1,181	1,201	...	...	...
A. tessellatus	267	315	325	...	...	...
A. kochi	208	234	241	...	...	...
A. hyrcanus nigerrimus ...	90	122	127	...	...	...
A. barbirostris	58	65	66	...	...	...
A. karwari	58	66	66	...	...	...
A. separatus	17	18	18	...	...	...
A. bæzai	13	14	14	...	...	...
A. hyrcanus C.	1	1	1	...	...	...
TOTAL ...	3,941	4,937	5,025	17	26	6

The above figures demonstrate the overwhelming importance of *balabacensis* in this area ; it was the species most frequently taken and showed by far the highest sporozoite rate (1·6 per cent as compared with 0·2 per cent for *A. sundaicus* and nil for all other species). *A. pujutensis*, a rather rare species on Labuan, was never taken in adult catches.

The conclusion that *balabacensis* is the principal vector in the area is in complete agreement with all available epidemiological evidence, with the reservation that, in sea-side villages, *A. sundaicus* plays a part, the importance of which has not yet been fully determined.

SEASONAL VARIATIONS.

To illustrate the seasonal variations in malaria transmission by *balabacensis*, monthly figures for dissections of this species, and sporozoite rates, are given in Table II. These show that a variable degree of transmission may occur during most months of the year, with the possible exception of the drier months, January to March. There is no indication of any definite malaria season.

TABLE II.

Monthly dissections of A. leucosphyrus balabacensis.

Month.	1948.		1949.	
	Total dissections.	Sporozoite rate, per cent.	Total dissections.	Sporozoite rate, per cent.
Jan. ...	0	0	4	0
Feb. ...	6	0	0	0
Mar. ...	0	0	37	0
Apr. ...	0	0	102	2·0
May ...	19	0	123	1·6
Jun. ...	65	0	501	0·6
Jul. ...	166	5·4	132	1·3
Aug. ...	106	2·0	25	0
Sep. ...	157	3·3	63	0
Oct. ...	85	1·2	27	0
Nov. ...	55	3·6	70	0
Dec. ...	68	1·5	9	0
TOTAL ...	727	2·9	1,113	0·8

During the thirteen months shown in Table III, accurate trapping records were kept. The table shows the monthly average catch per man per night, the monthly sporozoite rates, and a 'transmission index' (I) derived as the product of the two former figures. This latter is designed to indicate variations in the

relative intensity of transmission, but for various reasons, probably does not give a very accurate estimate of the absolute intensity. However, multiplication by 30, as shown in the fourth column, gives some approximation to the average number of infections received per inhabitant of the area in each month.

TABLE III.

Monthly variation in malaria transmission.

Month.	Average catch /man/night.	Sporozoite rate, per cent.	Transmission index (T).	$T \times 30$.
1948				
Jul. ...	5·6	5·4	0·302	9·1
Aug. ...	2·3	2·9	0·067	2·0
Sep. ...	3·4	3·3	0·112	3·4
Oct. ...	1·9	1·2	0·023	0·7
Nov. ...	1·6	3·6	0·058	1·7
Dec. ...	1·8	1·5	0·027	0·8
1949				
Jan. ...	0·2	0·0	0·0	0·0
Feb. ...	0·0	0·0	0·0	0·0
Mar. ...	1·1	0·0	0·0	0·0
Apr. ...	3·3	2·0	0·066	2·0
May ...	3·1	1·6	0·049	1·5
Jun. ...	6·4	0·6	0·038	1·1
Jul. ...	5·6	1·3	0·073	2·2

It is clear from these figures that transmission is by no means steady but tends to fluctuate, probably in accordance with climatic factors. But during a large part of the year an inhabitant of the area may receive, if unprotected, something of the order of one to two infective bites per month.

PREVIOUS RECORDS.

The foregoing results settle the identity of the vector on Labuan Island. However, the earlier results of McArthur and others, from which the importance of *A. leucosphyrus* throughout Borneo has been deduced, offer no definite evidence as to the form concerned. There remains then the possibility that they refer, in

part or whole, to *A. pujutensis*. *A. hackeri* may be safely excluded by reason of its extreme rarity, and it seems most unlikely that any other form could be sufficiently abundant to be of importance and yet have escaped detection to date.

With regard to the results of McArthur (1947, and unpublished), who incriminated *A. leucosphyrus* in the Tambunan and Sandakan areas of North Borneo, there are two items of evidence :—

1. Specimens of *leucosphyrus* sent from Tambunan to the Institute for Medical Research, Kuala Lumpur, in 1941, included no *pujutensis* (Reid, *loc. cit.*).

2. Larval surveys by the writer in both the above places have shown widespread breeding of *balabacensis* and complete absence of *pujutensis*. The Tambunan survey was particularly intensive and it is impossible that any significant degree of breeding of the latter species could have been missed.

It seems then that there are no reasonable grounds for doubting that these records refer to *balabacensis*.

On several other occasions, *A. leucosphyrus* has come under suspicion in Borneo and it seems likely that in these cases also *balabacensis* was the form involved. But the evidence is so flimsy that there would appear to be little point in any detailed discussion of these records.

To sum up then, it may be stated that previous incriminations of *A. leucosphyrus* in North Borneo may be safely ascribed to *balabacensis* and that this form is most probably responsible for all *leucosphyrus*-borne malaria in the country.

RECORDS FROM OTHER COUNTRIES.

As stated in the introduction to this paper, *A. leucosphyrus* has been incriminated as a vector in Assam and Burma. The writer has seen Burmese specimens collected by T. Macan and other Burmese material kindly loaned by L. C. Kuitert, and these were all *balabacensis*. This, together with the fact that no other member of the complex has been reported from those areas, points once more to *balabacensis* as the vector.

It is also of interest to note that over much of the Malay Peninsula, where *A. riparis* and *A. pujutensis* are the dominant members of the complex, *A. leucosphyrus* has for long been regarded as a harmless species and rarely, if ever, appears in adult catches. There is some reason then to doubt if these species are of any importance as vectors. There remains however the possibility that the type form, *leucosphyrus*, may be of some importance. Reid (*loc. cit.*) notes a probability that the type series of this form was captured indoors after biting, which may be of some significance, but there is at present no real evidence on this point.

SUMMARY.

1. Present published records of *A. leucosphyrus* as a vector of malaria do not distinguish between the various closely related members of the *leucosphyrus* complex.

2. Recent records from Borneo establish the presence there of three members of the complex—*A. leucosphyrus balabacensis*, *A. pujutensis* and *A. hackeri*.

3. Dissections from Labuan Island show conclusively that *balabacensis* is a dangerous vector there and it seems certain that the bulk of previous positive dissections from Borneo refer to this form.

4. Other evidence of *A. leucosphyrus* as a vector in Borneo and other countries is consistent with the view that *balabacensis* is the form referred to.

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