I.—INTRODUCTION.

The importance of the proper siting of military camps in malarious districts has been long recognized and, in some parts of the world, camp-siting has been a major factor in military anti-malaria work. This is true of parts of the Middle East, where anopheline breeding places may be few and far apart, and it has often been easy to pitch major camps in dry country outside the normal flight range of anophelines from these breeding places.

In West Africa very few districts are completely free from malaria risk and the consequences of correct camp-siting are therefore less spectacular. In areas where there are no anopheline-free districts camp-siting is a difficult and complicated matter because, when one is forced to choose between several localities, all containing anophelines, the particular behaviour of these mosquitoes as well as their relative densities determines the relative malaria risk within each area. But the importance of camp-siting is not diminished by its difficulty for there are many localities where malaria risk increases or decreases tenfold within 100 yards.

Many of the conclusions now recorded are based upon experimental work in military areas, details of which cannot yet be published, and while these results apply to West Africa it is likely that many of them will be applicable in some other malarious districts.

II.—COMPOSITION AND DENSITY OF THE MOSQUITO POPULATION.

The composition and quantity of the local mosquito population must be a very important factor in determining the malaria risk in any locality. This factor can only be accurately assessed by a competent entomological survey.

Entomological survey for military purposes is beset with difficulties, the chief one being that the survey must obtain results within a few days or even hours, and the conclusions drawn from these results are only an accurate guide to the malariousness of that locality at that time. The size of a mosquito population fluctuates tremendously and the seasonal variation in a population can only be estimated as the result of knowledge of the local climate and the breeding potentialities of similar districts. For this reason, too, entomological survey yields more useful data in the wet season, when mosquitoes are abundant, than in the dry season.

The difficulties attending the interpretation of an entomological survey are no reason for not carrying it out for inferences based upon a few known facts are likely to be of much greater value than inferences made without any facts to support them.
Methods of estimation of the composition and quantity of the local mosquito population are given in Appendices 1 and 2.

III.—RELATION BETWEEN THE HUMAN POPULATION AND THE MALARIA RISK.

The second most important factor in determining the malaria risk in an area is the human population, which is the reservoir of malaria infection, but the action of this factor is complex and its influence is frequently ignored or misunderstood.

(1) Malaria Prevention by Segregation of White Troops (fig. 1A).

Since the infected human population is the only source from which mosquitoes can become infected with malaria it is clear that any body of troops can be protected from malaria if they are not already infected (or have been successfully treated after infection) and if the distance between their camp and the nearest infected human population is outside the normal flight range of the mosquito. This protection would apply irrespective of the density of potential malaria-carrying anophelines in and around the camp. The maximum recorded flight range of West African anophelines is 4½ miles (De Meillon, 1934; Adams, 1940); the effective flight range (the distance which they are likely to travel in numbers sufficient to cause an appreciable malaria incidence) is variable but it is usually less than 3 miles. Hence malaria risk could be eliminated on any camp site occupied by uninfected troops and situated 5 miles from the nearest infected humans; and the risk would be small if the nearest infected humans were 2 miles away, irrespective of the number of anophelines on the site and providing the breeding grounds were not situated between the camp and the village. Where the breeding grounds are between the camp and the source of infection it must be remembered that the flight range of the anopheline will be in both directions from its breeding ground to which it must return at least once between the time of infection and infectivity. These
distances should, in this case, be increased, possibly to as much as 8 miles and 3 miles respectively.

Where this method of malaria prevention is contemplated, and there are native troops, it must be remembered that the native troops are usually already infected and therefore personnel to be protected should be separated after nightfall from native troops and native servants as well as from the local infected population. Elimination of infectiveness by regular administration of plasmoquine provides a possible alternative to this complete segregation (cp. Barber et al., 1932).

(2) Malaria Reduction by Human Deviation.

(a) Where the camp becomes part of an existing community (fig. 1B). As the size of a human population increases the size of its attendant anopheline population also tends to increase in consequence of both increased local breeding and the attraction of anophelines from greater distances: but the anopheline population is limited by the potentialities of its breeding ground and the increase in it is not so great as the increase in the human population and therefore the number of anophelines per person decreases. As the number
of anophelines per person decreases so does the risk of malaria transmission to any susceptible individual, or group of individuals, temporarily part of this population.

The converse also holds true: as the size of the human population decreases the size of the mosquito population also decreases, but less rapidly, and therefore the number of mosquitoes per person increases. This principle has been proved experimentally—when 90 per cent of the people were removed from a village in the Gold Coast the mosquito population attracted to that village decreased by 70 per cent but the number of mosquitoes per person was trebled.

This principle, that the number of anophelines per person in a community decreases as the size of that community increases, explains why the malaria risk in rural areas is usually much greater than in towns and why the number of anophelines found in isolated houses is usually much greater than the number found in similar houses in villages. (It may be noted, in parenthesis that, in the case of *Aedes aegypti* and other mosquitoes which breed domestically, the converse tends to apply.)

From this principle the deduction may be drawn that, except in the very fortunate instances where malaria prevention by elimination of the infected population is possible, the population in the immediate vicinity of military camps may, as far as malaria considerations are concerned, be disregarded or actively encouraged. In cases where complete removal of such populations is impracticable, partial removal is worse than useless (but a case could be made out, on other grounds, for removal of all children, the richest reservoir of infection, where this is possible but removal of all adults is impracticable.)

(b) Where the camp is separate from the existing community (fig. 1c, 1 and 2).

Normally it is incorrect to consider the camp as part of the local community because it is separated from this community by some distance. In these circumstances the communities must be considered as separate units.

Let us suppose that there is an infected native community situated at N and a military camp at T and that these both attract mosquitoes from a breeding ground at A. Then if the native population at N is increased it will attract to itself a greater proportion of the mosquito population and this will tend to decrease the malaria risk at T. But at the same time the increased population at N will provide more blood feeds and tend to enlarge the mosquito population at A, thereby tending to increase the malaria risk at T. The relative importance of these two opposite effects cannot always be calculated but considerations of the factors involved leads to the formulation of the following tentative working rule: where the infected community is nearer to the breeding place than the susceptible community any increase in the size of the former community will tend to reduce the malaria risk in the latter; but, where the infected community is much further from the breeding place than the susceptible community, any increase in the former will tend to increase the malaria risk in the latter.

(3) The Relation between White Troops and Black Troops (fig. 1d).

Although anophelines are able to travel long distances they normally prefer the nearest available blood meal. This is why when, as usually happens, the anopheline breeding places are outside a village, the anopheline infestation of the huts at the edge of that village is much greater than the infestation at its centre. One example of this will suffice: a small village in Sierra Leone, consisting of twenty-four huts, arranged in an irregular row. The centre of the village was 550 yards from the breeding place and the nearest hut was 400 yards from the breeding place; the anopheline population of the nearest hut was ten times as great as that of the huts in the centre of the village.

This example shows how the placing of an alternative source of blood meals between susceptible troops and anopheline breeding places can greatly reduce the malaria risk to the troops. In West Africa this fact has never been appreciated and, in consequence, in camps containing both white and black troops (the former susceptible, the latter infected and relatively immune) the white lines are often placed nearest to the water supply, which is often also the source of anophelines, and the native lines are beyond them—hence the white
troops act as a protective screen for the black troops and the attractiveness of the latter brings mosquitoes through the white lines, an exact reversal of what is desirable.

When white troops and native troops have to be camped together in malarious districts the native lines should be placed, where possible, between the anopheline breeding places and the white lines so that they serve as a very efficient protective screen.

There is a prevalent belief that, as an anti-malaria precaution, white troops must never be quartered in the immediate vicinity of native troops but, in many circumstances, this is incorrect, not merely because an increase in the number of men tends to produce a decrease in the number of anophelines per person but also because native troops provide a more attractive and easier food supply; hence, provided the natives are correctly sited between the whites and the anophelines, the presence of native troops in close proximity to white troops will frequently tend to divert some of the mosquitoes which would otherwise be attracted to these white troops.

IV.—Effect of Prevailing Wind on Anopheline Behaviour.

The maximum recorded flights of *A. gambiae* and *A. funestus* of distances up to 4½ miles were made either down or across wind but the same worker records a flight of 1½ miles made against a 4–7 m.p.h. wind (Adams, 1940). This datum provides evidence that mosquitoes can travel greater distances down wind but can also travel up wind; since anophelines hunt by scent they are likely to be most attracted to humans upwind.

Therefore if there is a strong and persistent prevailing wind (e.g. in some coastal areas) up wind camp sites are better but, when the wind is weak or variable, this advantage disappears and down wind sites may be healthier.

V.—Effect of Altitude on Anopheline Behaviour.

Experience in Sierra Leone leads to the conclusion that altitude is a very important factor in reducing anopheline infestation and that where there are two sites equidistant from the same breeding place, but one is a few hundred feet above the other, the higher will be the healthier. Hence camp-sites on hills are more suitable, not merely because they are better drained but also because their altitude deters anophelines. This may be due to the varied wind currents over hilly districts.

VI.—Effect of Bush on Anopheline Behaviour.

*A. gambiae* and *A. funestus* do not fly very close to the ground and therefore they are not mechanically hindered by dense high bush (De Meillon, 1937). A League of Nations Committee has also held that bush-clearing is not an effective anti-malaria measure (Hackett et al., 1938). Yet in some parts of West Africa extensive bush-clearance near camps has been carried out, ostensibly for this purpose.

Experiments designed to test the effect of bush-clearing, and carried out in the Gold Coast, showed that anopheline penetration was not reduced by the complete elimination of dense bush from an area 300 yards in diameter round a village and confirmed that dense bush does not encourage anopheline infestation. Hence when selecting or preparing a camp-site the presence of bush need only be considered in relation to anti-amosy and anti-fly measures and not to anti-malaria measures.

VII.—Acknowledgements.

I am indebted to members of the Staff of the Army School of Hygiene for valuable criticisms of the manuscript and to Private M. W. Smith for the illustrations.

VIII.—Summary.

(1) In West Africa a susceptible population can be kept completely free of malaria, irrespective of the number of potential malaria-carrying anophelines in their locality, if they are kept 5 miles from the nearest infected humans and they can achieve a considerable
degree of protection at a distance of 2 miles. These distances must be increased, possibly to as much as 8 and 3 miles, respectively, where the breeding grounds are between the susceptible and the infected humans.

(2) The number of anophelines per person in a community is in inverse ratio to the size of that community so the smaller the community the greater the malaria risk; hence towns are usually much safer than rural areas.

(3) Where camps are separate from, but not out of mosquito flight range of, the local infected community, if the latter is closer to the breeding place any increase in the size of the local community will tend to decrease the malaria risk within the camp and any reduction in its size (elimination, or elimination of all children, excepted) to increase it. Where the camp is closer to the breeding place any increase in the size of the local community will tend to increase the malaria risk within the camp.

(4) Placing of native troops in the immediate vicinity of white troops does not necessarily increase the malaria risk to the latter and may substantially reduce it.

(5) Where infected native troops and susceptible white troops have to camp together in malarious districts the native troops should be placed, where possible, between the anopheline breeding places and the white troops so that they serve as an efficient protective screen.

(6) The effects of altitude, wind and bush on anopheline behaviour are discussed.

(7) The use of and the methods used in anopheline surveys are described.

IX.—REFERENCES.


X.—APPENDIX 1.—ESTIMATION OF THE ADULT MOSQUITO POPULATION.

In West Africa, as in many other areas, nearly all the malaria risk is due to anophelines which are also house frequenters. *A. gambiae*, *A. melas*, and *A. funestus*, the three most important carriers, usually feed in houses and they remain in them, if they are suitable, for at least twelve hours after their meal. These three species are responsible for at least 95 per cent of all the military malaria and the simplest and most efficient method of estimating their prevalence is to sample native quarters (the equivalent of baited traps) in the district to be surveyed.

The anopheline density in individual rooms varies very greatly with their position and there is wide variation between the number attracted to the inhabitants of rooms on the edges of villages and the number attracted to those occupying rooms in the centre of such villages, even if the total human population is quite small. Hence, more comparable results are obtained if all rooms sampled are on the outskirts of villages or in isolated huts.

Suitable bedrooms should be chosen, preference being given to those which are dark and ill-ventilated (not because these attract more mosquitoes but because mosquitoes attracted to their occupants are more likely to remain in them when they have fed). Openings should be closed and the floor and furniture covered with white sheets. Each room should then be thoroughly fumigated with an insecticide and left for a few minutes. The sheets should then be carefully removed and spread out in the open and the mosquitoes collected from them and identified (Appendix 2).

The number caught will vary with both the number and attractiveness of its human inhabitants and the sampling error cannot be eliminated but I found that when daily catches were made in such rooms, under controlled conditions, on five occasions out of every six the actual number of anophelines caught was not more than double nor less than half the average number captured by daily catches in the same room throughout one week. This standard of
accuracy is sufficient for practical purposes in view of the large day-to-day and seasonal fluctuations in the mosquito population (Ribbands, 1944a) and especially as deductions will not be drawn from results from a single room but from several rooms.

When permanent camp sites are required the results of adult survey should be supplemented by a larval survey to discover the type and position of the local breeding grounds and accurate conclusions require knowledge of the local climate and of the breeding potentialities of similar districts at other seasons.

APPENDIX 2.—THE IDENTIFICATION OF ADULT WEST AFRICAN ANOPHELINES.

Distinction between Anophelines and other Insects.—All West African anophelines (except female A. smithi, which is uncommon and probably harmless) can be distinguished from culicines by the presence of dark markings on the leading edge of their wings. This character is easily seen with the naked eye and should be known to every soldier serving in West Africa. By the use of it anophelines can be separated from all other insects caught in house catches.

Recognition of Different Species of Female Anophelines.—Twenty-four species of anophelines occur in West Africa but, for anti-malaria purposes, it is not necessary to be able to recognize all of them. The commonest and most dangerous species are the most easily recognized and a hand-lens is the only equipment required.

A. Palps with Three Short Pale Bands (see fig. 2).

(1) Frequently found, usually gorged with blood.—A. funestus. VERY DANGEROUS.
(2) Seldom found in houses, very rarely gorged with blood.—A. rhodesiensis. Harmless.
B. Palps with Three Pale Bands, the Terminal Band Long, the others Short.
A. gambiæ and A. melas.¹ BOTH VERY DANGEROUS.
(A. brunnipes also, but this species is very rare, and also dangerous when found.)

C. Palps with Four Short Pale Bands.
(1) Palps smooth. No white markings on legs.—A. melas. VERY DANGEROUS.
(2) Palps shaggy. Legs with pale bands. (a) Sandy-coloured.—A. pharaonis. SLIGHTLY DANGEROUS. (b) Blackish.—A. constani or A. squamosus. Harmless.

D. Palps with Three Pale Bands, Two Terminal Ones both Long.
Eight species, mainly dangerous but seldom abundant.

E. Palps with One Pale Terminal Band only.
A. nili. VERY DANGEROUS.

F. Palps not as above.
Unimportant, usually quite harmless (not illustrated).

¹Methods of distinguishing A. gambiae and A. melas are given in detail elsewhere (Ribbands, 1944b). Usually between 25 per cent and 50 per cent of specimens of A. melas have palps with four short pale bands—hence if 25 per cent or more of the catch have Group C palps, and the rest Group B palps, the catch can be considered predominantly A. melas. If all the catch have Group B palps the catch consists of A. gambiae only. Other proportions indicate a mixture.

A. gambiae breeds in fresh waters, usually open and often temporary. A. melas breeds in brackish water. A. funestus prefers shaded clean waters, often slightly flowing. A. nili breeds in running streams. A. pharaonis prefers weedy swamps.