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Ten Years' Study (1955-64) of Host Selection by Anopheline Mosquitos

L. J. BRUCE-CHWATT,[1] C. GARRETT-JONES[1] & B. WEITZ[2]

The success of malaria eradication campaigns depends on the use of all methods that make for a better understanding of the biology and behaviour of mosquito vectors. One such method is precipitin testing, by which it is possible to identify the human or animal origin of blood-meals of mosquitos and thereby to determine their host preferences and vectorial importance, both generally and locally.

In 1955 the World Health Organization, in agreement with the Lister Institute of Preventive Medicine, Elstree, England, set up a precipitin test service available to national research institutions and field staff of malaria eradication projects. The results of the tests carried out in 1959-64 are now presented in summary form ; the data were obtained from nearly 41 000 blood smears collected from 79 species of Anopheles. *In addition, the previously published results of the 1955-59 period are retabulated and data are presented on nearly 27 000 tests carried out independently at the National Institute of Communicable Diseases, Delhi, India, on* Anopheles *from Ceylon, India and Nepal. Altogether the review covers some 124 000 precipitin tests on 92* Anopheles *species ; about 93 % of the tests gave a positive result with one or other of the antisera used, but attention is chiefly paid to the proportion of blood-meals taken on man.*

There are practical difficulties in achieving representative sampling of Anopheles *populations for determination of the human blood index, but some can be overcome by increased care in sampling from a representative selection of biotopes. In areas that have been sprayed with insecticide, an attempt should be made to include mosquitos knocked down by the insecticide after feeding.*

INTRODUCTION

The first account of the large-scale investigation of the blood-feeding habits of *Anopheles* mosquitos, co-ordinated by the World Health Organization as a service to research and carried out at the Lister Institute of Preventive Medicine, Elstree, England, was published a few years ago (WHO & Lister Institute, 1960). It gave the results of precipitin tests on blood-meals of over 56 000 female *Anopheles* representing 51 species. The human blood index of 39 species was related to their importance in the transmission of malaria.

The " human blood index " was formerly known as the " human blood ratio " and earlier still as the " anthropophilic index ". It is defined (World Health Organization, 1963, page 59) as " the proportion of freshly fed *Anopheles* giving a positive precipitin reaction for human blood . . . in the particular conditions in which capture was made ". Thus it represents the *degree* of mosquito-man contact and is a factor determining (together with the frequency of feeding and the relative densities of mosquito and man) the *incidence* of mosquito–man contact.

Interpretation of the results available in 1960 was not easy. Often they could not be validly compared with each other because of serious defects in the sampling. In some cases information was lacking on the spray-status of the locality or the site of collection. Many samples of blood-meals were too small to be of significance. As a result, from 1961 onwards all requests were screened before submission to the Lister Institute, thus ensuring better use of the precipitin test technique.

[1] Division of Malaria Eradication, World Health Organization, Geneva, Switzerland.
[2] Lister Institute of Preventive Medicine, Elstree, London, England.

A subsequent study (Garrett-Jones, 1964a) presented further results of precipitin tests and discussed the problems of sampling for the human blood index in relation to sprayed areas in malaria eradication operations. A modified method of deriving the index was proposed, for use where the distribution of the blood-fed female *Anopheles* in different resting-places is not known. Garrett-Jones tentatively graded 21 species according to their human blood index in unsprayed areas, and examined the evidence for any impact of residual insecticides on the index. The human blood index is also one of the factors determining vectorial capacity, which is recognized as of potential value in assessing the progress of insecticidal attack in malaria eradication (WHO Expert Committee on Malaria, 1964, 1966). Field assessment of vectorial capacity would, where feasible, provide a measure of the basic reproduction rate of malaria before and under attack (Garrett-Jones, 1964b); and since the vectorial capacity as defined varies as the square of the human blood index, reliable sampling for this index is clearly of epidemiological interest. Further field research is needed to discover practical means to ensure that the sampling will be unbiased—namely,

(1) A method of determining the local distribution of blood-fed female *Anopheles* having regard to (*a*) relative prevalence of different biotopes,[1] (*b*) average density of blood-fed females in each biotope and (*c*) movements of females from one biotope to another in the course of the day.

(2) A convenient measure of variations in the man/animal ratio, and a means of assessing their influence on the human blood index.

(3) A method of representing in samples those mosquito females which, after feeding in or near sprayed premises, disappear from their habitual resting-places before the hour of collection.

(4) A method of collecting statistically adequate monthly samples of blood-meal smears in conditions where vector density has been sharply reduced, owing to seasonal changes or to the use of residual insecticides.

The collaborative scheme of sampling and precipitin testing of *Anopheles* mosquitos, initiated in 1955 by the World Health Organization and the Lister Institute of Preventive Medicine and carried out by the unflagging efforts of numerous entomologists, continues in operation. The present paper presents a summary of results of precipitin tests carried out from mid-1959 to the end of 1964. The total number of smears tested during this period was 40 886, of which 39 199 (93.4%) gave a positive reaction to an antiserum used in the test. The number of recognized *Anopheles* species represented is 79.

In addition the data are combined for the decade 1955-64, covering 124 188 tests on *Anopheles* belonging to 92 different species or species-complexes.[2]

In the first summary (WHO & Lister Institute, 1960), data on the important species of the Indian subcontinent were meagre. This was because precipitin tests for that part of the world have been carried out separately at the National Institute of Communicable Diseases (NICD), Delhi, as a service to the malaria eradication programmes of Ceylon, India and Nepal. Through the kindness of the Director of the NICD, the summarized results of the 26 674 precipitin tests carried out from 1960 to 1964 on samples of 22 species are incorporated here in Tables 1 and 3. Of these tests, 96% gave a positive reaction.

The precipitin testing service set up at the Lister Institute of Preventive Medicine is able to deal with a large number of tests and has the undeniable advantages of uniformity of procedure, reliability of results, and use of standardized antisera for a wide range of hosts. However, in some conditions it would be advantageous to determine the origin of blood-meals on the spot. With this purpose in mind steps were taken in 1963 to design a simple test kit for rapid determination of human and non-human blood. The prototype test kit consisted of a rubber suction unit with a screw-clip clamped to a board, a rack for test-tubes, a stand for capillary tubing and an adequate supply of the necessary glassware.

[1] The term biotope is used here as equivalent to habitat niche or micro-habitat, as used by Allee et al. (1949) and given as an alternative definition by Henderson et al. (1960).

[2] Closely allied forms are not always distinguished (or separately recorded) by the collectors of blood-meal samples. Such forms may have specific, subspecific or varietal rank. Where two or more forms may be represented in the same group of samples we have used the best-known specific name, followed by "s.l." (*sensu lato*). Thus, "*A. maculipennis* s.l." may include, in addition to the type form, specimens of the subspecies, *A. m. messeae* and *A. m. melanoon*, and of the sibling species, *A. labranchiae labranchiae* and its subspecies *A. l. atroparvus*. On the other hand, the designation "*A. labranchiae* s.l." refers only to the two subspecies of *A. labranchiae* s.l.

In determining where to add "s.l." in the tables, we have been guided generally by the classification of Stone, Knight & Starcke (1959).

Vials with freeze-dried antisera (anti-human and anti-mammal) and diluting fluid were included, each vial of 2.5 ml containing enough reagent for testing about 50 blood-meals.

Trials of this kit in the field indicated its potential value in the hands of very careful workers. Much depended on the cleanliness of the glassware, adequate reconstitution of freeze-dried antisera and a precise testing procedure. Careful assessment of the kit in the field led to the conclusion that the present centralized precipitin testing service, with its standardized technique, high reliability and economy in the use of antisera, should be maintained for general use. This decision is not incompatible with the view that in some conditions a simple field test using only two antisera can sufficiently demonstrate the primate or non-primate origin of the blood-meals (Macdonald, 1957).

PRESENTATION OF RESULTS

The tabulated data in the first summary (WHO & Lister Institute, 1960) showed the total number of tests classified by species, proportion of specimens found to contain human blood, biotope of collection, and year. An alternative classification was added, comprising the year and the origin of the blood according to host species (or host group in some cases). Numerous supplementary tables expressed the findings in particular malaria vectors according to various parameters of epidemiological interest.

While wishing to make the present summary comparable in its main features to that of 1960, we have considered it essential to introduce some changes of presentation in the light of recent practical and theoretical developments. We now have a better understanding of the problems of sampling a mosquito population for its human blood index. This had led us to modify the arrangement of the two main tables with the aim of giving proper attention to the following factors:

(*a*) the spray-status of the collection area;

(*b*) the identity of the residual insecticide in use, if any;

(*c*) the country of origin (rather than the year of origin) of the samples;

(*d*) the presence or absence of man as an available host in the biotope where the sample was collected;

(*e*) the minimum size of sample warranting calculation of the proportion positive for primate blood.

The tabulated results of over 124 000 precipitin tests carried out during the past 10 years at the Lister Institute and at the National Institute of Communicable Diseases, Delhi, are presented in a simplified way to give them a common denominator (Table 1).

Comparison between the two or three rows of data given for each species in this table (and indicated I, II and III) should be made with caution. Each row refers to an index derived from all the smears from one species (or complex) and from one or several countries. This may conceal wide disparities, for instance when samples originate from different parts of the Indian subcontinent under different phases of the malaria eradication programme. Moreover, it should be stressed that the technique of precipitin testing in routine use at the NICD is somewhat different from that used at the Lister Institute with regard to the standardization of antisera and the method of the test itself.

Table 2 gives the consolidated results of precipitin tests carried out from July 1959 to December 1964 at the Lister Institute. This table lists 446 samples, each composed of all the tested blood-meals referring to a given *Anopheles* species (or complex), country, spray-status and biotope class.

Only two classes of biotope are distinguished for the purpose of this review: the symbol " H " refers to those in which man is normally available as a host throughout the greater part of the night, i.e., human dwellings and mixed (human and animal) habitations. The other class, " O ", includes all other biotopes—notably animal sheds and outdoor resting-places (whether natural or artificial). In sprayed areas, where the animal sheds are usually treated and the outdoor shelters are not, the bulk of specimens from biotope Class-O usually comes from outdoor resting-places of one kind or another. The recording of a proportion with primate blood in these samples may be due to any of three factors: outdoor contact with man or other primates, natural outdoor resting by an endophagic mosquito, or outdoor resting due to irritant or deterrent action of the insecticide.

In areas where human and mixed habitations are sprayed with an insecticide, many mosquito samples are small. This indicates that the indoor sampling has been defeated by the difficulties of finding blood-fed mosquitos in the treated premises. It means that an undetermined proportion of mosquitos feeding inside the dwellings and afterwards dying or escaping is not represented in the samples.

TABLE 1

COMPARATIVE RESULTS OF THREE SERIES OF PRECIPITIN TESTS CARRIED OUT BETWEEN 1955 AND 1964

Species of *Anopheles* and series [a, b]		Total blood smears	Total positive tests	Positive specimens by class of biotope: Human and mixed dwellings	Positive specimens by class of biotope: Other shelters (including outdoors)	Positive specimens by class of biotope: Unspecified	Positive for primate blood: Number	Positive for primate blood: %	Countries
A. aconitus	I	3 338	2 945	1 031	901	1 013	173	5.9	Indonesia
	II	1 070	930	390	540		85	9.1	Indonesia, Pakistan, Viet-Nam
	III	112	109	29	80		5	4.8	Nepal
A. albimanus	I	1 446	1 433	572	795	66	133	9.3	Colombia, Ecuador, Mexico, Peru
	II	1 137	1 122	138	984		15	1.4	Colombia, Costa Rica, Ecuador, Mexico
A. albitarsis	I	164	148	124	24		35	23.6	Bolivia, Colombia, Paraguay
	II	285	276	232	44		145	52.5	Bolivia, Colombia, Paraguay
A. albotaeniatus	II	19	19	19			0	—	Sabah (Malaysia)
A. annularis	I	510	508	12	298	198	33	6.5	Indonesia
	II	802	629	125	504		2	0.3	India, Indonesia, Pakistan, Viet-Nam
	III	2 934	2 741	628	2 113		182	6.6	Ceylon, India, Nepal
A. balabacensis	I	2 586	2 511		1 618	893	1 278	50.9	Sabah (Malaysia)
	II	64	63	63			48	76.2	Sabah (Malaysia)
A. barbirostris s.l.	I	2 711	2 682	2 215	26	441	1 552	57.9	Indonesia, Sarawak (Malaysia)
	II	204	183	64	119		43	23.5	Indonesia, Pakistan, Sarawak, Viet-Nam
	III	120	118	55	63		0	0.0	India
A. benarrochi	II	24	5		5		1	—	Peru
A. braziliensis	II	6	6	4	2		0	—	Bolivia, Paraguay
A. brohieri	I	7	6			6	1	—	
	II	23	22		22		1	—	Upper Volta
A. christyi	II	119	118	7	111		0	0.0	Ethiopia, Uganda
A. cinereus	I	152	137			137	0	0.0	Saudi Arabia
A. claviger	II	231	127	1	126		95	74.8	Israel, Morocco, Turkey
A. coustani s.l.	I	118	109	18	70	21	28	25.7	Cameroon, Ghana, Nigeria, S. Rhodesia, Tanganyika and Zanzibar (Tanzania), UAR, Upper Volta
	II	126	123	13	110		8	6.5	Cameroon, Ghana, Nigeria, S. Rhodesia, UAR, Upper Volta, Zanzibar (Tanzania)
A. coustani tenebrosus	II	2	2	2			0	—	Zanzibar (Tanzania)
A. culicifacies	II	721	712	456	256		73/223	32.7	Ceylon (unsprayed area)
							0/489	0.0	India (mainly DDT-sprayed area)
	III	6 830	6 432	4 045	2 387		198	3.1	Ceylon, India, Nepal
A. darlingi	I	116	114	114			53	46.5	Bolivia, Colombia
	II	9	9		9		4	—	Paraguay
A. demeilloni	I	96	96		46	50	3	3.1	Congo (Democratic Republic), S. Rhodesia
	II	60	60	46	14		3	5.0	Ethiopia, S. Africa
A. domicolus	II	8	7		7		2	—	Upper Volta

For key see p. 412.

TABLE 1 (*continued*)

Species of *Anopheles* and series [a, b]		Total blood smears	Total positive tests	Positive specimens by class of biotope: Human and mixed dwellings	Positive specimens by class of biotope: Other shelters (including outdoors)	Positive specimens by class of biotope: Unspecified	Positive for primate blood: Number	Positive for primate blood: %	Countries
A. dthali	II	275	258	219	39		38	14.7	Morocco, Somalia
A. elegans	III	130	128		128		126	98.4	India (Madras)
A. evansae (strodei)	II	46	46	32	14		33	—	Paraguay
A. farauti	II	676	638	329	309		517	81.0	British Solomon Islands, Territory of Papua and New Guinea, West Irian (Indonesia)
A. flavicosta	I	100	73	7	43	23	11	15.0	Upper Volta
	II		95	1	94		5	4.1	Madagascar, Upper Volta
A. fluviatilis	I	75	58	1	57		19	32.8	Iran, Iraq, Saudi Arabia
	II	526	519	119	400		3	0.6	India, Nepal, Pakistan, Saudi Arabia
	III	5 035	4 751	2 275	2 476		678	14.3	Ceylon, India, Nepal
A freetownensis	II	1	1		1		0	—	Ghana
A. funestus s.l.	I	5 125	4 762	2 771	1 256	735	3 007	63.2	Cameroon, Ghana, Liberia, Nigeria, S. Rhodesia, Tanganyika (Tanzania), Uganda, Upper Volta, Zanzibar (Tanzania)
	II	4 975	4 809	3 440	1 369		3 404	70.5	Cameroon, Ghana, Guinea, Liberia, Madagascar, Mozambique, Nigeria, S. Rhodesia, Swaziland, Togo, Uganda, Upper Volta, Zanzibar (Tanzania)
	III	118	114	114			114	100	Nigeria
A. fuscicolor	II	16	16	7	9		0	—	Madagascar
A. gambiae s.l.	I	13 150	12 370	8 157	1 457	2 756	10 032	81.1	Cameroon, Congo (Democratic Republic), Ethiopia, Ghana, Liberia, Mauritius, Nigeria, Saudi Arabia, Somalia, S. Rhodesia, Sudan, Tanzania, Uganda, Upper Volta
	II	12 070	11 627	7 491	4 136		5 913	50.8	Cameroon, Ghana, Madagascar, Mauritania, Mauritius, Mozambique, Nigeria, Saudi Arabia, Sierra Leone, Somalia, S. Africa, S. Rhodesia, Swaziland, Togo, Uganda, Upper Volta, Zanzibar (Tanzania)
	III	400	397	397			390	98.2	Nigeria
A. garnhami	II	5	5	5			0	—	Uganda
A. hancocki	I	46	45	4		41	44	—	Cameroon, Liberia
	II	30	26	26			19	—	Liberia, Uganda
A. hargreavesi	II	154	154	121	33		151	98.0	Cameroon, Ghana
	III	120	119	119			119	100.0	Nigeria
A. hispaniola	II	216	208	171	37		0	0.0	Morocco
A. hyrcanus s.l.	III	491	449	180	269		14	3.1	Ceylon, India, Nepal (see also *A. nigerrimus* and *A. sinensis*)
A. implexus	I	88	57			57	2	3.5	Upper Volta
A. jeyporiensis s.l.	II	12	12		12		0	—	Pakistan, Viet-Nam
	III	244	237	36	201		20	8.4	India, Nepal

TABLE 1 (*continued*)

Species of *Anopheles* and series [a, b]		Total blood smears	Total positive tests	Positive specimens by class of biotope			Positive for primate blood		Countries
				Human and mixed dwellings	Other shelters (including outdoors)	Un-specified	Number	%	
A. kingi	II	38	38	1	37		0	—	Uganda
A. kochi	I	414	414	6	26	382	0	0.0	Cambodia, Indonesia
	II	16	16		16		0	—	Indonesia, Viet-Nam
A. koliensis	II	366	345	115	230		277	80.3	British Solomon Islands, Territory of Papua and New Guinea, West Irian (Indonesia)
A. labranchiae labranchiae	I	600	578	306	272		113	19.5	Morocco
	II	495	477	205	272		74	15.5	Morocco
A. letifer	II	1	1		1		1	—	Sarawak (Malaysia)
A. leucosphyrus leucosphyrus	I	1 567	1 562	1 335	13	214	1 478	94.6	Sarawak (Malaysia)
A leucosphyrus s.l.	I	257	255	176	79		112	43.9	Burma, Cambodia, Kalimantan (Indonesia)
	II	9	9	9			9	—	Sarawak (Malaysia)
A. listeri	II	64	64	64			0	0.0	S. Africa
A. longipalpis	II	3	3		3		0	—	S. Rhodesia
A. longirostris	II	3	2		2		1	—	Territory of Papua and New Guinea
A. lungae	II	4	4		4		0	—	British Solomon Islands
A. maculatus s.l.	I	274	270	256	3	11	1	0.4	Cambodia, China (Taiwan), Indonesia
	II	84	80	7	73		0	0.0	Indonesia, Nepal
	III	2 567	2 432	288	2 144		55	2.3	Ceylon, India, Nepal
A. maculipalpis	I	167	166		166		0	0.0	Ghana, S. Rhodesia, Zanzibar (Tanzania)
	II	52	52		52		0	0.0	S. Rhodesia, Zanzibar (Tanzania)
A. maculipennis s.l.	I	1 246	1 159	114	1 043	2	18	1.5	Greece, Iran, Iraq, Portugal
	II	1 411	1 354	183	1 171		18	1.3	Greece, Portugal, Turkey
A. maculipennis messeae	II	121	119		119		0	0.0	Romania
A. marshalli	I	254	239	22	57	160	86	36.0	Congo (Democratic Republic), S. Rhodesia, Tanzania, Uganda
	II	210	194	190	4		7	3.6	Ethiopia, Mozambique, S. Rhodesia, Uganda, Zanzibar (Tanzania)
A. mascarensis	II	54	54	19	35		1	1.9	Madagascar
A. mattogrossensis	I	5	5	5			1	—	Colombia
A. minimus minimus	I	186	129		52	77	10	7.7	Cambodia, China (Taiwan)
	III	2 625	2 511	2 455	56		2 295	91.4	Nepal
A. minimus flavirostris	II	1	1		1		0	—	Indonesia
A. moucheti		155	148	2	2	144	122	82.4	Cameroon, Nigeria
A. multicolor	I	311	278	162	62	54	17	6.1	Iran, Saudi Arabia, Tunisia
	II	223	216	79	137		22	10.2	Morocco, Saudi Arabia, Tunisia

TABLE 1 *(continued)*

Species of *Anopheles* and series [a, b]		Total blood smears	Total positive tests	Positive specimens by class of biotope			Positive for primate blood		Countries
				Human and mixed dwellings	Other shelters (including outdoors)	Un-specified	Number	%	
A. nigerrimus	I	145	145	1		144	11	7.6	Sumatra (Indonesia)
	II	8	8		8		1	—	
A. nili	I	427	378	178	188	12	324	85.7	Cameroon, Ghana, Upper Volta
	II	190	187	73	114		156	83.4	Ghana, S. Rhodesia, Upper Volta
A. oswaldoi	I	48	48	48			1	—	Colombia
A. pallidus	III	119	82	1	81		11	13.4	Ceylon
A. paludis	II	32	32		32		32	—	Cameroon
A. pharoensis	I	1 249	1 218	476	601	141	629	51.6	Cameroon, Congo (Democratic Republic), Ethiopia, Ghana, Nigeria, Uganda, UAR
	II	868	854	251	603		266	31.1	Cameroon, Ghana, Nigeria, Sudan, UAR
A. philippinensis	III	111	111	2	109		2	1.8	India
A. pretoriensis	I	163	156	1	155		1	0.6	Cameroon, Ghana, S. Rhodesia
	II	108	106	102	4		1	0.9	Cameroon, S. Africa, S. Rhodesia
A. pseudopunctipennis s.l.	I	3 387	3 189	2 450	564	175	964	30.2	Bolivia, Colombia, Mexico, Peru
	II	2 363	1 585	124	1 461		18	1.1	Bolivia, Costa Rica, El Salvador, Mexico, Peru
A. pulcherrimus	I	536	448	73	373	2	24	5.4	Iran, Iraq, Saudi Arabia
	II	263	206	61	145		18	8.6	Afghanistan, Saudi Arabia
A. punctimacula	I	132	131			131	0	0.0	Ecuador
	II	506	495	103	392		37	7.5	Costa Rica, Ecuador, Peru
A. punctulatus s.l.	II	137	136	55	81		106	77.9	British Solomon Islands, Territory of Papua and New Guinea, West Irian (Indonesia) (see also *A. farauti*, *A. koliensis*)
A. ramsayi	II	25	25	6	19		0	—	Pakistan
A. rivulorum	I	335	329	15	314		3	0.9	Zanzibar (Tanzania)
	II	45	44	12	32		3	—	Zanzibar (Tanzania)
A. rufipes s.l.	I	572	548	156	275	117	56	10.2	Cameroon, Ghana, Nigeria, S. Rhodesia, Upper Volta
	II	629	615	169	446		34	5.5	Cameroon, Mozambique, S. Africa, S. Rhodesia, Upper Volta
A. sacharovi	I	6 547	6 342	1 239	4 766	337	316	5.0	Afghanistan, Greece, Iraq, Syria
	II	3 010	2 973	823	2 150		224	7.6	Greece, Romania, Syria
A. sergenti	I	652	609	132	477		40	6.6	Morocco, Saudi Arabia, Tunisia
	II	1 134	957	254	703		74	7.7	Jordan, Morocco, Saudi Arabia, Tunisia
A. sinensis	I	177	172	49		123	3	1.7	China (Taiwan), Indonesia, Korea
	II	824	816	151	665		87	10.6	Korea, Viet-Nam
A. sineroides	II	11	11		11		0	—	Korea
A. smithi rageaui	I	71	24			24	24	—	Upper Volta
	II	143	86		86		2	2.3	Ghana

TABLE 1 (*concluded*)

Species of *Anopheles* and series [a, b]		Total blood smears	Total positive tests	Positive specimens by class of biotope: Human and mixed dwellings	Positive specimens by class of biotope: Other shelters (including outdoors)	Positive specimens by class of biotope: Un-specified	Positive for primate blood: Number	Positive for primate blood: %	Countries
A. splendidus	II	5	4	1	3		1	—	Viet-Nam
	III	914	865	232	633		12	1.4	India, Nepal
A. stephensi s.l.	I	562	469	109	326	34	25	5.3	Iran, Iraq, Saudi Arabia
	II	298	298	109	189		1	0.3	Pakistan, Saudi Arabia
	III	394	355	144	211		5	1.4	India
A. subpictus subpictus	I	517	509	11		498	124	24.4	Indonesia
	II	158	104	55	49		28	26.9	Indonesia, Territory of Papua and New Guinea, Viet-Nam
	III	2 795	2 607	1 334	1 273		241	9.2	Ceylon, India, Nepal
A. subpictus malayensis	I	1 035	879	323	2	554	8	0.9	Indonesia
	II	188	182	118	64		0	0.0	Indonesia
A. sundaicus	I	1 106	1 064	503	4	557	822	77.3	Indonesia
	II	644	615	528	87		376	61.1	Indonesia
	III	160	127	55	72		9	7.1	India (W. Bengal)
A. superpictus	I	1 725	1 404	62	893	449	60	4.3	Afghanistan, Greece, Iran, Iraq, Saudi Arabia, Syria
	II	1 133	1 071	115	956		26	2.4	Afghanistan, Greece, Jordan, Saudi Arabia, Syria, Turkey
A. tessellatus s.l.	I	80	79	6	19	54	6	7.6	Indonesia, Sarawak (Malaysia)
	II	29	29	2	27		0	—	Indonesia, Sabah (Malaysia), Viet-Nam
	III	403	360	2	358		4	1.1	India
A. triannulatus davisi	I	87	86	86			2	2.3	Colombia
A. triannulatus s.l.	II	17	17	17			4	—	Colombia, Paraguay
A. turkhudi	II	7	7	6	1		1	—	Somalia
A. umbrosus	I	85	82	19	63		55	67.1	Indonesia, Sarawak (Malaysia)
	II	2	2		2		0	—	Indonesia
A. vagus s.l.	I	882	865	63	244	558	3	0.3	Cambodia, Indonesia
	II	709	676	315	361		22	3.3	Indonesia, Pakistan, Viet-Nam
	III	464	425	196	229		30	6.5	Ceylon, India, Nepal
A. varuna	II	43	29	10	19		0	—	Pakistan
	III	226	216	71	145		59	27.3	India, Nepal
A. wellcomei	I	375	325		6	319	320	98.5	Cameroon, Nigeria
Total (92 species)		124 188	116 468	53 921	50 837	11 710	39 266	—	

[a] Series I refers to the 1955-59 series of tests, previously summarized by WHO & The Lister Institute (1960). Series II refers to the 1959-64 tests at the Lister Institute, summarized here (Tables 2 and 4). Series III refers to samples from Ceylon, India, Nepal and Nigeria, tested at the National Institute of Communicable Diseases, Delhi, during the period 1960-64, and included by courtesy of that Institute.

[b] For an explanation of the use of " s.l. " throughout this table, see footnote, p. 406 of text.

TABLE 2

PRECIPITIN TESTS ON *ANOPHELES* CARRIED OUT AT THE LISTER INSTITUTE, JULY 1959 TO DECEMBER 1964

Species	Country	Spray status of area [a]	Testing of smears		Positive samples by class of biotope [b]		Positive for primate blood		No. positive for bovine blood	No. positive for other host-groups [c]
			No. tested	No. positive	Biotope class	No. of smears	No.	%		
A. aconitus	Indonesia	?	405	346	H	50	4	8.0	32	14
					O	296	1	0.3	279	16
		N	563	509	H	306	68	22.2	107	131
					O	203	5	2.5	185	13
		1	5	5	O	5	5	—	0	0
		2	2	2	H	2	1	—	1	0
	Pakistan	N	53	27	H	18	0	—	7	11
					O	9	0	—	7	2
		3	15	14	H	5	0	—	5	0
					O	9	0	—	9	0
	Viet-Nam	?	3	3	O	3	0	—	3	0
		N	23	23	H	9	0	—	8	1
					O	14	1	—	11	2
		1	1	1	O	1	0	—	1	0
A. albimanus	Colombia	1	40	40	H	32	0	—	24	8
					O	8	0	—	8	0
	Costa Rica	1	114	111	H	15	1	—	5	9
					O	96	1	1.0	42	53
	Ecuador	2	423	420	H	20	0	—	0	20
					O	400	13	3.2	135	252
	Mexico	1	560	551	H	71	0	0.0	0	71
					O	480	0	0.0	8	472
A. albitarsis	Bolivia	?	29	27	H	7	5	—	0	2
					O	20	6	—	0	14
	Colombia	1	62	57	H	35	7	—	0	28
					O	22	4	—	0	18
	Paraguay	N	18	18	H	16	8	—	0	8
					O	2	0	—	0	2
		1	30	30	H	30	13	—	1	16
		2	146	144	H	144	102	70.8	4	38
A. albotaeniatus	Sabah (Malaysia)	N	19	19	H	19	0	—	19	0
A. annularis	India	?	32	32	O	32	0	—	32	0
		1	112	112	H	64	0	0.0	64	0
					O	48	0	—	47	1
	Indonesia	?	36	36	H	21	0	—	21	0
					O	15	0	—	15	0
		N	13	13	O	13	0	—	11	2
	Pakistan	N	564	408	H	39	1	—	35	3
					O	369	0	0.0	298	71
		1	32	15	O	15		—	6	9
	Viet-Nam	?	1	1	H	1	1	—	0	0
		1	12	12	O	12	0	—	11	1

For key see p. 424.

TABLE 2 (*continued*)

Species	Country	Spray status of area [a]	Testing of smears		Positive samples by class of biotope [b]		Positive for primate blood		No. positive for bovine blood	No. positive for other host-groups [c]
			No. tested	No. positive	Biotope class	No. of smears	No.	%		
A. balabacensis	Sabah (Malaysia)	N	64	63	H	63	48	76.2	11	4
A. barbirostris s.l.[d]	Indonesia	N	21	21	O	21	1	—	19	1
	Pakistan	N	57	43	O	43	0	—	22	21
		1	23	16	O	16	0	—	16	0
	Sarawak (Malaysia)	N	16	16	H	16	9	—	0	7
		1	78	78	H	46	21	—	0	25
					O	32	5	—	0	27
	Viet-Nam	N	9	9	H	2	2	—	0	0
					O	7	5	—	2	0
A. benarroch	Peru	N	24	5	O	5	1	—	0	4
A. braziliensis	Bolivia	?	2	2	O	2	0	—	0	2
	Paraguay	2	4	4	H	4	0	—	0	4
A. brohieri	Upper Volta	N	6	5	O	5	1	—	0	4
		1	17	17	O	17	0	—	17	0
A. christyi	Ethiopia	1	104	103	H	2	0	—	2	0
					O	101	0	0.0	101	0
	Uganda	N	15	15	H	5	0	—	5	0
					O	10	0	—	9	1
A. claviger	Israel	N	9	6	O	6	6	—	0	0
	Morocco	N	109	10	O	10	0	—	2	8
	Syria	N	6	6	H	1	1	—	0	0
					O	5	0	—	1	4
	Turkey	1	107	105	O	105	88	83.8	4	13
A. coustani s.l.	Cameroon	N	14	14	H	10	2	—	1	7
					O	4	0	—	0	4
		1	5	5	O	5	0	—	0	5
	Egypt (UAR)	N	26	25	O	25	2	—	10	13
	S. Rhodesia	2	1	1	H	1	1	—	0	0
	Upper Volta	?	1	1	H	1	0	—	1	0
		N	1	1	O	1	1	—	0	0
		1	8	7	O	7	1	—	4	2
	Zanzibar (Tanzania)	?	5	4	O	4	0	—	4	0
		2	1	1	H	1	1	—	0	0
A. coustani tenebrosus	Zanzibar (Tanzania)	?	1	1	H	1	0	—	0	1
		2	1	1	H	1	0	—	1	0
A. coustani ziemanni	Ghana	N	45	45	O	45	0	—	45	0
	Nigeria	1	19	19	O	19	0	—	2	17

TABLE 2 (*continued*)

Species	Country	Spray status of area [a]	Testing of smears		Positive samples by class of biotope [b]		Positive for primate blood		No. positive for bovine blood	No. positive for other host-groups [c]
			No. tested	No. positive	Biotope class	No. of smears	No.	%		
A. culicifacies	Ceylon	N	227	223	H	223	73	32.7	108	42
	India	N	16	16	O	16	0	—	15	1
		1	478	473	H	233	0	0.0	209	24
					O	240	0	0.0	199	41
A. darlingi	Paraguay	2	9	9	O	9	4	—	0	5
A. demeilloni	Ethiopia	N	46	46	H	46	3	—	38	5
	S. Africa	N	14	14	O	14	0	—	9	5
A. domicolus	Upper Volta	1	8	7	O	7	2	—	2	3
A. dthali	Morocco	N	217	203	H	203	38	18.7	4	161
		1	41	38	O	38	0	—	36	2
	Somalia	N	1	1	H	1	0	—	0	1
		1	16	15	H	15	0	—	2	13
A. evansae (strodei)	Paraguay	N	15	15	H	1	1	—	0	0
					O	14	1	—	0	13
		2	31	31	H	31	31	—	0	0
A. farauti	British Solomon Islands	N	77	77	H	19	12	—	0	7
					O	58	23	39.7	0	35
		1	112	83	O	83	71	85.5	0	12
	Territory of Papua and New Guinea	N	465	457	H	310	266	85.8	0	44
					O	147	126	85.7	0	21
	West Irian (Indonesia)	N	22	21	O	21	19	—	0	2
A. flavicosta	Madagascar	N	1	1	H	1	1	—	0	0
	Upper Volta	N	1	1	O	1	1	—	0	0
		1	119	93	O	93	3	3.2	69	21
A. fluviatilis	India	N	167	165	H	11	0	—	11	0
					O	154	1	0.7	117	36
		3	48	48	H	48	0	—	44	4
	Nepal	N	11	9	O	9	0	—	1	8
		2	39	39	H	8	2	—	6	0
					O	31	0	—	31	0
	Pakistan	N	118	115	H	52	0	0.0	49	3
					O	63	0	0.0	57	6
	Saudi Arabia	2	143	143	O	143	0	0.0	123	20
A. freetownensis	Ghana	N	1	1	O	1	0	—	0	1
A. funestus s.l.	Cameroon	?	14	14	H	14	10	—	3	1
		N	291	290	H	219	154	70.3	30	35
					O	71	24	33.8	23	24
		1	227	221	H	121	101	83.5	11	9
					O	100	67	67.0	17	16
		2	3	3	H	3	2	—	0	1

TABLE 2 (*continued*)

Species	Country	Spray status of area [a]	Testing of smears: No. tested	Testing of smears: No. positive	Positive samples by class of biotope [b]: Biotope class	Positive samples by class of biotope [b]: No. of smears	Positive for primate blood: No.	Positive for primate blood: %	No. positive for bovine blood	No. positive for other host-groups [c]
A. funestus s.l. (*contd.*)	Ghana	?	36	30	H	1	1	—	0	0
					O	29	27	—	1	1
		N	546	526	H	397	391	98.5	0	6
					O	129	43	33.3	78	8
	Guinea	?	4	4	H	4	4	—	0	0
	Liberia	?	43	43	H	43	43	—	0	0
		N	823	803	H	763	757	99.2	0	6
					O	40	34	—	0	6
	Madagascar	2	450	434	H	338	176	52.1	87	75
					O	96	8	8.3	46	42
	Mozambique	N	185	185	H	185	175	94.6	7	3
		1	118	115	H	1	0	—	1	0
					O	114	0	0.0	104	10
	Nigeria	?	42	42	O	42	40	—	0	2
		N	114	114	H	114	111	97.4	1	2
		1	2	2	H	2	1	—	1	0
	S. Rhodesia	N	187	187	H	26	19	—	4	3
					O	161	0	0.0	160	1
		1	4	4	H	4	3	—	1	0
		3	43	41	H	16	3	—	7	6
					O	25	2	—	20	3
	Swaziland	N	1	1	H	1	0	—	0	1
	Togo	N	270	267	H	80	80	100	0	0
					O	187	186	99.5	0	1
	Uganda	?	48	48	H	48	48	—	0	0
		N	842	787	H	781	537	68.7	111	133
					O	6	1	—	5	0
	Upper Volta	?	61	61	H	61	61	100	0	0
		N	213	209	H	155	136	87.8	3	16
					O	54	41	76.0	12	1
		1	384	355	H	47	44	—	1	2
					O	308	61	19.8	166	81
	Zanzibar (Tanzania)	?	14	13	H	13	13	—	0	0
		2	9	9	H	3	0	—	3	0
					O	6	0	—	6	0
A. fuscicolor	Madagascar	?	16	16	H	7	0	—	7	—
					O	9	0	—	9	—
A. gambiae s.l.	Cameroon	?	112	112	H	112	112	100	—	—
		N	431	428	H	361	294	81.4	46	21
					O	67	34	50.2	24	9
		1	180	179	H	87	70	80.5	8	9
					O	92	66	72.8	11	15
		2	86	86	H	59	57	97.7	1	1
					O	27	19	—	5	3

TABLE 2 (*continued*)

Species	Country	Spray status of area [a]	Testing of smears		Positive samples by class of biotope [b]		Positive for primate blood		No. positive for bovine blood	No. positive for other host-groups [c]
			No. tested	No. positive	Biotope class	No. of smears	No.	%		
A. gambiae s.l. (*contd.*)	Ghana	N	498	471	H	286	275	96.2	1	10
					O	185	143	77.3	—	42
	Madagascar	?	148	145	H	37	8	—	28	1
					O	108	4	3.7	98	6
		N	99	87	H	58	21	36.2	25	12
					O	29	0	—	26	3
		1	13	9	H	1	0	—	1	—
					O	8	3	—	—	5
		2	112	112	O	112	0	0.0	111	1
	Mauritania	N	87	87	H	80	61	76.3	11	8
					O	7	3	—	2	2
	Mauritius	N	17	16	O	16	0	—	16	—
		1	164	164	O	164	2	1.2	144	18
	Mozambique	N	599	594	H	433	415	95.8	2	16
					O	161	59	36.7	80	22
		1	283	283	H	88	84	95.5	—	4
					O	195	23	11.8	151	21
		2	62	61	H	55	51	92.7	2	2
					O	6	1	—	1	4
	Nigeria	N	188	186	H	144	142	98.7	—	2
					O	42	22	—	—	20
		1	70	68	H	22	13	—	9	—
					O	46	31	—	2	13
	Saudi Arabia	N	485	483	H	483	345	71.4	100	38
	Sierra Leone	N	54	51	H	31	31	—	—	—
					O	20	16	—	3	1
	Somalia	N	863	848	H	817	422	51.7	247	148
					O	31	14	—	7	10
		1	240	228	H	228	141	61.8	13	74
	S. Africa	N	45	44	H	13	0	—	12	1
					O	31	0	—	20	11
		1	42	42	H	42	0	—	32	10
		3	1 117	1 096	H	963	2	0.2	856	105
					O	133	0	0.0	116	17
	S. Rhodesia	N	517	507	H	127	114	89.8	11	2
					O	380	103	27.1	206	71
		1	30	30	H	30	0	—	15	15
		2	27	25	H	3	0	—	3	—
					O	22	0	—	16	6
		3	613	608	H	203	15	7.4	149	39
					O	405	2	0.5	338	65
	Swaziland	3	295	294	H	278	221	79.5	33	24
					O	16	1	—	2	13
	Togo	N	208	201	H	96	94	97.9	—	2
					O	105	75	71.4	—	30

TABLE 2 (*continued*)

Species	Country	Spray status of area [a]	Testing of smears		Positive samples by class of biotope [b]		Positive for primate blood		No. positive for bovine blood	No. positive for other host-groups [c]
			No. tested	No. positive	Biotope class	No. of smears	No.	%		
A. gambiae s.l. (*contd.*)	Uganda	?	606	605	H	605	573	94.7	3	29
		N	357	356	H	356	330	92.7	18	8
		1	646	638	H	262	258	98.5	—	4
					O	376	96	25.5	222	58
	Upper Volta	?	268	265	H	265	224	84.5	11	30
		N	250	243	H	201	184	91.5	3	14
					O	42	41	—	1	—
		1	50	47	H	38	30	—	2	6
					O	9	6	—	1	2
	Zanzibar (Tanzania)	1	630	576	H	66	30	45.4	36	—
					O	510	44	8.6	454	12
		2	1 578	1 372	H	561	469	83.6	72	20
					O	811	19	2.3	674	118
A. garnhami	Uganda	N	5	5	H	5	0	—	4	1
A. hancocki	Liberia	N	16	12	H	12	5	—	—	7
	Uganda	N	14	14	H	14	14	—	—	—
A. hargreavesi	Cameroon	N	37	37	H	5	5	—	—	—
					O	32	31	—	1	—
	Ghana	N	117	117	H	116	114	98.3	1	1
					O	1	1	—	—	—
A. hispaniola	Morocco	N	216	208	H	171	0	0.0	44	127
					O	37	0	—	14	23
A. hyrcanus s.l.	Indonesia	?	27	27	H	12	1	—	11	—
					O	15	0	—	15	—
	Pakistan	N	33	20	H	4	0	—	4	—
					O	16	0	—	15	1
	Romania	1	48	47	O	47	0	—	45	2
A. jeyporiensis s.l.	Pakistan (East)	N	11	11	O	11	0	—	11	—
	Viet-Nam	1	1	1	O	1	0	—	1	—
A. kingi	Uganda	N	38	38	H	1	0	—	1	—
					O	37	0	—	31	6
A. kochi	Indonesia	N	2	2	O	2	0	—	2	—
	Viet-Nam	N	14	14	O	14	0	—	14	—
A. koliensis	British Solomon Islands	N	71	71	H	46	44	—	—	2
					O	25	19	—	—	6
	Territory of Papua and New Guinea	N	70	69	H	69	60	87.0	—	9
	West Irian (Indonesia)	N	225	205	O	205	154	75.1	—	51

TABLE 2 (*continued*)

Species	Country	Spray status of area [a]	Testing of smears		Positive samples by class of biotope [b]		Positive for primate blood		No. positive for bovine blood	No. positive for other host-groups [c]
			No. tested	No. positive	Biotope class	No. of smears	No.	%		
A. labranchiae	Morocco	?	274	265	H	37	12	—	11	14
					O	228	2	0.9	148	78
		N	10	10	O	10	1	—	3	6
		1	211	202	H	168	56	33.3	24	88
					O	34	3	—	24	7
A. letifer	Sarawak (Malaysia)	1	1	1	O	1	1	—	—	—
A. leucosphyrus s.l.	Sarawak (Malaysia)	1	9	9	H	9	9	—	—	—
A. listeri	S. Africa	N	64	64	H	64	0	0.0	61	3
A. longipalpis	S. Rhodesia	N	3	3	O	3	0	—	3	—
A. longirostris	Territory of Papua and New Guinea	N	3	2	O	2	1	—	—	1
A. lungae	British Solomon Islands	N	4	4	O	4	0	—	—	4
A. maculatus	Indonesia	?	7	7	H	7	0	—	7	—
		N	4	4	O	4	0	—	4	—
	Nepal	N	73	69	O	69	0	0.0	43	26
A. maculipalpis	S. Rhodesia	3	7	7	O	7	0	—	—	7
	Zanzibar (Tanzania)	2	45	45	O	45	0	—	45	—
A. maculipennis s.l.	Greece	N	722	706	H	114	0	0.0	104	10
					O	592	14	2.4	553	25
		2	41	36	H	36	2	—	33	1
	Portugal	N	608	572	O	572	0	0.0	318	254
	Turkey	?	8	8	H	7	2	—	4	1
					O	1	0	—	—	1
		N	32	32	H	26	0	—	15	11
					O	6	0	—	5	1
A. maculipennis messeae	Romania	1	121	119	O	119	0	0.0	50	69
A. marshalli	Ethiopia	N	172	172	H	172	5	2.9	159	8
	Mozambique	N	4	4	H	4	0	—	4	0
		1	2	2	O	2	0	—	2	0
	S. Rhodesia	N	1	1	H	1	1	—	0	0
		3	3	3	H	1	1	—	0	0
					O	2	1	—	0	1
	Uganda	N	12	11	H	11	0	—	8	3
	Zanzibar	3	16	1	H	1	0	—	0	1

TABLE 2 (*continued*)

Species	Country	Spray status of area [a]	Testing of smears		Positive samples by class of biotope [b]		Positive for primate blood		No. positive for bovine blood	No. positive for other host-groups [c]
			No. tested	No. positive	Biotope class	No. of smears	No.	%		
A. mascarensis	Madagascar	N	46	46	H	19	1	—	8	10
					O	27	0	—	17	10
		1	8	8	O	8	0	—	6	2
A. matto-grossensis	Colombia	1	5	5	H	5	1	—	0	4
A. minimus flavirostris	Indonesia	N	1	1	O	1	0	—	1	0
A. multicolor	Morocco	N	46	45	H	45	17	—	4	24
	Saudi Arabia	N	172	168	H	31	1	—	25	5
					O	137	3	2.2	56	78
	Tunisia	N	5	3	H	3	1	—	0	2
A. nigerrimus	Indonesia	N	1	1	O	1	0	—	—	1
	Viet-Nam	N	6	6	O	6	1	—	5	—
		1	1	1	O	1	0	—	1	—
A. nili	Ghana	N	47	46	H	18	18	—	0	0
					O	28	23	—	2	3
	S. Rhodesia	2	3	3	H	1	0	—	1	0
					O	2	0	—	0	2
	Upper Volta	N	16	16	O	16	12	—	4	0
		1	124	122	H	54	44	81.5	3	7
					O	68	51	75.0	2	15
A. oswaldoi	Colombia	1	48	48	H	48	1	—	18	29
A. paludis	Cameroon	N	32	32	O	32	32	—	0	0
A. pharoensis	Cameroon	N	39	39	H	38	7	—	8	23
					O	1	0	—	0	1
		1	6	6	O	6	0	—	6	0
	Egypt (UAR)	N	542	529	H	132	91	68.9	33	8
					O	397	73	18.4	227	97
		1	102	101	O	101	11	10.9	80	10
	Ghana	N	19	19	H	15	15	—	0	0
					O	4	1	—	2	1
	Nigeria	N	3	3	O	3	0	—	0	3
		1	93	93	H	2	2	—	0	0
					O	91	27	29.7	14	50
	Sudan	2	64	64	H	64	39	60.9	1	24
A. pretoriensis	Cameroon	N	16	16	O	16	0	—	12	4
		1	4	4	H	1	0	—	0	1
					O	3	0	—	1	2

TABLE 2 (*continued*)

Species	Country	Spray status of area [a]	Testing of smears: No. tested	Testing of smears: No. positive	Positive samples by class of biotope [b]: Biotope class	Positive samples by class of biotope [b]: No. of smears	Positive for primate blood: No.	Positive for primate blood: %	No. positive for bovine blood	No. positive for other host-groups [c]
A. pretoriensis (*contd.*)	S. Africa	N	1	1	O	1	0	—	0	1
		3	16	14	H	1	0	—	1	0
					O	13	0	—	9	4
	S. Rhodesia	N	1	1	O	1	0	—	1	0
		3	70	70	H	2	0	—	1	1
					O	68	1	1.5	54	13
A. pseudopuncti-pennis s.l.	Bolivia	?	39	37	H	37	11	—	0	26
	Costa Rica	1	20	19	O	19	0	—	16	3
	El Salvador	N	10	10	H	10	0	—	3	7
		1	139	128	O	128	3	2.3	77	48
	Mexico	1	122	115	O	115	2	1.7	67	46
	Peru	?	2 033	1 276	H	77	2	2.6	43	32
					O	1 199	0	0.0	1 041	158
A. pulcherrimus	Afghanistan	1	209	155	H	61	3	4.9	47	11
					O	94	9	9.6	39	46
	Saudi Arabia	2	54	51	O	51	6	11.8	26	19
A. punctimacula	Costa Rica	1	284	276	H	71	11	15.5	16	44
					O	205	1	0.5	72	132
	Ecuador	2	203	200	H	13	9	—	0	4
					O	187	5	2.7	97	85
	Peru	2	19	19	H	19	11	—	2	6
A. punctulatus s.l.	British Solomon Islands	N	25	25	H	15	14	—	0	1
					O	10	2	—	0	8
	Territory of Papua and New Guinea	N	40	40	H	40	40	—	0	0
	West Irian (Indonesia)	N	72	71	O	71	50	70.4	0	21
A. ramsayi	Pakistan (East)	3	25	25	H	6	0	—	6	0
					O	19	0	—	16	3
A. rivulorum	Zanzibar (Tanzania)	2	45	44	H	12	3	—	9	0
					O	32	0	—	24	8
A. rufipes s.l.	Cameroon	N	60	60	H	17	3	—	10	4
					O	43	3	—	23	17
		1	88	88	H	25	1	—	15	9
					O	63	2	3.2	25	36
		2	29	28	H	3	1	—	1	1
					O	25	0	—	20	5
	Mozambique	1	6	6	O	6	0	—	6	0
	S. Africa	1	4	4	O	4	0	—	4	0
		2	10	9	H	9	0	—	5	4

TABLE 2 (*continued*)

Species	Country	Spray status of area [a]	Testing of smears: No. tested	Testing of smears: No. positive	Positive samples by class of biotope [b]: Biotope class	Positive samples by class of biotope [b]: No. of smears	Positive for primate blood: No.	Positive for primate blood: %	No. positive for bovine blood	No. positive for other host-groups [c]
A. rufipes s.l. (*contd.*)	S. Rhodesia	2	30	29	H	2	0	—	2	0
					O	27	0	—	20	7
		3	284	280	H	19	1	—	14	4
					O	261	1	0.4	236	24
	Upper Volta	?	82	78	H	78	8	10.3	47	23
		N	17	16	H	15	14	—	1	0
					O	1	0	—	1	0
		1	19	17	H	1	0	—	1	0
					O	16	0	—	9	7
A. sacharovi	Greece	N	1 242	1 226	H	305	25	8.2	74	206
					O	921	56	6.1	209	656
		1	1 472	1 452	H	357	31	8.7	202	124
					O	1 095	39	3.6	626	430
	Romania	N	56	56	O	56	0	0.0	40	16
	Syria	N	176	176	H	161	67	41.6	66	28
					O	15	3	—	7	5
		1	64	63	O	63	3	4.8	34	26
A. sergenti	Jordan	N	16	16	O	16	1	—	0	15
	Morocco	N	682	521	H	82	5	6.0	36	41
					O	439	3	0.7	299	137
	Saudi Arabia	N	432	419	H	172	60	35.0	47	65
					O	247	5	2.0	128	114
	Tunisia	N	4	1	O	1	0	—	0	1
A. sinensis	Korea	?	383	383	O	383	5	1.3	239	139
		N	192	190	H	51	45	88.2	5	1
					O	139	2	1.4	108	29
		1	96	95	O	95	0	0.0	92	3
		3	139	134	H	100	33	33.0	45	22
					O	34	0	—	33	1
	Viet-Nam	N	9	9	O	9	2	—	7	0
		1	5	5	O	5	0	—	5	0
A. sineroides	Korea	N	11	11	O	11	0	—	9	2
A. smithi rageaui	Ghana	N	143	86	O	86	2	2.3	0	84
A. solomonis	British Solomon Islands	N	6	6	O	6	0	—	0	6
A. splendidus	Viet-Nam	?	2	2	H	1	1	—	0	0
					O	1	0	—	1	0
		1	3	2	O	2	0	—	2	0
A. squamosus	Upper Volta	1	2	2	O	2	0	—	2	0
A. stephensi s.l.	Pakistan	N	259	259	H	109	0	0.0	108	1
					O	150	1	0.8	149	0

TABLE 2 (*continued*)

Species	Country	Spray status of area [a]	Testing of smears: No. tested	Testing of smears: No. positive	Positive samples by class of biotope [b]: Biotope class	Positive samples by class of biotope [b]: No. of smears	Positive for primate blood: No.	Positive for primate blood: %	No. positive for bovine blood	No. positive for other host-groups [c]
A. stephensi s.l. *(contd.)*	Saudi Arabia	2	39	39	O	39	0	—	37	2
A. subpictus subpictus	Indonesia	N	28	24	H	16	0	—	14	2
					O	8	0	—	6	2
	Territory of Papua and New Guinea	N	72	24	H	24	24	—	0	0
	Viet-Nam	N	58	56	H	15	4	—	11	0
					O	41	0	—	41	0
A. subpictus malayensis	Indonesia	?	1	0	O	0	0	—	0	0
		N	188	182	H	118	0	0	109	9
					O	64	0	0	60	4
A. sundaicus	Indonesia	?	68	68	H	13	5	—	8	0
					O	55	0	0.0	47	8
		N	537	510	H	482	340	70.5	94	48
					O	28	0	—	25	3
		1	7	7	H	4	3	—	3	1
					O	3	0	—	3	0
		2	32	30	H	29	27	—	1	1
					O	1	1	—	0	0
A. superpictus	Afghanistan	?	12	12	O	12	0	—	11	1
		N	23	23	O	23	0	—	19	4
	Greece	N	366	363	O	363	0	0.0	235	128
		1	226	220	O	220	0	0.0	198	22
	Jordan	N	94	93	O	93	4	4.2	0	89
	Saudi Arabia	N	336	284	H	60	3	5.0	31	26
					O	224	6	2.7	49	169
	Syria	N	68	68	H	49	12	—	7	30
					O	19	0	—	9	10
	Turkey	?	8	8	H	6	1	—	1	4
					O	2	0	—	0	2
A. tessellatus s.l.	Indonesia	N	5	5	H	1	0	—	1	0
					O	4	0	—	3	1
	Sabah (Malaysia)	N	16	16	O	16	0	—	16	0
	Viet-Nam	N	6	6	O	6	0	—	4	2
		1	2	2	H	1	0	—	1	0
					O	1	0	—	0	1
A. triannulatus s.l.	Colombia	1	8	8	H	8	0	—	0	8
	Paraguay	1	2	2	H	2	1	—	0	1
		2	7	7	H	7	3	—	1	3
A. turkhudi	Somalia	N	1	1	O	1	0	—	1	0
		1	6	6	H	6	1	—	2	3

TABLE 2 (*concluded*)

Species	Country	Spray status of area [a]	Testing of smears		Positive samples by class of biotope [b]		Positive for primate blood		No. positive for bovine blood	No. positive for other host-groups [c]
			No. tested	No. positive	Biotope class	No. of smears	No.	%		
A. umbrosus	Indonesia	?	2	2	O	2	0	—	2	0
A. vagus s.l.	Indonesia	?	12	12	H	12	0	—	12	0
		N	11	11	H	4	0	—	4	0
					O	7	0	—	7	0
	Pakistan	N	240	219	H	10	0	—	9	1
					O	209	1	0.5	207	1
		3	32	27	H	21	0	—	19	2
					O	6	0	—	4	2
	Viet-Nam	?	39	37	H	29	0	—	29	0
					O	8	0	—	8	0
		N	189	186	H	124	6	4.8	116	2
					O	62	14	22.6	45	3
		1	186	184	H	115	1	0.9	113	1
					O	69	0	0.0	69	0
A. varuna	Pakistan	N	43	29	H	10	0	—	8	2
					O	19	0	—	16	3

[a] ? = unspecified; N = unsprayed; 1 = DDT; 2 = dieldrin; 3 = HCH.
[b] H = human and mixed habitations; O = all other biotopes.
[c] Including " unidentified mammal ".
[d] For an explanation of the use of " s.l." throughout this table, see footnote, p. 406 of text.

Therefore the sampling and precipitin testing of *Anopheles* from sprayed areas can give, in many cases, only an approximate estimate of the human blood index (Hamon, 1964). This consideration deters us from adopting the modified approach to the computation of the human blood index suggested by Garrett-Jones (1964a). We prefer simply to record the actual percentage of smears found to contain primate blood, once the species, spray-status of the area, and class of biotope have been stated. We have refrained from so doing where the classified sample giving a positive reaction contains less than 50 specimens. For samples of 50 and over the percentage is recorded to one place of decimals.

The data on the tests carried out during 1960-64 at the National Institute of Communicable Diseases on *Anopheles* from Ceylon, India and Nepal are presented in Tables 3a, 3b and 3c, respectively. The results include eight samples of more than 1000 smears, 19 of between 100 and 1000, seven of between 50 and 100, and only two of less than 50 smears. However, it should be noted that each " sample " comprises all the collections from one species and country found to give a positive reaction. Thus, where such a cumulative " sample " originated from different parts of a country as large as India, the summarized results may conceal wide disparities by area or time of collection.

The entire island of Ceylon had entered the consolidation phase of malaria eradication by May 1964. Although some DDT spraying was resumed in 1965 in the eastern part of the country, insecticidal pressure on the vector population has been slight over most of the island since 1962.

India, with the largest single malaria eradication programme in the world, has been passing gradually since 1958 from the attack to the consolidation phase, spraying being discontinued over an increasing number of areas between 1960 and 1964. At present 85% of the population in the area originally malarious (470 million population) is in the consolidation or maintenance phase.

In Nepal the attack phase in the malarious part of the country has expanded zone by zone since 1962, and the cumulative samples may have been collected partly in areas with no previous spray-history and

TABLE 3. RESULTS OF PRECIPITIN TESTS ON ORIENTAL *ANOPHELES* CARRIED OUT AT THE NATIONAL INSTITUTE OF COMMUNICABLE DISEASES, DELHI, 1960-64 [a]

Species	Testing of smears [b]		Positive samples by class of biotope [c]		Positive for primate blood		No. positive for bovine blood	No. positive for other hosts	States
	No. tested	No. positive	Biotope class	No. of smears	No.	%			
				(a) Samples from Ceylon					
A. annularis	90	78	O	78	7	8.9	68	3	
A. culicifacies	116	84	H	82	31	37.8	46	5	
			O	2	2	—	0	0	
A. fluviatilis	75	70	H	19	2	—	17	0	
			O	51	4	7.8	47	0	
A. hyrcanus s.l.	51	36	O	36	11	—	25	0	
A. maculatus	72	62	H	1	0	—	1	0	
			O	61	3	4.9	58	0	
A. pallidus	119	82	H	1	0	—	1	0	
			O	81	11	13.6	65	5	
A. subpictus subpictus	578	470	H	359	49	13.6	308	2	
			O	111	21	18.8	76	14	
A. vagus vagus	97	77	H	8	0	—	8	0	
			O	69	26	37.7	40	3	
				(b) Samples from India					
A. annularis	731	672	H	255	64	25.1	191	0	Andhra Pradesh, Assam, Bihar, Madhya Pradesh, Mysore, Uttar Pradesh
			O	417	79	18.9	338	0	
A. barbirostris s.l.	120	118	H	55	0	0.0	55	0	Andhra Pradesh, Madras, Mysore
			O	63	0	0.0	63	0	
A. culicifacies	2 808	2 662	H	1 155	29	2.5	1 126	0	Andhra Pradesh, Bihar, Bombay, Gujerat, Madhya Pradesh, Uttar Pradesh
			O	1 507	23	1.5	1 483	1	
A. elegans	130	128	O	128	0 [d]	0.0	2	126 [d]	Madras
A. fluviatilis	1 431	1 372	H	500	24	4.8	475	1	Andhra Pradesh, Bihar, Madhya Pradesh, Mysore, Uttar Pradesh, West Bengal
			O	872	7	0.8	864	1	
A. hyrcanus s.l.	338	314	H	125	0	0.0	125	0	Andhra Pradesh, Mysore
			O	189	0	0.0	189	0	
A. jeyporiensis s.l.	204	200	H	18	0	—	18	0	Andhra Pradesh, Madras, Mysore
			O	182	1	0.5	181	0	
A. maculatus s.l.	161	143	H	95	11	12	84	0	Assam, Madhya Pradesh, Madras
			O	48	0	—	48	0	
A. philippinensis	111	111	H	2	2	—	0	0	Assam, West Bengal
			O	109	0	0.0	109	0	
A. splendidus	97	95	O	95	1	1.1	94	0	Madhya Pradesh, Madras
A. stephensi s.l.	394	355	H	144	4	2.8	140	0	Madhya Pradesh, Mysore, Uttar Pradesh
			O	211	1	0.5	210	0	
A. subpictus subpictus	2 154	2 078	H	934	70	7.5	864	0	Andhra Pradesh, Bihar, Madhya Pradesh, Mysore, Uttar Pradesh
			O	1 144	101	8.8	1 042	1	
A. sundaicus	160	127	H	55	3	5.5	52	0	West Bengal
			O	72	6	8.3	66	0	
A. tessellatus s.l.	403	360	H	2	0	—	2	0	Andhra Pradesh, Bombay, Madras, Mysore
			O	358	4	1.1	354	0	
A. vagus vagus	33	33	H	28	0	—	28	0	Andhra Pradesh, Madras, Mysore, Uttar Pradesh, West Bengal
			O	5	0	—	5	0	
A. varuna	118	117	O	117	1	0.9	116	0	Bombay, Madhya Pradesh

TABLE 3 (*concluded*)

Species	Testing of smears [b]		Positive samples by class of biotope [c]		Positive for primate blood		No. positive for bovine blood	No. positive for other hosts
	No. tested	No. positive	Biotope class	No. of smears	No.	%		
(*c*) Samples from Nepal								
A. aconitus	112	109	H	29	5	—	24	0
			O	80	0	0.0	80	0
A. annularis	2 113	1 991	H	373	15	4.0	358	0
			O	1 618	17	1.1	1 599	2
A. culicifacies	3 906	3 688	H	2 808	103	36.7	2 704	1
			O	880	10	1.1	870	0
A. fluviatilis	3 529	3 309	H	1 756	605	34.5	1 150	1
			O	1 553	36	2.3	1 517	0
A. hyrcanus s.l.	102	99	H	55	2	3.6	53	0
			O	44	1	—	43	0
A. jeyporiensis s.l.	40	37	H	18	16	—	2	0
			O	19	3	—	16	0
A. maculatus s.l.	2 334	2 227	H	192	21	10.9	171	0
			O	2 035	20	1.0	2 015	0
A. minimus minimus	2 625	2 511	H	2 455	2 280	92.9	172	3
			O	56	15	27	41	0
A. splendidus	817	770	H	232	5	2.2	227	0
			O	538	6	1.1	532	0
A. subpictus subpictus	63	59	H	41	0	—	41	0
			O	18	0	—	18	0
A. vagus vagus	334	313	H	158	2	1	156	0
			O	155	2	1	153	0
A. varuna	108	99	H	71	57	80	14	0
			O	28	1	—	27	0

[a] Spray-status at sampling unspecified throughout this table.
[b] These totals do not include the number of specimens from unspecified and unclassified resting-places.
[c] H = human and mixed habitations; O = all other biotopes.
[d] None positive for *human* blood, but 126 positive for monkey blood.

partly in areas sprayed with DDT for one or two years.

Some information on the relative host-selection habits of 52 anopheline species can be gathered from Table 4, which gives the differential percentages of positive reactions to the antisera of primates, Equidae, Bovinae, Ovinae, dogs, pigs and birds. Only samples containing over 50 positive smears per species and series have been included. The consolidated data for the period 1955-64 represent a total of 87 128 precipitin tests positive for known categories of hosts.

Finally, Tables 5 and 6 indicate the relationship of the human blood index in some species of *Anopheles* in areas where the history of residual spraying is well known and where a change of host selection in certain malaria vectors may be suspected.

DISCUSSION

Human blood index of the various Anopheles *species*

Of the total of 124 188 precipitin tests shown in Table 1, 93.8% gave positive results. This leaves substantially the same proportion of negative tests as was found during the first five years of the precipitin test service (WHO & Lister Institute, 1960). The 6.2% of negative tests are due either to the fact that some blood-feeds were incomplete or old or to the mosquitos having fed on animals other than those tested for.

Bearing in mind that a single " sample " in Table 1 may be spread over several countries and over a period of five years, the degree of " anthropophily " that may be assigned to it constitutes only the roughest indication of the host-selection pattern.

TABLE 4

PRECIPITIN ANALYSIS OF HOSTS OF 52 *ANOPHELES* SPECIES IN SERIES I AND II (SEE TABLE 1)

Species and series [a]		Country	No. of positive reactions	Percentage of positive smears containing blood of								
				Primates	Bovinae	Equidae	Ovinae	Canidae	Suidae	Birds	Mixed animal groups	Other animals or unclassified
A. aconitus	I	Indonesia	2 945	5.3	93.5	<1	<1				<1	<1
	II	Indonesia	862	9.7	70.0	0	<1	0	<1	0	0	19.8
A. albimanus	I	Colombia, Ecuador, Mexico, Peru	1 433	9.3	10.3	3.5	7.4	33.0	31.0	1.3	0.4	<1
	II	Costa Rica	111	1.8	42.3	9.9	0	0	27.0	0	1.8	17.1
		Ecuador	420	3.1	32.1	0	0	2.4	61.4	0	0	<1
		Mexico	551	0	1.5	5.8	0	0	89.8	0	<1	2.0
A. albitarsis	I	Bolivia, Colombia, Paraguay	148	23.6	4.7	18.9	0	23.0	8.8	7.4	0	12.8
	II	Paraguay	192	64.1	2.6	2.6	3.1	13.5	0	5.2	0	8.9
A. annularis	I	Indonesia	508	<1	93.2	<1	0	0	0	0	0	0
	II	India	144	0	99.3	0	0	0	0	0	0	<1
		Pakistan	423	<1	80.1	0	<1	0	0	0	0	18.9
A. balabacensis	I	Sabah (Malaysia)	2 511	50.5	41.5	0	<1	5.9	1.4	<1	0	0
A. barbirostris s.l.	I	Indonesia, Sarawak (Malaysia)	2 782	64.5	8.4	0	0	28.2	8.5	0	<1	0
A. christyi	II	Ethiopia	103	0	100.0	0	0	0	0	0	0	0
A. cinereus	I	Saudi Arabia	137	0	78.7	17.0	0	0	0	0	0	4.4
A. claviger	II	Turkey	105	83.8	4.8	8.6	0	0	0	0	0	2.8
A. coustani s.l.	I	Cameroon, Ghana, Nigeria, S. Rhodesia, Tanganyika, UAR, Upper Volta, Zanzibar (Tanzania)	109	10.7	44.5	34.0	2.1	0	0	0	0	8.5
A. culicifacies	II	Ceylon	223	34.1	48.4	0	0	17.5	0	0	0	0
		India	489	0	86.5	<1	<1	0	0	0	0	12.5
A. darlingi	I	Bolivia, Colombia	114	45.5	0	0	0	49.0	0	0	0	4.5
A. dthali	II	Morocco	241	15.8	16.6	28.2	25.7	3.7	<1	0	0	9.1
A. farauti	II	British Solomon Islands	161	65.8	0	<1	0	23.0	8.7	<1	0	1.2
		Territory of Papua and New Guinea	457	85.8	0	<1	0	10.5	<1	<1	0	2.6
A. flavicosta	I	Upper Volta	73	15.0	68.4	0	4.1	4.1	0	6.8	0	1.4
	II	Upper Volta	94	4.3	73.4	0	3.2	1.1	0	1.1	0	17.0
A. fluviatilis	I	Iran, Iraq, Saudi Arabia	58	3.4	58.0	14.0	6.5	1.7	0	6.5	10.0	0

TABLE 4 (*continued*)

Species and series [a]		Country	No. of positive reactions	Percentage of positive smears containing blood of								
				Primates	Bovinae	Equidae	Ovinae	Canidae	Suidae	Birds	Mixed animal groups	Other animals or unclassified
A. fluviatilis (*contd.*)	II	India	213	<1	80.7	0	0	0	0	0	0	18.8
		Pakistan	115	0	92.2	0	0	0	0	0	0	7.8
		Saudi Arabia	143	0	83.0	7.0	0	0	0	0	0	7.0
A. funestus s.l.	I	Cameroon, Ghana, Liberia, Nigeria, S. Rhodesia, Tanzania, Uganda, Upper Volta	4 762	70.0	24.9	1.6	1.2	<1	<1	<1		3.0
	II	Cameroon	528	67.8	15.9	7.6	4.9	<1	0	0	0	3.6
		Ghana	556	83.1	14.2	0	<1	0	<1	0	0	2.2
		Liberia	845	98.7	0	0	0	<1	<1	0	0	1.1
		Madagascar	434	42.4	30.6	0	<1	2.5	<1	<1	0	22.6
		Mozambique	300	58.3	37.3	0	1.7	<1	1.7	0	0	<1
		Nigeria	158	96.2	1.3	1.3	0	0	0	0	0	1.3
		S. Rhodesia	234	11.5	82.9	<1	<1	2.1	0	0	0	2.6
		Togo	267	99.6	0	0	0	0	<1	0	0	0
		Uganda	835	70.2	13.9	0	4.3	1.4	0	0	0	10.2
		Upper Volta	625	54.9	29.1	0	2.7	<1	<1	<1	0	11.7
A. gambiae s.l.	I	Cameroon, Congo (Democratic Republic), Ethiopia, Ghana, Liberia, Mauritius, Nigeria, Saudi Arabia, Somalia, S. Rhodesia, Sudan, Tanzania, Uganda, Upper Volta	12 370	81.0	14.2	1.0	<1	<1	<1	<1	<1	2.1
	II	Cameroon	805	81.0	11.8	3.4	<1	<1	<1	0	0	2.7
		Ghana	471	88.7	0	0	<1	3.0	5.7	<1	<1	1.7
		Madagascar	353	1.0	81.9	0	0	<1	<1	0	0	6.2
		Mauritania	87	73.5	14.9	6.9	3.4	1.2	0	0	0	0
		Mauritius	180	1.1	88.9	0	4.4	2.2	<1	<1	0	2.2
		Mozambique	938	67.6	25.3	0	<1	1.8	1.1	0	0	3.9
		Nigeria	254	81.9	4.3	12.2	<1	<1	0	0	0	<1
		Saudi Arabia	483	71.4	20.7	<1	1.2	0	0	<1	0	5.8
		Somalia	1 072	53.4	24.9	<1	3.3	<1	0	<1	1.9	16.0
		S. Africa	1 187	<1	87.6	1.2	5.2	<1	<1	0	0	5.3
		S. Rhodesia	1 170	20.0	63.1	1.3	7.4	4.4	<1	0	0	3.2
		Swaziland	294	75.5	11.9	<1	<1	2.0	1.4	0	0	8.2
		Togo	201	84.0	0	0	0	<1	13.9	<1	0	<1
		Uganda	1 599	78.6	14.6	0	1.0	<1	0	<1	0	4.8
		Upper Volta	555	87.4	3.2	1.6	<1	<1	0	0	0	7.2
		Zanzibar (Tanzania)	1 959	28.8	63.5	0	<1	<1	<1	0	0	7.0
A. hargreavesi	I	Ghana	117	98.3	<1	0	0	0	0	0	0	<1
A. hispaniola	II	Morocco	208	0	27.9	10.6	0	2.4	0	<1	0	58.6
A. kochi	I	Cambodia, Indonesia	414	0	99.5	<1	0	0	0	0	0	0
A. koliensis	II	West Irian (Indonesia)	345	80.3	0	0	0	7.8	<1	2.0	0	9.0

TABLE 4 (continued)

Species and series [a]		Country	No. of positive reactions	Percentage of positive smears containing blood of								
				Primates	Bovinae	Equidae	Ovinae	Canidae	Suidae	Birds	Mixed animal groups	Other animals or unclassified
A. labranchiae labranchiae	I	Morocco	578	19.5	41.5	19.3	<1	2.3	0	0	0	16.8
	II	Morocco	477	15.5	44.0	21.4	<1	2.1	0	0	0	16.6
A. leucosphyrus leucosphyrus	I	Sarawak (Malaysia)	1 562	95.0	0	<1	0	3.7	<1	<1	0	0
A. maculatus s.l.	I	Cambodia, Indonesia, Taiwan (China)	270	<1	99.2	0	0	<1	0	0	0	0
A. maculipalpis	I	Ghana, S. Rhodesia, Zanzibar (Tanzania)	166	0	94.5	2.4	<1	1.2	0	0	0	0
A. maculipennis s.l.	I	Greece, Iran, Iraq, Portugal	1 159	1.7	63.5							
	II	Greece	706	2.0	93.1	<1	<1	<1	2.0	1.1	<1	<1
		Portugal	572	0	55.6	<1	<1	0	30.8	<1	0	11.9
A. maculipennis messeae	II	Romania	119	0	42.0	0	3.4	0	54.6	0	0	0
A. marshalli	I	Congo (Democratic Republic), S. Rhodesia, Tanganyika (Tanzania)	238	26.5	64.5		4.6	<1			<1	
	II	Ethiopia	172	2.9	92.4	0	4.7	0	0	0	0	0
A. minimus minimus	I	Cambodia, China (Taiwan)	129	7.7	90.0	0	0	0	1.5	<1	0	0
A. minimus flavirostris	I	Indonesia, Philippines	140	47.1	48.6	0	0	0	4.3	0	0	0
A. moucheti	I	Cameroon, Nigeria	148	82.5	6.8	6.8	1.4	2.0	0	0	<1	0
A. multicolor	I	Iran, Saudi Arabia, Tunisia	278	6.1	51.0	25.2	0	0	0	<1	5.5	6.9
	II	Saudi Arabia	168	2.4	48.2	25.0	0	0	0	0	0	24.4
A. nigerrimus	I	Indonesia (Sumatra)	145	7.6	90.5	0	1.4	0	0	0	0	<1
A. nili	I	Cameroon, Ghana, Upper Volta	378	85.8	3.2	<1	<1	2.6	<1		<1	7.0
	II	Upper Volta	138	77.5	6.5	3.0	0	3.0	<1	<1	0	8.6
A. pharoensis	I	Cameroon, Congo (Democratic Republic), Ethiopia, Ghana, Nigeria, Uganda, UAR	1 218	51.3	28.2	9.6	1.2	1.3	0	0	<1	6.0
	II	UAR	630	27.8	54.0	3.8	<1	1.4	0	0	<1	12.7
A. pretoriensis	I	Cameroon, Ghana, S. Rhodesia	156	<1	93.6	2.6	<1	1.3	0	0	0	1.3
A. pseudopunctipennis s.l.	I	Bolivia, Colombia, Mexico, Peru	3 189	33.7	30.0	12.9	3.0	11.6	5.4	1.0	<1	4.6
	II	El Salvador	138	2.2	58.0	12.3	0	3.6	<1	0	0	23.1
		Mexico	115	1.7	58.3	24.3	0	1.7	<1	0	0	13.0
		Peru	1 276	<1	85.0	1.1	0	2.3	<1	<1	0	10.7

TABLE 4 (*concluded*)

Species and series [a]		Country	No. of positive reactions	Percentage of positive smears containing blood of: Primates	Bovinae	Equidae	Ovinae	Canidae	Suidae	Birds	Mixed animal groups	Other animals or unclassified
A. pulcherrimus	I	Iran, Iraq, Saudi Arabia	444	5.4	65.0	27.6	<1	0	0	0	0	2.7
	II	Afghanistan	158	7.6	54.4	9.5	1.3	<1	0	0	0	26.6
A. punctimacula	I	Ecuador	131	0	72.5	22.8	0	0	0	0	0	4.6
	II	Costa Rica	276	4.3	31.9	13.8	0	<1	46.0	0	0	3.6
		Ecuador	200	7.0	48.5	0	0	<1	43.0	0	0	<1
A. rivulorum	I	Zanzibar (Tanzania)	329	<1	95.5	<1	0	<1	0	0	0	1.5
A. rufipes s.l.	I	Cameroon, Ghana, Nigeria, S. Rhodesia, Upper Volta	548	9.4	73.2	4.7	4.0	1.3	<1	0	0	2.7
	II	Cameroon	176	5.7	53.4	22.7	8.0	0	0	0	<1	9.7
		S. Rhodesia	309	<1	88.0	1.9	4.2	1.9	0	0	0	3.2
		Upper Volta	111	19.8	53.2	5.4	0	0	1.8	0	0	19.8
A. sacharovi	I	Afghanistan, Greece, Iraq, Syria	6 342	5.8	49.7	23.7	7.6	1.2	10.9	<1	<1	<1
	II	Greece	2 678	5.6	41.5	18.6	13.6	2.1	15.3	<1	<1	2.2
		Syria	239	30.5	44.7	12.6	5.0	<1	0	0	0	6.7
A. sergenti	I	Morocco, Saudi Arabia, Tunisia	609	6.5	69.3	14.4	<1	<1	1.3	0	2.3	5.5
	II	Morocco	520	1.5	64.4	13.1	1.2	1.5	1.5	0	<1	15.8
		Saudi Arabia	419	15.5	41.8	24.1	0	0	0	<1	0	18.3
A. sinensis	II	Korea	802	10.6	65.1	0	0	<1	21.0	0	0	2.6
A. stephensi s.l.	I	Iran, Iraq, Saudi Arabia	469	5.3	42.5	49.5	4.0	<1		<1	<1	0
	II	Pakistan	259	<1	99.2	0	0	0	0	0	0	<1
A. subpictus subpictus	I	Indonesia	498	24.8	75.0	<1	<1	0	0	0	0	0
A. subpictus malayensis	I	Indonesia	885	<1	98.5	<1	0	0	0	<1	<1	
	II	Indonesia	182	0	92.9	0	0	0	0	0	0	7.1
A. sundaicus	I	Indonesia	1 064	77.1	21.9	0	<1	0	<1	<1	<1	<1
	II	Indonesia	615	61.1	28.9	0	0	1.2	0	0	0	8.8
A. superpictus	I	Afghanistan, Greece, Iran, Iraq, Saudi Arabia, Syria	1 404	4.3	59.5	11.7	12.4	<1	1.5	<1	2.2	8.3
	II	Greece	583	0	74.3	3.3	9.6	0	<1	0	0	12.7
		Saudi Arabia	284	3.2	28.2	13.4	3.2	0	0	0	1.4	50.7
A. vagus s.l.	I	Cambodia, Indonesia	865	<1	99.5	0	<1	0	0	0	<1	0
	II	Pakistan	261	<1	97.3	0	0	0	0	0	0	2.3
		Viet-Nam	407	5.2	93.4	0	0	0	1.2	<1	0	0
A. wellcomei	I	Cameroon, Nigeria	325	98.4	<1	1.5	0	0	0	0	0	0

[a] Series I, 1955 to mid-1959; Series II, mid-1959 to 1964. All tests performed at the Lister Institute.

TABLE 5

RELATIONSHIPS OF THE HUMAN BLOOD INDEX IN *ANOPHELES* SPECIES FROM SOME AREAS TREATED WITH RESIDUAL INSECTICIDES AND FROM UNSPRAYED AREAS

Spray status at sampling	Species classified according to unweighted mean proportions positive for primate blood		
	High (> 50 %)	Medium (10 %-50 %)	Low (< 10 %)
Unsprayed	*farauti* (Territory of Papua and New Guinea) *funestus* (Cameroon, Ghana, Togo, Upper Volta *gambiae* s.l. (Cameroon, Ghana, Mozambique, S. Rhodesia, Togo)	*aconitus* (Indonesia) *pharoensis* (UAR) *sergenti* (Saudi Arabia) *sinensis* (Korea) *vagus* s.l. (Viet-Nam)	*fluviatilis* (Pakistan) *maculipennis* s.l. (Greece) *sacharovi* (Greece) *sergenti* (Morocco) *stephensi* s.l. (Pakistan) *subpictus malayensis* (Indonesia) *superpictus* (Saudi Arabia)
DDT	*funestus* s.l. (Cameroon) *gambiae* s.l. (Cameroon, Mozambique, Uganda) *nili* (Upper Volta)	*gambiae* s.l. (Zanzibar (Tanzania))	*albimanus* (Mexico) *culicifacies* (India) *pulcherrimus* (Afghanistan) *punctimacula* (Costa Rica) *sacharovi* (Greece) *vagus* s.l. (Viet-Nam)
Dieldrin		*funestus* s.l. (Madagascar) *gambiae* (Zanzibar)	
HCH			*gambiae* s.l. (S. Africa, S. Rhodesia)

TABLE 6

ANALYSIS OF SAMPLES OF *A. GAMBIAE* s.l. FROM ZANZIBAR AND PEMBA ISLANDS (TANZANIA)

Territory	Insecticide (and period)	Testing of smears		Positive samples by class of biotope		Positive for primate blood		No. positive for bovine blood	No. positive for other host-groups [b]
		No. tested	No. positive	Biotope class [a]	No. of smears	No.	%		
Zanzibar Island	dieldrin (1958-60)	674	609	H	256	245	95.8	7	4
				O	353	2	0.6	310	51
	DDT (1961-64)	149	130	H	15	15	—	0	0
				O	115	23	20.0	86	6
Pemba Island	Unsprayed (May 1958-Jan. 1959)	336	335	H	335	331	98.8	0	4
	dieldrin (1959-60)	1 010	893	H	509	351	69.0	120	38
				O	384	15	3.9	307	62
	DDT (1960-64)	481	446	H	51	15	29.4	36	0
				O	395	21	5.3	368	6

[a] H = human and mixed habitations; O = other biotopes (all out-of-doors).

[b] Including a few " unidentified mammal ", which might be of human, bovine or other origin.

More intensive sampling and testing would usually be required to determine the human blood index of a species at a given time and place:

> " Logically, to obtain unbiased results it would seem necessary to examine specimens from all possible resting places, including the outdoor ones, and possibly at different times of the day and night. We must confess that we have not yet developed a satisfactory method for using a test which is, by itself, extremely satisfactory " (Pampana, 1963, page 36).

In the three series of Table 1 representing 92 species, about 47% of the specimens were collected from human or mixed dwellings and 44% from other shelters, including outdoor ones. The remainder were from unspecified biotopes. In the second series (1960-64), 47% were collected from human or mixed dwellings and 53% from other shelters. The technical reasons for the small size of many samples from biotope Class-H in sprayed areas have been mentioned above. It is none the less unfortunate that only two of the 446 samples shown in Table 2 exceeded 1000 smears giving a positive reaction, whereas 343 (77%) were of less than 100 smears each and 290 (65%) of less than 50 each.

Subject to the reservations already mentioned, the consolidated results given in Table 1 provide, we believe, valid indications of the human blood index of the various *Anopheles* species sampled. The geographical exceptions—those areas where primates other than man provide a source of blood to particular species—will be familiar to the field workers directly concerned. They are, moreover, best qualified to judge whether the sampling of a species from Class-H and Class-O biotopes fairly represents its actual diurnal distribution, having regard to the relative prevalence of the biotopes themselves and of the blood-fed females resting in each biotope. That is why we prefer to exercise caution in discussing the data presented, and to leave it to those well acquainted with a given country and vector to place their own interpretation on the summarized findings. Only some general conclusions pertaining to important vector species will be given here.

Host selection by Anopheles *and malaria of man and animals*

One of the most interesting developments in malariology is related to the recent substantial increase in observations of *Anopheles* found infected with malaria parasites of non-human origin. The precipitin test indicated the probable rodent origin of infections with *Plasmodium berghei* (Vincke & Lips, 1950), transmitted by *A. dureni* in the Congo. Since this discovery, other natural vectors of animal plasmodia have been found. It is now known that species of *Anopheles* carry plasmodia of tree rats, porcupines, mouse-deer, squirrels, antelopes and bats, as well as primates. Recent records of *Anopheles* vectors of animal malaria parasites have been summarized by Bray & Garnham (1964). The role of precipitin testing for the eventual discovery of unknown vectors of known parasites (e.g., *P. voltaicum* van der Kaay) or known vectors of unknown parasites (e.g., *A. machardyi*) has been discussed by Reid & Weitz (1961). A recent study by Adam (1965) of a group of at least seven African cave-dwelling *Anopheles* species showed that their host-selection habits may give a clue to the identity of the malaria parasites they carry.

The rapid increase of our knowledge of simian malaria (Coatney, 1963) has directed attention to the importance of distinguishing between the mosquito blood-meals taken on man and those from other primates. Warren & Wharton (1963) indicate that, of 65 species of *Anopheles* recognized as vectors of human malaria, not less than 21 are natural or experimental vectors of simian malaria.

In blood-meal samples collected from uninhabited forest and found to be positive for primate blood, it is likely that monkeys were the hosts. But where the mosquito may have fed either on man or on other animals, the precipitin test cannot provide the answer; more precise analysis requires the use of the agglutination-inhibition test described by Weitz (1956).

A modified technique, using erythrocytes treated with bis-diazotized benzidine (Gordon, Rose & Sehon, 1958), gives more reproducible results. However, the method is more elaborate than the precipitin test and requires a better quality of blood smear. In spite of the diversity of primates in various parts of the world, it is hoped in time to provide for the identification of blood-meals taken from many of them.

Reid & Weitz (1961) recorded the blood-meal analysis of samples of several *Anopheles* of Malaya, where, in the warm humid climate, all members of the genus were largely exophilic and some species completely so. The locality studied was on the fringe of the mangrove forest. In such conditions the classification of biotopes into " H " and " O "

TABLE 7

RESULTS OF PRECIPITIN AND AGGLUTINATION-INHIBITION TESTS ON OUTDOOR-RESTING MOSQUITOS [a]

Anopheles species	No. tested	No. positive	No. with primate blood			No. with bovid blood			No. with unidentified mammalian blood
			Total primate	Man	Monkey	Total bovid	Ox	Goat	
A. baezai	158	138	1	1	—	94	15	20	43
A. barbirostris [b]	29	27	27	17	8	—	—	—	—
A. hackeri	178	68	56	1	25	2	2	—	10
A. pujutensis	88	35	24	1	2	—	—	—	11

[a] After Reid & Weitz (1961).

[b] The *A. barbirostris* sample was the dark-winged form subsequently described by Reid (1962) as *A. campestris* sp. n. and identified as an important vector of malaria of man on the western coastal plain of Malaya and also as a probable vector of monkey malaria.

becomes inapplicable, and the human blood index can be estimated only in samples from the natural biotope or biotopes of the given species, the sites of sampling being well distributed in and around the inhabited locality. The results of precipitin and agglutination-inhibition tests on outdoor-resting samples gave the general picture shown in Table 7.

Discussing these results, Reid & Weitz (1961) considered it probable that most of the unidentified primate blood-meals of *A. hackeri* and *A. pujutensis* were from monkeys. The chief host of *A. baezai* was thought to be an undetermined wild mammal, possibly mouse-deer. Both *A. baezai* and *A. hackeri* were found, on dissection of large samples, to have a sporozoite rate of 2.0%.

The complicated situation in South-East Asia, with a record of no less than 33 anopheline species, is of great scientific and practical interest. Several members of the *A. leucosphyrus* group are responsible for transmission of both human and simian malaria. Thus *A. hackeri* transmits *Plasmodium knowlesi*, *P. cynomolgi*, *P. coatneyi*, and *P. fieldi*; *A. leucosphyrus leucosphyrus* transmits *P. inui*; *A. balabacensis* (sensu lato) transmits *P. cynomolgi* and *P. inui* (Wharton & Eyles, 1961; Wharton et al., 1962; Warren & Wharton, 1963; Eyles et al., 1963; Cheong et al., 1965). *A. letifer*, a vector of human malaria in Selangor, Malaya, is probably also a vector of two animal plasmodia, one of which may be simian (Moorhouse, 1965). A noteworthy finding is that 98% of the blood-meals of *A. elegans* from Madras, India, are of simian origin, as indicated in Table 3b; this species is an Indian representative of the *leucosphyrus* group (Colless, 1956, page 75).

Apparent changes of host-selection habits

In malaria eradication the possible influence of the large-scale use of residual insecticides on host selection by the vectors is of epidemiological interest (Hamon, Chauvet & Mouchet, 1963; Mouchet, 1963). Some observations of apparent changes in the human blood index are shown in Table 5. The classification, based on data from Table 2, applies to samples collected in 1959-64 and refers to the unweighted mean of the proportions containing primate blood in the samples from Class-H and Class-O biotopes. This eliminates any bias due to the relative smallness of the samples collected in sprayed premises (Garrett-Jones, 1964a). The samples exhibiting less than 10% of biting-contact with primates are from 14 species. The inclusion of *A. gambiae* s.l. (Southern Rhodesia) in this class is now recognized as an effect of interspecific selection within the complex, leading to the predominance of "*A. gambiae-C*", a species that is naturally exophilic and zoophilic (Paterson, 1964; Ramsdale, unpublished results).

The results from Southern Asia (Table 3) relate to three countries (Ceylon, India and Nepal) where malaria eradication programmes are well advanced. In the recognized vectors the following human blood indices (Table 8) may be inferred by the method of the unweighted mean for India and Nepal, respectively. The human blood index (HBI) is expressed as a fraction of unity (e.g., 0.1 = 10%) for con-

TABLE 8
HUMAN BLOOD INDICES OF *ANOPHELES* SPECIES IN INDIA AND NEPAL

Species	Human blood index (and size of sample)	
	India	Nepal
A. annularis	0.22 (672)	0.026 (1 991)
A. culicifacies	0.040 (2 622)	0.189 (3 688)
A. fluviatilis	0.027 (1 372)	0.184 (3 309)
A. minimus	—	0.600 (2 511)
A. stephensi	0.018 (355)	—
A. sundaicus	0.07 (127)	—

venience in calculating the mosquito's vectorial capacity (Table 8).

Human blood indices of less than 0.1 may also be inferred for *A. barbirostris*, *A. subpictus* and *A. hyrcanus* in India, and for *A. splendidus*, *A. vagus* and *A. maculatus* in Nepal. On the other hand, *A. subpictus* in Ceylon showed an HBI of more than 0.1.

Much lower degrees of contact with man are shown for *A. culicifacies* and *A. fluviatilis* in India than in Nepal. The long-maintained DDT spraying in India may have reduced the human blood index in the principal vector species. That could hardly be attributed to increased outdoor resting by DDT-irritated mosquitos surviving in the sprayed areas, since any movement of engorged females from sprayed to unsprayed shelters would tend to increase, rather than to decrease, the estimated HBI. If the DDT pressure has produced real changes in the host-selection pattern, they may reflect changes of host preference, which should persist for some time after withdrawal of the pressure.

A. annularis is the only species to show a much higher HBI in India than in Nepal. The figures seem to imply that in India *A. annularis* might constitute a greater potential danger than *A. culicifacies* or *A. stephensi*, in circumstances where the three vectors show comparable biting density and longevity. However, other results for *A. annularis* (Table 2) indicate a zero HBI in DDT-sprayed areas of India and a very low index in unsprayed areas of Pakistan. Senior-White (1947) identified human blood in 3.6% of samples from houses in the Orissa Plain, where *A. annularis* was a vector, but in only 0.2% of samples from cowsheds.

For *A. culicifacies* also, Table 2 shows a zero HBI in DDT-sprayed areas of India. Bhatia & Krishnan (1961) assembled earlier records (but from unspecified biotopes) for *A. culicifacies*, and showed that the proportion containing human blood ranged from 0.25% to 80%. In WHO & Lister Institute (1960) no data are given on this species, while Garrett-Jones (1964a) estimated an average HBI of 0.16 in unsprayed areas of West Pakistan, India and Ceylon.

Similar low indices from unspecified biotopes were found by earlier workers for *A. stephensi*, according to Krishnan (1961), but he reports that in 1949-50 samples with proportions of 41% and 47% containing human blood were collected in Hyderabad State. Possibly those were from urban areas, in view of the breeding habits of *A. stephensi stephensi*. Data in the later reviews refer only to samples representing the rural *A. stephensi mysorensis* from Iran, Iraq and Saudi Arabia, where an HBI of about 0.12 in 1957-58 may be estimated from the results given in WHO & Lister Institute (1960).

A large increase of the index in *A. fluviatilis* apparently occurred between 1938-39 (1.4%) and 1949-52 (41.2%) in the Tarai of Uttar Pradesh, where this species was then the main vector (Issaris, Rastogi & Ramakrishna, 1953). In the interval the region had been transformed from a densely wooded, sparsely populated country into one where the forests had been cleared and the land drained for agriculture, and where large-scale rural settlement was in progress. This development created opportunities for a much higher degree of mosquito-man contact than before (Ramakrishnan & Satya Prakash, 1953; Sharma, 1961). Issaris, Rastogi & Ramakrishna (1953) compared their results in the unsprayed Tarai with those of Senior-White (1947) in East Central India (Table 9).

The figures in Table 9 imply a human blood index of about 0.37 in East Central India and about 0.48 in the Tarai. Much lower values have been recorded over the past five years: 0.184 in Nepal and 0.028 in India (Table 3), zero in Pakistan (Table 2).

Lastly, *A. minimus* from Nepal (Table 3c) shows an HBI of 0.60, on a sample of 2511. Senior-White (1947), on a sample of 367 smears from this species in East Central India, recorded 79.9% with human blood in houses, against 41.4% in Class-O biotopes. An HBI of 0.61 is estimated from his findings.

Table 6 analyses the results obtained on the *A. gambiae* complex from the islands of Zanzibar and Pemba (Tanzania). The two islands are of

TABLE 9
PRECIPITIN TESTS ON BLOOD-MEALS OF *A. FLUVIATILIS* IN TWO AREAS OF INDIA BEFORE SPRAYING

Biotope	East Central India (Senior-White, 1947)		U. P. Tarai, 1949-52 (Issaris et al., 1953)	
	No. of smears	% with human blood	No. of smears	% with human blood
Cattle sheds	445	11.7	134	28.4
Out of doors	39	(74.4)	38	(44.7)
Human dwellings	1 050	56.8	73	63.0
Total	1 534	44.1; 36.8 [a]	245	41.2; 47.5 [a]

[a] Weighted means, as used by the authors cited, followed by unweighted means.

different formation and support different *A. gambiae* populations. This table comprises samples from the pre-spray period, from the period when the islands were sprayed with dieldrin, and from the period since spraying with DDT began. The results from Pemba show that the proportion of mosquitos with primate blood in houses fell from about 99% before spraying to 69% under dieldrin and to 29% under DDT. In Class-O biotopes the proportion remained low on Pemba but increased to 20% under DDT on Zanzibar.

These results should be related to the observation that Pemba possessed freshwater and saltwater members of the complex, whereas Zanzibar was inhabited by freshwater species only (Iyengar, 1962; and unpublished reports to WHO). The latter, irritated in the presence of DDT, would make increased use of outdoor resting-places after feeding. On Pemba the freshwater *A. gambiae* were eliminated or severely reduced by the insecticides, while the saltwater species (*A. merus*) persisted. This species rests mainly out of doors and exhibits (in the presence of DDT at any rate) a low human blood index.

Davidson (unpublished results) has determined the identity of specimens from Zanzibar and Pemba by crossing to known strains. The only species of the group yet identified from Pemba is *A. merus*. Outdoor samples from DDT-sprayed villages in Zanzibar contained two species, *A. gambiae*-B and *A. gambiae*-C. Interspecific selection may thus explain the observation of Garrett-Jones (unpublished) that in 1963 more than half the total biting-contact with man took place out of doors and in the first two hours of darkness—a departure from the known biting-cycles of the endophilic species (A and B). The presence of at least two species, one more affected by DDT than the other, would account for the apparent changes in the biting-cycle and the human blood index of samples representing *A. gambiae* s.l.

Value of precipitin testing in studies of the epidemiology of malaria [1]

The difficulties of adequate and unbiased sampling have discouraged some field workers and made them doubt the epidemiological value of precipitin testing. But knowledge of the vector's human blood index is required in assessing the probable incidence of new infections from any case of malaria that may be present in an area (or be imported) after the parasite reservoir is depleted. The importance of this aspect of entomological research within the over-all epidemiological evaluation of malaria eradication programmes has been sufficiently stressed by the WHO Expert Committee on Malaria (1964, 1966). The information relevant to the estimation of the human blood index in normal field operations was listed by Garrett-Jones (1964a), who pointed out that there are still insufficient data for many major vectors.

The possibility of an inherited change occurring in the feeding habits of the vector under the pressure of insecticide is of direct concern in malaria eradication. In theory such a change might contribute to the interruption of transmission as significantly as the

[1] The preparation of this part of the paper benefited from much advice given by Dr R. C. Muirhead-Thomson, whose co-authorship of the main ideas is gratefully acknowledged.

insecticidal impact. The evidence presented suggests that a reduced degree of contact with man may have played a major part in interrupting transmission by *A. culicifacies* in those parts of India where high vector densities persisted through the attack phase. Similar effects are indicated in *A. funestus*, *A. rufipes* and *A. sacharovi*.

Reduction of the human blood index could be due to diverse causes: (*a*) progressive elimination and replacement of the species or subspecies having a preference for feeding on man (interspecific selection); (*b*) the deterrent or irritant effect of the insecticide (chiefly DDT), which may interfere with the feeding of the vector species inside dwellings; (*c*) elimination of the more " anthropophilic " individuals in a population polymorphic for host-preference (intraspecific selection); (*d*) a decrease in the man/animal ratio owing to geographical displacement; or (*e*) a seasonal retreat indoors, rendering man less readily available than his cattle as host.

The long-term effect of a considerable change in the man/animal ratio on the transmission of malaria has been well demonstrated in the past, particularly in Europe. The usual examples of " zoophilic deviation " cite the decrease of malaria subsequent to an increase in the number of domestic animals. A recent observation in Guyana described the reverse: an outbreak of malaria due to *A. aquasalis* as a consequence of a decrease in the number of cattle in the area (Giglioli, 1963).

A natural increase may occur in the human blood index of a vector because of a seasonal change in the sleeping habits of man. In the Bandar Abbas area of southern Iran, villagers sleep indoors from October to May, while some cattle are kept outdoors in autumn and in spring; but in the summer months all people and cattle sleep outside. *A. fluviatilis* in the area feeds indoors or outdoors according to the availability of hosts, and appears to rest indoors only when it has fed there. Samples collected in October 1964 and in July 1965 were tested by the Institute of Public Health Research, Teheran (personal communication to WHO). In October 1964, 24.5% of 200 blood-meals collected in houses and 11.0% of 200 collected from outdoor shelters were found to be from man. At the same capture stations in July 1965, when resting *A. fluviatilis* could be found only outdoors, 55.3% of a sample of 123 blood-meals contained human blood. The estimated human blood index thus showed a seasonal rise from 0.18 to 0.55. It may be supposed that closer observation of exophilic vectors elsewhere might lead to analogous findings important for the planning of attack measures.

Integration of field studies on vector feeding habits

The nature of changes in host-selection habits during malaria eradication could best be demonstrated by a combined programme, in a restricted area, of sampling for the precipitin test, standard bait catches, and release of samples into cages with mixed baits. The programme should be so designed that uniform procedures are followed before, during, and after the period of insecticide spraying and in an untreated comparison area.

The human blood index must be assessed in the light of a careful survey of such factors as the man/domestic-animal ratio and the night-time distribution of animals in relation to human habitations. Adequate sampling from all biotopes, distributed in and around the village and corrected for the observed prevalence of each biotope, offers the best means of reducing gross bias and achieving progress towards representative sampling of the vector population as a whole.

When the area is sprayed, increasing reliance may have to be placed on outdoor biotopes because, apart from the mortality factor, insecticide-treated houses may prove less attractive as resting-places for blood-fed mosquitos. But a systematic effort should also be made to include specimens knocked down by contact with the insecticides after feeding.

In the same villages, standard collections on human and animal baits should be established before the insecticidal attack and should be repeated at intervals after spraying. If any marked change in host selection is indicated, the routine catches should be continued at intervals after the withdrawal of spraying.

A distinction must be drawn between the mosquito's actual selection of hosts in a given situation and its host-preference spectrum, which is one of several factors determining host selection. In a test developed for assessing differences or changes in host preference, samples of hungry mosquitos are brought into simultaneous proximity to a choice of hosts by release (or emergence) within a large cage containing different host species in constant numbers.

This technique was recently improved by Hadjinicolau (unpublished) in studies of *A. gambiae* in Southern Rhodesia. By means of preliminary trials the numbers are so adjusted as to minimize bias in favour of a given host on account of its greater bulk or passivity. The blood-fed mosquitos are collected and their blood-meal smears subjected to the precipitin test. Such samples should, however, always be carefully distinguished from the samples collected from the normal resting-places of the mosquito. The effects of such variables as differential flight-range, range of attraction and wind direction are largely eliminated by the use of the host-preference test cage, which is a technique approaching a standard laboratory test. It permits a comparison of the preferences of different species, or of strains of one species from sprayed and unsprayed areas, or of a single population before and after the application of selection pressure. The method may also be of value where vector density is too low to provide good samples in nature, but where samples can be bred from wild-caught larvae or from the eggs of wild-caught females.

We do not see the need to draw a further distinction between host-preference and the " relative attractiveness " of different host species, as suggested by some authors (Service, 1964; Service & Boorman, 1965). Catches on baits placed well apart may vary with the wind and reflect the direction of approach of the mosquitos, not the relative attractiveness of the baits.

Finally, the precipitin test to determine the origin of blood-meals is a technique whose value depends on careful sampling, full recording of circumstances and cautious interpretation of the results. In the assessment of the vectorial roles of certain *Anopheles* species in human malaria, in the study of the natural vectors of animal plasmodia and in the investigation of changes in the feeding habits of mosquitos as a result of malaria eradication activities, the method has proved its value.

CONCLUSIONS

The consolidated results of 124 188 tests on blood-meal samples from 92 *Anopheles* species are considered to give, in the main, a valid indication of the proportion of bites being taken on man at the time and place of sampling.

Some reservations in the estimation of the human blood index are dictated by the difficulties of sampling, notably (*a*) mosquito scarcity (natural or due to spraying) rendering some monthly samples too small for comparative analysis; (*b*) non-inclusion of blood-meals from mosquitos that, in sprayed areas, are killed after feeding but before the hour of collection; (*c*) lack of knowledge of the true biotopic distribution of the blood-fed females; and (*d*) the low efficiency of available sampling techniques in outdoor shelters.

Further field research is required to overcome the sampling difficulties. Its importance should be gauged by the epidemiological value, during malaria eradication, of a knowledge of vectorial capacity, which cannot be gained without estimating the human blood index.

In the presence of DDT and, possibly, other insecticides the human blood index of anophelines usually appears to be low—often lower than before spraying. There is no experimental evidence as yet to show whether apparent changes in feeding behaviour are due to inherited changes in host preference under insecticide pressure, induced by selection within the species. The application of a standardized technique for testing host preference would be of help in elucidating this point in operational areas.

Massive deviation of the vectors from man to animal hosts, however achieved, may offer supplementary or alternative means to interrupt malaria transmission in some countries. Continuing efforts to assess the human blood index of *Anopheles* populations are warranted, provided that the difficulties mentioned are taken into account when interpreting the precipitin analysis of samples from the field.

RÉSUMÉ

Dans toutes les opérations d'éradication du paludisme, il est important d'évaluer, sur la base des données entomologiques, les taux de reproduction potentiels avant, pendant et après la phase d'attaque. Il faut déterminer à cet effet la capacité vectrice du moustique qui est visée par les mesures d'attaque. La capacité vectrice ainsi que le taux de reproduction de l'infection varient comme le carré de la proportion des repas de sang pris par le vecteur sur l'hôte humain. Cette proportion (indice d'anthropophilie) s'estime au moyen de la technique de séroprécipitation appliquée aux échantillons pris dans les abris diurnes.

Un service spécialisé dans cette technique a été établi par l'OMS en 1955, dans le cadre d'un accord avec le Lister Institute of Preventive Medicine, d'Elstree (Royaume-Uni), à l'intention des institutions de recherche nationales et des équipes opérationnelles des projets d'éradication du paludisme. Son activité fait l'objet de rapports périodiques.

Les résultats des épreuves pratiquées au cours de la période 1959-1964 sont maintenant exposés dans un deuxième résumé, qui couvre les observations faites sur près de 41 000 frottis sanguins provenant de 79 espèces d'anophèles. On a d'autre part reproduit sous forme de tableaux les données contenues dans le premier résumé (1955-1959) et présenté les résultats de près de 27 000 réactions de séroprécipitation exécutées indépendamment par le National Institute of Communicable Diseases de Delhi (Inde) sur des anophèles originaires de Ceylan, de l'Inde et du Népal.

Dans l'ensemble, la récapitulation porte sur plus de 124 000 précipitino-réactions opérées sur 92 espèces d'anophèles: c'est donc la plus vaste étude de ce genre qui ait jamais été entreprise à ce jour. Environ 94% des épreuves ont donné des résultats positifs avec l'un ou l'autre des immunsérums utilisés, mais on s'est surtout intéressé à la proportion des repas de sang pris sur l'homme.

Si les épreuves aux précipitines effectuées sur des échantillons satisfaisants capturés sur le terrain donnent une bonne idée de la sélection de l'hôte par le vecteur, il existe, pour déterminer la préférence trophique dans des conditions contrôlées, une technique d'essai sur le terrain complémentaire qui mériterait d'être plus largement appliquée. Il est suggéré un schéma d'études opérationnelles combinées sur les habitudes alimentaires des vecteurs, tant avant que pendant la phase d'attaque, dans les zones techniquement difficiles.

La réalisation d'un échantillonnage représentatif des populations d'anophèles pour l'estimation de l'indice d'anthropophilie se heurte à des difficultés pratiques, mais il est possible de surmonter certaines d'entre elles en fixant judicieusement les modalités de capture et en prenant soin d'orienter les collectes d'insectes vers un choix représentatif de biotopes. Il faut en outre s'efforcer, dans les régions qui ont été traitées aux insecticides, de recueillir des moustiques qui ont été étourdis (*knocked down*) par l'insecticide après s'être gorgés.

L'intérêt épidémiologique de l'indice d'anthropophilie est discuté dans ses rapports avec les programmes actuels d'éradication du paludisme. D'après certaines observations, il semblerait que des modifications dans le choix de l'hôte puissent se produire chez certaines espèces d'anophèles dans des régions où les insecticides à action rémanente sont utilisés massivement. Le mécanisme des changements apparents de comportement des vecteurs du paludisme n'est pas pleinement élucidé. Tout ce qui réduit l'indice d'anthropophilie chez un vecteur doit nécessairement contribuer à réduire la transmission du paludisme et, par conséquent, favoriser l'éradication.

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