Memorandum on measures for the control of mosquito nuisances in Great Britain.

MINISTRY OF HEALTH

MEMORANDUM ON MEASURES FOR THE CONTROL OF MOSQUITO NUISANCES IN GREAT BRITAIN

Revised November, 1948

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PREFATORY NOTE TO THE ORIGINAL EDITION BY THE CHIEF MEDICAL OFFICER.

To the Right Hon. MALCOLM MACDONALD, M.P.,
Minister of Health.

Sir,

I beg to submit a report by Colonel Sinton and Mr. P. G. Shute, on measures recommended for the control of mosquito nuisances in this country.

During the past twenty years mosquitoes have become much more noticeable as causes of public health problems than they were in the past. After the last war the introduction of large numbers of malarious patients from abroad into areas where suitable mosquitoes and other conditions prevailed resulted in the occurrence of many cases of malaria among the local populations. As a result of measures instituted by the Ministry of Health these outbreaks were brought under control comparatively rapidly, and for many years locally-acquired malaria has become a negligible problem. If, however, many such cases were reintroduced into these localities, there is a considerable risk that the disease would again be transmitted locally. The prevention and control of such outbreaks will depend largely upon the early institution of adequate anti-mosquito measures there when such conditions occur. The investigation of these earlier and other outbreaks has resulted in the accumulation of much valuable practical information, which the present report makes available.

Apart however from the danger of disease, mosquitoes have given rise to serious public health problems because of their biting propensities. Reports of such nuisances have been numerous in recent years. This increase has been brought about mainly not so much by a greater prevalence of these insects but rather by changes in the habits of the people, which have brought them into more intimate contact with mosquitoes. There has been a great migration of people from large towns into rural and seaside areas, where mosquitoes are more common. At the same time the more open-air life, which is now affected by the population, and the greater exposure of the body by modern clothing make the individual more liable to attack.

Where large numbers of people are residing either temporarily or permanently in rural, sylvan or seaside areas, cases of mosquito nuisance almost invariably occur. In some areas on the southern and eastern coasts these nuisances may be great and may interfere very seriously not only with the amenities of life but also with the work of the population affected.

Many mosquito nuisances have been investigated by officers of the Ministry of Health, and as a result a large amount of practical information has been collected about the most suitable methods for the control of these pests. The main points of our knowledge of mosquito control in Great Britain have been summarised in the report by Colonel Sinton and by Mr. Shute, who has been intimately associated with this work since its inception by the Ministry. Sufficient details have been given to enable local authorities and others to deal with most of their mosquito problems properly and effectively, even in the absence of the expert advice which the Medical Department of the Ministry are always willing to give.

I have the honour to be, Sir,
Your obedient Servant,

ARTHUR S. MACNALTY.

Whitehall, S.W.1.
July, 1940.

PREFATORY NOTE TO THE REVISED EDITION BY THE CHIEF MEDICAL OFFICER.

To the Right Hon. ANEURIN BEVAN, M.P.,
Minister of Health.

SIR,

This memorandum was issued originally in July, 1940, and revised in 1942, by Dr. P. G. Stock with the help of the Keeper of Entomology, British Museum, (Natural History). The exhaustion of the revised edition has necessitated another reprinting and the opportunity has been taken to introduce further amendments, particularly in regard to the use of the more modern insecticides, such as DDT and "Gammexane".

Dr. Stock has again been responsible for the revision, with the collaboration of Major-General Sir Gordon Covell, the Minister's Adviser on Malaria, Mr. P. G. Shute, the Assistant Malaria Officer, and Dr. R. A. E. Galley, the Secretary of the Insecticide Standing Conference.

I have the honour to be, Sir,

Your obedient Servant,

WILSON JAMESON.

Whitehall, S.W.1.
November, 1948.

CONTENTS

INTRODUCTION.

During the years 1917 and 1918 a number of cases of malaria occurred in various parts of England among children and adults who had never left this country. In the latter year these cases became so numerous in some localities that malaria was made notifiable by the Pneumonia, Malaria and Dysentery Regulations of 1919, which were subsequently amended by the Public Health (Infectious Diseases) Regulations, 1927. A few cases also occurred during the period immediately following the second world war.

An officer of the Ministry of Health investigated every case notified, and suggested appropriate methods to prevent the spread of the disease. During this and later work, a large amount of information was obtained, not only about the species of mosquito responsible for the carriage of malaria but also about many others whose bites were merely a nuisance to the local residents and to visitors.

Appended to the memorandum are two maps showing the distribution of indigenous malaria in England and Wales about 1860 and after the Great War of 1914-18. It will be noted that the distribution is very similar in the two periods and that the areas most affected were the South East and South Coast districts.

MOSQUITOES IN RELATION TO THE HEALTH AND COMFORT OF MAN.

In England and Wales* although these insects may carry malaria under certain conditions, it is mainly because of the nuisance caused by their bites that anti-mosquito measures are undertaken.

(1) Mosquitoes and Malaria.

During the last century indigenous cases of malaria were known to be occurring in some part of England, more especially in the south and east but early in this century indigenous malaria was apparently either absent entirely or a very rare disease.

The localised outbreaks, which occurred during and after the two world wars, were initiated by the return of large numbers of infected soldiers from abroad into areas where the conditions were suitable for the transmission of the disease.

The only species of Anopheline likely to be of importance in the spread of malaria in England is *A. maculipennis*. It is especially dangerous because the adults habitually live in close association with man, either in dwellings or in animal houses.

Because this species is present in small or large numbers throughout the country, there is always a danger that fresh cases of malaria may occur, *if an infective person comes into such an area and is exposed to their bites.* Fortunately it is only during the summer months that temperature conditions are such as to allow of the completion of the parasitic cycle in the mosquito; and this takes about 15-20 days in England. The conditions of favourable temperature and humidity occur most commonly along the southern and south-eastern parts of England, usually on the coasts, and this is where locally contracted cases of malaria have been most commonly recorded. In many other parts of England, although the mosquito is present and human carriers have been introduced, the disease rarely spreads, unless warm weather continues for some time combined with a high relative humidity (over 60 per cent.). In such areas if malaria occurs it is usually only as isolated cases.

* For notes on Anopheles and Malaria in Scotland, see J. H. Ashworth, *Proc. R. Soc. Edinburgh* 47 (1) 81-93, 1927.

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(2) Mosquitoes as a Nuisance.

Apart from the danger of spreading disease, mosquitoes may cause a considerable amount of discomfort, both by their bites and by the disturbance of sleep caused by their buzzing.

That more is heard about mosquito nuisances now-a-days than was the case many years ago, may be attributed to a number of factors. The habits of the people have changed in many ways and the widespread use of motor transport has enabled many more people to leave the large towns and reside either temporarily or permanently in seaside or country districts where mosquitoes are more prevalent.

THE HABITS, DISTRIBUTION AND PREVALENCE OF THE BRITISH SPECIES OF MOSQUITO IN RELATION TO ANTI-MOSQUITO MEASURES.

(1) General Considerations.

There are 30 species of mosquito recorded from the British Islands. Of these the following species are so rare or so seldom bite man that they may be considered unimportant as causes of public health problems in this country:— *Culex* (*Neoculex*) *apicalis*, *Theobaldia* (*Culicella*) *fumipennis*, *T.* (*C.*) *morsitans*, *T.* (*C.*) *litorea*, *T.* (*Allotheobaldia*) *longiareolata*, *Orthopodomyia pulchripalpis*, *Aedes* (*Ochlerotatus*) *communis*, *A.* (*O.*) *sticticus*, and *A.* (*O.*) *leucomelas*.

If anti-mosquito measures are to be carried out effectively and economically it is necessary to take into consideration: (i) the species of mosquito responsible for the nuisance or danger to health, and (ii) the habits of the insect concerned.

Sometimes the insect causing the trouble is inconspicuous and is breeding in some out-of-the-way pool or ditch, while a mosquito which is quite harmless may be more conspicuous in its habits and breeding places. It is *essential* therefore that the species of mosquito responsible for the nuisance should be determined,* otherwise money, labour and material may be wasted in destroying a harmless insect while the real cause of the trouble receives no attention. This fact cannot be over-emphasised.

When the species of mosquito responsible for the trouble has been determined correctly, it is then possible to gain an intimate knowledge of its life history and habits. If the species is to be attacked in its adult stage, it is essential to know its usual habitat and the season when it can best be destroyed there. Similarly, the larval stages may be found only in special types of breeding grounds and may occur there only at certain seasons, so measures applied to destroy such stages at inappropriate times or in unlikely habitats will not only be useless but also a needless expenditure of time and money.

The bionomics of the different species of British mosquitoes have been summarised in the following descriptions, and the relationship of their habits and seasonal prevalence to methods of control have been indicated.

* Brief technical descriptions of the British species and simple keys for their recognition are included in Economic Pamphlet No. 4A, British Mosquitoes and their Control, by F. W. Edwards and S. P. James. Those who are specially interested are advised to obtain a copy of "The British Mosquitoes" by J. F. Marshall (1938). Both can be obtained from the British Museum (Natural History), S.W.7, price 4d. and 20/- respectively.

Mosquitoes may be divided into two main groups—the Anophelines and the Culicines (*vide* Appendix I). The Anophelines are chiefly important because they are capable of conveying malarial infections, while the Culicines, which never carry malaria, are usually a nuisance only because of their biting propensities.

(2) Anopheline Mosquitoes.

Anopheles (*Anopheles*) *claviger* Meigen.

(syn. *A. bifurcatus*).

Habits.—This insect passes through the winter in the larval stage and in this state can survive even after being frozen.

The chief breeding grounds are more or less permanent pools on the edges of woods, or, more rarely, inside them. They are grassy lakes, ponds and ditches, which are invariably shaded by overhanging trees or bushes. In the winter the larvae may be plentiful in such situations, while in the summer they are often found also in tanks and water-butts, more especially if their natural breeding places have dried up.

In normal seasons the first adults emerge about the end of March. These then seek the shelter of animal houses where they feed on cattle, horses, pigs, etc. When the weather gets warmer (about the end of April) they leave their shelters to lay eggs and usually spend the rest of their lives in the open, hidden in foliage within about 100 yards of their breeding places. They attack persons in the vicinity after sunset. Successive generations of adults appear during the summer, but die off early in September.

Importance in relation to Man.—It is very seldom, if ever, that adults of this species enter houses, therefore they are only troublesome out-of-doors. As they often breed in water-tanks, cisterns, etc., in gardens and green-houses, their bites may be a source of annoyance to people sitting in gardens, as well as to people working on allotments.

Methods of Control.—Ponds and lakes found to be harbouring larvae should be treated with larvicides or oil, whichever is most suitable to the conditions. If all the breeding grounds are treated in October (after all the adults have died off), no further trouble should be experienced during the ensuing year. The same satisfactory result would be obtained if the breeding grounds were properly treated in February, before any of the adults have emerged. The latter is preferable.

Distribution.—Common throughout Great Britain.

Anopheles (*Anopheles*) *maculipennis* Meigen.

This species is made up of a number of varieties or sub-species. Two varieties occur in England—one (var. *messeae*) breeds in the fresh water of inland ponds and streams, the other (var. *atroparvus*) mainly in brackish water in coastal areas, but may be present in smaller numbers in inland areas. The latter variety is the chief carrier of malaria in this country.

The females of these two varieties are readily separated by the shape of the plume scales of the wings; the males by the shape of the outer spines of the harpago, and the eggs by the surface pattern and the structure of the " floats ".*

Habits.—The insect is distributed over the whole of Britain, but is more numerous near low-lying coastal areas than further inland.

The larvae are found in both brackish and fresh water, but under the latter conditions the adults are never so numerous as under the former. The larvae are found chiefly where there is an abundance of aquatic vegetation and where green algae, such as *Spirogyra*, are plentiful. The breeding grounds are usually fully exposed to the direct rays of the sun and the water may be either moving slightly (as at the edge of rivers), or may be quite still (as in the case of lakes and ponds). Larvae are *never* found naturally in highly polluted water.

The females of this species pass the greater part of their adult life in dwellings. As soon as they emerge from pupae they usually enter houses, either animal or human, in search of food and shelter. Provided the house is occupied at night, they remain there until their ovaries are mature (usually about six days) and then leave the shelter to lay their eggs, returning again

* " The value of the Wing Scales as an Aid to the Taxonomy of Adult *Anopheles maculipennis* ". Ungureanu E. & Shute, P. G. *Proc. Roy. Ent. Soc. London*, 1947.

when this has been done. When another batch of eggs is mature they sally forth again. They may sometimes fly several miles in search of food or suitable breeding places.

To a fairly great extent A. *maculipennis* in England is zoophilic, *i.e.*, prefers the blood of animals to that of man. They seldom or never attack in the open air. In areas where they are numerous, for every single specimen which can be collected in a human habitation, hundreds, sometimes thousands, may be found in near-by pigsties, stables or cowsheds, and rabbit hutches where they may be observed hanging from old cobwebs (often a hundred or more attached to one cobweb).

In human habitations they show a very decided preference for dark, ill-ventilated rooms and for places where they are not disturbed by domestic activities. They are often found resting in dark corners, under beds, behind cupboards, etc. If there are high dark staircases, they may often be found resting on cobwebs which have accumulated on the ceilings of such places.

Many houses have such high ceilings, which are well out of reach of the housewife's brush and consequently contain numerous cobwebs, which are only removed at long intervals, usually when whitewashing is done. These undisturbed cobwebs offer ideal resting-places for mosquitoes. The so-called "malarious houses" in England are usually of this dark, ill-ventilated type.

A. maculipennis is nocturnal in its activities, and will often enter clean, well-lighted and well-ventilated bedrooms at night, but at daybreak seeks more congenial surroundings such as have been described above.

Towards the end of August and early in September, all the adult males die off, as also do the larvae. The ovaries of the female cease to develop and the insects remain in the shelter of the houses, usually animal. During the late autumn they have entered into a state of hibernation (complete or partial according to the variety) in which their activities are largely in abeyance and blood meals are seldom or never taken. Large numbers survive through the winter in this state. They renew their activities when the warmer weather of spring comes, and sally forth to lay eggs. The first spring generation appears about May.

Importance in relation to man. It is seldom that the bites of this insect are a serious nuisance to man.

This species is, however, the most important carrier of the malaria parasite in Europe and North Africa.* Should a case of malaria occur in a district where this species is known to be plentiful, more serious notice should be taken of its presence. The fact immediately becomes a public-health problem which should be dealt with on the lines of the Pneumonia, Malaria and Dysentery Regulations of 1919.

Methods of Control.—Spraying the inside of animal shelters with a suitable insecticide during July, August and September will greatly reduce the number of adults, both male and female. Any premises in which a case of malaria is contracted should also be thoroughly sprayed; in coastal areas spraying in March and April would kill those females which have survived the winter and are preparing to leave their winter quarters to lay eggs. Spraying is, perhaps,

* During the last 25 years more than 500 cases of malaria proved to be locally contracted and due to *Plasmodium vivax*, have occurred in this country, mostly in the south-eastern area. The majority occurred during the first world war and immediately afterwards, but there were only a few immediately following World War II. In almost every instance *A. maculipennis* (var. *atroparvus*) was proved to be the transmitting agent.

the most practical and economical control method at present known *when* the breeding grounds of this mosquito are very extensive and cannot be dealt with properly for any reason, financial or otherwise.

If the breeding grounds are more localised, or greater financial assistance available, other measures should be adopted also. The larvae, when present in lakes, ponds, rivers and streams will always be found where aquatic vegetation is plentiful. The clearance of such vegetation makes the breeding ground unsuitable and also exposes the larvae to the attacks of fish. Old disused gravel pits and quarries often form suitable breeding grounds, in fact in some districts this species would be absent, or present only in small numbers, were it not for these " man-made " breeding places. Wherever possible these should be filled in or drained, otherwise oil or chemical larvicides should be applied. Where this species hibernates in large numbers in animal houses, spraying with DDT in late September and October would reduce breeding in the following spring.

Distribution.—This species is widely distributed throughout the British Isles. Its maximum prevalence appears to be around low-lying areas on the south and south-east coasts of England.

Anopheles (*Anopheles*) *plumbeus* Stephens.

This is a sylvan species which breeds in the water of tree-holes, *never* in lakes or ponds. During the summer it may attack man in woodland areas near its breeding places, but is seldom numerous enough to cause a serious nuisance.

Method of Control.—The hollows in trees should be filled in with some waste material such as clinker, gravel, etc., and faced with asphalt or cement. This will eliminate the breeding grounds at very little cost and without damaging the trees in any way.

Distribution.—The species is present throughout the British Isles in parks and woodland country.

Anopheles (*Anopheles*) *algeriensis* Theobald.

This species has been reported in Great Britain only from marshes near the Norfolk Broads where it was found biting campers. It may be very numerous and troublesome in such districts.

Methods of Control.—Larvicides sprayed or dusted over the breeding grounds in early spring should greatly reduce the numbers of this species. This could be repeated with advantage in the late autumn. As marshes are the recognised breeding places of this species in England, it is probable that the use of copper arsenite or paris green would be better than oil for its control.

(3) Culicine Mosquitoes.

Culex (*Culex*) *pipiens* Linnaeus.

Habits.—*C. pipiens* feeds almost exclusively on birds and frogs. Specimens gorged with blood are occasionally found sheltering in houses, but on examination the blood is found not to be mammalian in origin. Between the months of May and September the larvae may be found in enormous numbers in almost any artificial collection of water. Tanks, water-butts, rain-water cisterns, old tins, firebuckets and stagnant ditches are all suitable breeding grounds. In September breeding ceases, and all the males die off. The fertilized females find their way into cold dark cellars where they hibernate during the winter months. When the warm days of spring appear, usually in April, they again become active; their ovaries develop and they leave their winter quarters to lay their eggs.

Importance in relation to man.—It is extremely doubtful whether this species ever attacks man. Most of the older reports probably refer to the bites of *C. molestus*, a species which was formerly confused with *C. pipiens*.

When the nights get cold about September, very large numbers of these insects may enter dwellings for shelter and hibernation. The sound of their buzzing at such time may be a serious nuisance because of the disturbance of sleep caused.

When a nuisance is caused by mosquito bites, great care should be taken that anti-mosquito measures are not misdirected against this species.

Methods of Control.—Where adults are found collecting together during the winter months usually in cellars, spraying with an insecticide will destroy them and so reduce the numbers available to start the spring generations.

In the summer all artificial water containers should, as far as possible, be emptied and brushed out once every week. Pots, pans, old tins and other potential receptacles of water on and around refuse heaps or scattered about elsewhere should be collected and buried, or made unsuitable for holding water. Rain-water butts should be fitted with suitable covers to prevent mosquitoes from depositing their eggs in them. Fire-buckets and water stored for fire-fighting purposes often act as breeding places. These should be treated with cresol larvicide, DDT* or BHC.†

Distribution.—Very common everywhere in Great Britain.

Culex (*Culex*) *molestus* Forskal.

Habits.—Recent investigations indicate that this species, like most others, is selective in its choice of breeding grounds. It appears to select water in continuous darkness or semi-darkness and larvae have been found to be numerous everywhere in the stagnant water in the inverts below the station platforms of the London Underground Railways as well as in the sumps along the railway line. On rare occasions larvae have been found in water above ground but the information is incomplete, though up to the present *molestus* larvae have not been found in the numerous static water tanks constructed above ground for fire-fighting purposes.

Under favourable conditions breeding in nature continues uninterruptedly throughout the year; e.g., in the Underground Railways where the atmospheric temperature below the station platforms rarely falls below 60°F. (16°C.). Because this species breeds in underground waters it does not follow that the adults are never troublesome above ground, and there is some evidence that they migrate in search of a blood meal.

Importance in relation to man.—It is a most persistent biter, and where it is present in large numbers it probably is a greater *indoor* nuisance to man than any other species of English mosquito.

Methods of Control.—In urban districts where a mosquito nuisance is being investigated a search should be made for collections of stagnant water below ground. Shallow pools containing larvae can be treated with one of the cresol larvicides. Deep pools such as sumps and disused lift shafts, etc., should be sprayed with DDT or BHC emulsion or with a suitable oil.

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* *DDT* is the well established abbreviation for Di-chloro-di-phenyl-tricholethane.

† *BHC* is the abbreviation gradually coming into use for the new insecticide "Gammexane". The accurate chemical name is "Hexachlorocyclohexane", but as this does not readily lend itself to abbreviation, the substance is frequently called, though less accurately, Benzene Hexachloride. The abbreviation BHC, therefore, signifies a mixture of isomers, the individual isomers being referred to as alpha, beta, gamma or delta BHC as necessary.

Distribution.—North, south and south-east of England. More numerous in areas where there are collections of stagnant water below ground.

Theobaldia (*Theobaldia*) *annulata* Schrank.

Habits.—No important British species of mosquito appears to be so indifferent in its choice of breeding places as *T. annulata*. The larvae are to be found in the clear water of grassy lakes, in the drainings of manure heaps, in sewage, in wells, cisterns, and water-butts, in stagnant brackish water around coastal areas, etc. Larvae may be found all the year round and the sea itself seems to be the only type of water from which they have not been recorded.

Although the adult females go into semi-hibernation during very cold weather, they quickly become active again when a warm spell occurs. They feed on man and animals in winter and summer, both by day and by night. The immediate effects of the bites are not painful but the later ones are and the irritation which follows makes it extremely difficult to resist scratching. Quite commonly the seat of the bite becomes a large swelling (much larger than that caused by any other British species).

Importance in relation to man.—That this species is a serious pest in many parts of the country, there is ample evidence. Mosquito surveys carried out by us during the last twenty years have shown that, in urban areas, on most occasions this species was involved in the nuisance to a greater or lesser extent. These insects bite both indoors and outside.

They are, probably, the only British species of mosquito which attacks man readily in mild weather during the winter. In summer they are to some extent a nuisance everywhere, attacking man with great boldness. When complaints are received from inland areas that persons are being bitten in gardens, etc., it is very often this species which is responsible. In such cases the insect is usually breeding in stagnant water in the near vicinity.

Methods of Control.—T. annulata has been found breeding in all kinds of water except the sea itself. All old pots, tins, cans, and other receptacles likely to hold water, should be removed or buried, especially in the spring, summer and autumn. Water-butts should be emptied once weekly and brushed out. Where rainwater is stored, the containers should be provided with closely fitting lids to prevent the entry of the female mosquito to lay her eggs, and a tap should be inserted near the bottom to allow the water to be drawn off. If larvae are found in such tanks, they should be either emptied or oiled.

Liquid manure tanks* are very favourite breeding places of this mosquito. These should be provided, if possible, with a close-fitting cover and a tap as described above. As this liquid is very valuable to gardeners, they are loath to throw it away. Should it become infested with mosquito larvae they may be killed with petrol or liquid paraffin as described later, otherwise it should be used at once or thrown away. Public allotments always contain numerous butts and tanks for water and liquid manure. Houses near such places are often troubled by mosquitoes which are usually of this species. The simple measures mentioned above, if carried out by every householder on his own

* Water contaminated with nitrogenous matter appears to afford an especially attractive breeding place for this species.

premises, will do much to abate the nuisance. Roadside ditches are also important breeding places, and sanitary inspectors should always search these also when complaints are received from adjacent houses. This mosquito may breed in fire-buckets and in water stored for fire-fighting purposes. These should be treated with cresol larvicide or with oil. All breeding places should be dealt with at least monthly from March to October.

Sewage-disposal works are, perhaps, even more important as large-scale breeding areas than any of those already mentioned.

If ground receiving the effluent from such works is not allowed to dry up every ten days, it is almost certain that such conditions will give rise to active breeding of *T. annulata* in any part of the country where they are present. Local Authorities should arrange that such stagnation of effluent should not be allowed to occur, especially during the warmer months of the year. This type of breeding place may be very extensive, and is usually very unsuitable for treatment with either cresol larvicides or oil.* The best solution of the problem would seem to be for the Medical Officer of Health and his Sanitary Inspector to confer with the Engineer in charge of the works and together devise a scheme whereby large areas of water are not allowed to collect and stagnate. If however, such flooding cannot be avoided, the distribution of the effluent should be so arranged that each area is allowed to become *dry, and remain so continuously* for at least three days once every fourteen days between the months of April and October.

Distribution.—Common throughout Great Britain.

Theobaldia (*Theobaldia*) *subochrea* Edwards.

Habits.—This species resembles *T. annulata* in its habits but it is less numerous. It is widespread but has been found most often in coastal areas. Larvae can apparently live in brackish water.

Methods of Control.—As for *T. annulata*.

Theobaldia (*Theobaldia*) *alaskaensis* Ludlow.

This species also resembles *T. annulata* but has been reported only from the extreme north of England and from Scotland. The methods of control would be similar to those used for *T. annulata*.

Taeniorhynchus (*Coquilettidia*) *richiardii* Ficalbi.

Habits.—This is, probably, the most remarkable species of mosquito in this country, because both the larvae and pupae live permanently under water, whereas the larvae and pupae of all the other species mentioned here have to come to the surface to breathe. These immature stages attach themselves to the roots of aquatic plants, often several feet below the water surface, and obtain oxygen by piercing these with their modified breathing tubes. The plants commonly attacked are those of the genera *Ranunculus, Acorus, Glyceria* and *Typha*. Therefore, unless a pond or lake contains some of these fairly large plants, it will usually be useless to search for the larvae of this species. In addition, the orthodox method of dipping for larvae with a ladle would be quite unsuccessful so far as this species is concerned.

* Frequent oiling of such areas is liable to cause a water-proofing of the surface, and therefore may interfere with the percolation on which many such methods of sewage disposal usually depend, while chemical larvicides of the phenol group may interfere with the bacterial action. The pyrethrum larvicide described later has been used successfully in America on sewage-disposal works without damage to the process, and might perhaps be tried in this country.

When the larvae of this species are being searched for in a pond or lake where there is much aquatic vegetation, it is necessary to pull up some plants, making sure that the roots are obtained, and then wash them vigorously in a large basin of clean water. By this procedure, if larvae be present, some will become detached and will be seen crawling, rather than swimming, on the bottom of the basin. They are milky-white in colour and resemble "maggots" rather than the ordinary mosquito larvae or "wrigglers." It should be noted that not every suitable plant has larvae attached to it. The search should not be abandoned until at least several dozens of each kind of plant have been examined from different parts of the pond.

Importance in relation to man.—The females bite man readily, and, where they are sufficiently numerous, they may be very troublesome both indoors and out. They appear to be very sensitive to light and until dusk they remain hidden in the long grass around their breeding grounds. When it is nearly dark they fly about in search of a blood meal. If there are houses within easy reach of the breeding ground, *e.g.*, two to three hundred yards, they will enter bedrooms, take a blood meal, and leave again before daylight arrives.

Methods of Control.—On account of the habits of this insect in both its adult and larval stages, it is easily overlooked as the cause of a nuisance, and much energy and money may be wasted in attacking some more conspicuous but relatively harmless mosquito suspected to be the culprit.

As the larvae live attached to the roots of plants it is doubtful whether surface larvicides like oil would have much effect, unless used often enough to kill the vegetation. The oily film on the surface might, however, damage the emerging adults.

DDT or BHC emulsion would probably prove the most effective larvicide. Failing this, the only alternative would appear to be the complete removal of the plants on which they live.

Distribution.—Throughout the country wherever suitable breeding grounds occur.

Aedes (*Finlaya*) *geniculatus* Oliver.

Habits.—This species breeds only in water in tree-holes. The larvae are often found in company with those of *Anopheles plumbeus*. The adults are rarely numerous.

Importance in relation to man.—Where tree-holes abound, this species may be quite troublesome as the adults are very persistent biters, but only in the shade, as they seldom or never leave the shelter of the woodlands in which they breed. The adults occur most commonly from June to September.

Method of Control.—As for *Anopheles plumbeus*.

Distribution.—General in woodland districts throughout the country.

Aedes (*Aedes*) *cinereus* Meigen.

Habits.—Flooded meadows and the overflow of woodland ponds and streams seem to form the chief breeding grounds of *A. cinereus*. This species passes about 8 months of the year in the egg stage. It is not until April that the eggs hatch; and larvae then grow rather quickly and by about the middle of May the adults are on the wing. Often the larvae are found in flooded meadows in which the water is only a few inches deep. The females seem to be very timid.

Importance in relation to man.—Adults are very troublesome in some parts of England between the months of June and August, mainly about sunset and afterwards. Some may be on the wing in late May and a few may still

be found in September. The life span of the adults of this species is shorter than that of most of our species of mosquito.

Methods of Control.—As there is only one generation each year, it should not be difficult to control this species in an infested area, providing the anti-larval work is carried out at the *right time*. If the work be carried out in March the eggs would not have hatched, while if it be carried out in June most of the adults would be on the wing, therefore anti-larval work should be carried out in April. This applies to killing the larvae by larvicides or oil. But as this species breeds in flooded meadow land, in many places it may be not advisable to use larvicides, especially where, later in the summer when the water has evaporated, the meadow may be valuable as pasture land for cattle or for hay-making. The formation of breeding grounds of this nature should be prevented by some system of embankment or drainage sufficient to hinder grassland from becoming flooded, or remaining so for more than a few days at a time. Pyrethrum larvicide might be used on the residual pools.

Distribution.—Fairly plentiful in southern counties.

Aedes (*Aedimorphus*) *vexans* Meigen.

Habits.—A relatively rare mosquito in Great Britain with a localised distribution. Its bites may be a serious nuisance. Larvae have been found from spring to autumn in all kinds of ponds and in flooded meadows, preferably those exposed to sunshine.

Methods of Control.—Where possible, breeding places should be filled or drained. If this be not possible oil or other larvicides should be used in late spring (May) and, if possible, repeated two or three times during the summer. Pools remaining after anti-flood measures in meadows might be treated with pyrethrum larvicide.

Aedes (*Ochlerotatus*) *rusticus* Rossi.

Habits.—A. rusticus is a vicious biter in and around woodland country in spring and early summer (April to July). The larvae may be found in woodland pools and ditches as early as October, and although the larvae may be fully grown before Christmas, the adults do not appear until the end of March or early in April. It is a single-brooded species, *i.e.*, there is only one generation each year. In April, May and June they may be very troublesome to man, both in and on the outskirts of wooded country.

Importance in relation to man.—The irritation following the bite is both painful and persistent. The adult insects live in the grass and shrubs in shaded areas and they bite by day as well as by night, although they do not travel far from their breeding grounds.

Methods of Control.—Woodland pools are often quite small, sometimes holding only a few gallons of water, yet such pools may harbour large numbers of the larvae of three or four sylvan species of *Aedes*, such as *rusticus, cantans, punctor,* and *annulipes*. When such pools contain larvae the best method of dealing with them is to fill them up if possible. On the other hand, if pools be numerous and it is not possible to fill them in, cresol larvicides or oil may be used with good results. As these four species produce only one brood of larvae in the year the importance of carrying out anti-larval measures at the right season to destroy the maximum number of larvae cannot be over-emphasised, for an attack on the adult stages is not practical because these insects live hidden away in trees, bushes and other vegetation, and seldom enter houses in large numbers.

Unfortunately the habits of the three most troublesome species are different in that the hatching of eggs and the emergence of adults do not occur at

the same time.* If the pools be treated in December, the larvae of *A. rusticus*, will be killed, but *A. punctor* and *A. cantans* will still be in the egg stage and will mostly escape destruction. On the other hand, if the water be treated in April, many, if not most, of the *rusticus* larvae will have emerged as adults in sufficient numbers to provide a nuisance during the following summer.

The best time to destroy the larvae of *A. rusticus* is in January or February. Treatment in March will destroy *A. cantans*, *A. punctor*, and *A. annulipes*. Where woodland pools contain the larvae of two or three troublesome species, they should be treated at the times when the greatest number of larvae are present, usually a few weeks before adults begin to emerge. As a rough guide it may be stated that such pools should be treated on two occasions—once in January and once early in March. In January most of the larvae of *A. rusticus* are destroyed before adults begin to emerge, while in March the larvae of *A. cantans*, *A. punctor*, and *A. annulipes* are killed. If, however, it is only found practicable to treat the breeding grounds once, this had best be done about the second week in March. At that time the larvae of all these species will be present although some adults of *A. rusticus* may have emerged and some of the eggs of *A. cantans*, *A. punctor*, and *A. annulipes* may not yet have hatched.

Distribution.—*A. rusticus* is common in most parts of the country where suitable breeding places occur.

Aedes (*Ochlerotatus*) *cantans* Meigen.

Habits.—When the adults of three of the common sylvan species of *Aedes* (*A. cantans*, *A. punctor*, and *A. annulipes*) are abundant in the summer months, their main breeding places (woodland pools) are frequently dry for long periods, so they very often lay their eggs on the ground in shaded and usually low-lying spots. The winter rains and melting snow carry the eggs into hollows and the larvae hatch only when pools are formed early next year. Although the eggs may be submerged as early as October, yet the larvae are not found until about January or later. On the other hand, eggs which have been kept for a year or so without becoming completely desiccated will hatch when placed in water, often within a few minutes.

A. cantans is a sylvan species and the larvae are found in the same kind of breeding places as *A. rusticus*, except that they are not found in exposed pools and ditches but only in the presence of shade. The adults attack man between the months of June and September.

Importance in relation to man.—There is ample evidence to show that the bites of this species are a really serious nuisance to man throughout the summer and early autumn, but only in wooded areas. The insects are confined to the woodlands where they breed.

Methods of Control.—(See under *A. rusticus*.) The best time to apply larvicides is in March. The larvae may continue to appear throughout the summer, if torrential rains again form pools into which more of the eggs surviving from the previous year are washed. It may be advisable in some cases, therefore, to repeat the larvicidal treatment again at a later date. Some work done by Marshall suggests that the removal of bushes, etc., shading breeding pools, may result in a cessation of breeding.

Distribution.—General throughout the country where there are forest and woodland pools.

* In Plate I the seasonal prevalence of the different stages of these insects has been shown diagrammatically.

Aedes (*Ochlerotatus*) *punctor* Kirby.

This is another sylvan species, but is not so restricted in its choice of its breeding places as are *A. cantans* and *A. rusticus*. Larvae may be found on open heaths or commons in temporary pools shaded by shrubs or small trees. Marshall states that this species breeds almost exclusively in districts with a sandy or gravelly soil, and when found in woods, pine and birch trees predominate.

Young larvae may be found as early as December and as late as May, and, if there be heavy rain in May or June, eggs which have remained moist since the previous summer may be washed into collections of water in June and will then hatch almost at once.

Importance in relation to man.—This is undoubtedly one of the most troublesome of our English sylvan mosquitoes. It is a persistent biter and will attack man both by day and by night. Like most of our so-called *wild* mosquitoes, this species feeds a great deal on wild animals in the forests. Although it cannot be said that it is a domestic mosquito, it does, on occasion, enter houses at night and bites man.

Methods of Control.—(See under *A. rusticus*.) As with the other two sylvan species mentioned already, there is only one generation each year, so control work should not be difficult to carry out effectively, if undertaken at the proper time. The best season for the application of larvicides is during March. The search for breeding grounds should be carried out not only in woods and forests, but also in the surrounding country especially where there are shaded pools. It will always be found that there is a layer of dead leaves on the bottom of the pools where larvae are present.

Distribution.—Recorded throughout the country where suitable breeding grounds are present.

Aedes (*Ochlerotatus*) *annulipes* Meigen.

The larvae of this species are indistinguishable from those of *A. cantans*, but their habits are quite different. The latter breed only in pools in woodland country, whereas *A. annulipes* seem to prefer more open breeding grounds. They are to be found almost entirely in temporary pools on heathland and on the outskirts of woods.

Importance in relation to man.—The female adults bite man viciously and where they are present in large numbers are a serious nuisance.

Methods of Control.—(See under *A. rusticus*.) Larvicides should be applied in March. The results are good provided *all* the breeding grounds have been located and treated.

Distribution.—These insects probably occur in most parts of the country in localized areas, but are not equally distributed, being absent from many districts.

Aedes (*Ochlerotatus*) *flavescens* Muller.

In England this species has been reported only from Kent and Essex. The larvae have been found in slightly brackish water in semi-stagnant ditches near the sea. One brood of larvae appears each year about April or May.

Females readily attack man and animals but do not appear to travel far from their breeding places.

Methods of Control.—(See under *A. rusticus*). Larvicides should be used in April.

Aedes (*Ochlerotatus*) *dorsalis* Meigen.

The larvae have been found sharing the same breeding places as *A. flavescens*. Although the insect has only a localized distribution, when present it may be very numerous and bites man viciously, both by day and by night.

Method of Control.—Unlike some of our English *Aedes*, multiple generations are produced throughout the summer. Adults first appear in May, so that, although there are a number of generations between May and September, if their breeding grounds are properly treated during the month of April the source of the majority of the potential parent insects will be destroyed. If the breeding grounds are not very extensive, they could, of course, be treated again in June or July.

Distribution.—Not recorded from many areas in England, but has been collected in small numbers in widely separated parts of the country. Probably more numerous around coastal districts.

Aedes (*Ochlerotatus*) *caspius* Pallas.

Unlike most of our English mosquitoes, the larvae of *A. caspius* are able to develop in either brackish or fresh water. This species may therefore be very troublesome both inland and on the coast. The adults are able to fly long distances, and it has been reported that in autumn (September) they have been caught two to three miles from the nearest known breeding ground. The first of the new season's adults appear late in April or early in May, but they are not really numerous until June. During some years they are very troublesome in mid-September. Larvae in enormous numbers are sometimes seen in semi-stagnant brackish ditches.

Inland, this species has been found breeding in fresh-water ponds on heaths and commons, and on one occasion in a sewage works. In such situations it is rarely or never so numerous as in coastal areas.

Importance in relation to man.—A. caspius is a vicious biter. Where the adults occur they are often in enormous numbers, and are very troublesome. As far as is known they do not enter houses but bite in the open. On hot, dry, summer days they stay in the grass and undergrowth, but at sunset they appear on the wing and fly about in search of a blood-meal. On dull days and in shady situations, they may bite during the day-time.

Methods of Control.—Where ditches are found to be infested they should, if possible, be filled in, or, if this be not possible, the ditches should be regraded and the bottom levelled, or better still they should be lined with masonry or replaced by pipes. If this is impracticable and anti-larval work is indicated, larvicides should be used in late March or early in April. This would apply also where the larvae are found in ponds on open heaths and commons. Where very extensive breeding grounds occur major drainage works may be required.*

Because the adults are able to fly long distances, the mosquitoes may not have bred in water near where the nuisance has arisen. It is absolutely essential, therefore, before any large-scale anti-larval operations requiring time, labour and money are undertaken, that it is definitely determined that

* This is discussed more fully later under the heading of "Anti-mosquito Measures."

the campaign is directed against the source of *A. caspius* and not against the breeding grounds of the common harmless species, *C. pipiens*.

Distribution.—Extremely numerous around coastal districts and in some places inland. Probably widespread throughout the country wherever breeding grounds are suitable.

Aedes (*Ochlerotatus*) *detritus* Haliday.

So far as is known this mosquito is able to breed *only* in brackish water, mainly along the coast in salt marshes. It is the only British species known to breed exclusively in such water. If the breeding places are sufficiently extensive, as in salt marshes, it may become a very great nuisance. On the only recorded occasion on which the larvae have been found inland, the brackish water originated from brine springs.

The maximum prevalence of the adults of this species is from June to October. Although most of them die off in the latter month, a few can usually be found in every month of the year. Unlike many other species both eggs and larvae can be found during the winter.

Like *A. caspius*, *A. detritus* has been found in small numbers as far as five miles from its nearest known breeding ground. It should, of course, be remembered that although individuals may be able to fly long distances, it does not follow that *all* of them do so. Usually a species is only very troublesome at or near its breeding grounds, but the fact that a species has been found at long distances from its breeding place, even in very small numbers, is, of course, very important. *A. detritus* is numerous, in moderate numbers, few or absent, according to the suitability for breeding of the water collections in the vicinity.

It is, of course, true that in an infested area larvae may be more numerous in some places than they are in others. Providing the water is brackish and semi-stagnant, that it is not flooded at every tide, and that it is free of natural enemies of the larvae, experience has shown that, in the great majority of cases, larvae of *A. detritus* are present.

Importance in relation to man.—Although the prevalence of this species is confined almost entirely to coastal areas, it has been responsible for a greater number of serious nuisances than any of the other British species of mosquito.

Methods of Control.—This species breeds only in brackish water. Providing the water is brackish the actual situation seems not to be important. It may be a ditch beyond the sea-wall, a pond or lake, pots and pans filled with brackish water along sea-marsh lands, flooded golf bunkers or borrow pits or disused gravel pits. Faulty sluice-gates often cause the production of large stretches of stagnant sea-water; such gates may not prevent the water getting in at high tides nor let it all flow away when the tides recede. The result is that acres of land, which are not at the time being tilled, are neglected and so eventually may become a prolific breeding ground of this species. Broken and leaky sea-walls also help to provide large expanses of stagnant brackish water. Such conditions obtain frequently very close to seaside resorts, and, because the land is not being used, no effort is made to repair the sea-wall and sluice-gates, or to drain the land. If it were realised what prolific breeding grounds for *A. detritus* such swamps become, more attention would undoubtedly be paid to them.

Another type of man-made breeding ground is often seen. During recent years golf courses have sprung up at most of our seaside resorts. To build bunkers and for levelling purposes, soil is often removed from waste land at

a short distance from the town or near the sea-wall. This is asking for trouble. At exceptionally high tides, the sea water flows over the sea-wall and instead of flowing away, as it would do if the ground was left undisturbed, the pits left by the excavations become brackish pools and then it is only a short time before they become infested with the larvae of *A. detritus*, and also those of *A. caspius*. The results of many surveys have proved that the increase of the mosquito nuisance in such places in recent years has arisen because the breeding grounds have been allowed to become more numerous and have been extended by the removal of soil, leaving large hollows which eventually fill up with brackish water. Steps should be taken to ensure that, if such dangerous excavations be made, they are either properly drained or filled so that they do not form mosquito breeding places in the future.

Where only a relatively few ditches, pools, or ponds are infested by the larvae of *A. detritus* or *A. caspius*, effective minor anti-larval measures can be easily carried out. These are best started in February and repeated monthly till October.

In many districts, however, the breeding grounds may be very numerous and in some cases cover many acres. When such is the case, it is essential to obtain expert advice about the measures to be adopted. The drainage of extensive expanses of brackish water, often at or below sea-level, is not easily dealt with, and always requires expert engineering advice.

Distribution.—This species occurs throughout Great Britain in coastal areas. It is most numerous where there are extensive areas of stagnant brackish water, such as "salt marshes."

MOSQUITO CONTROL IN GREAT BRITAIN.

The problem of the transmission of malaria by mosquitoes is seldom a serious one in this country, and measures against mosquitoes are usually undertaken to reduce their numbers to a level at which they no longer cause a nuisance by their bites. This mostly means their control in relatively small breeding places such as woodland pools, stagnant ditches, lakes in public parks, water in disused gravel and sand pits, sewage farms, and domestic water-containers of all kinds around dwellings, farms, allotments, etc. The only relatively large-scale operations are those in connection with the breeding of such mosquitoes as *A. detritus* and *A. caspius* in the brackish water of coastal marshes. These may often need to be extended over a large area on account of the prolificity of these species and their length of flight.

While the nuisance caused by certain species of mosquito may be diminished by measures directed against them in the adult stage, the most satisfactory results can only be obtained by attacks upon the breeding places of these insects.

Wherever possible anti-mosquito measures should aim at destruction of breeding places by abolishing them *permanently*, either by preventing their formation or by draining or filling them up.

Wherever such permanent measures cannot be undertaken the insects may be attacked by the use of larvicides of various kinds (*vide infra*). It must be remembered, however, that the action of such substances is only temporary and palliative, and their application has usually to be repeated at varying intervals *ad infinitum* until the breeding grounds are permanently abolished, or made unsuitable for breeding.

To obtain the best effect of such larvicidal measures, it is essential that they be applied at the proper season of the year. In the case of those species the larvae of which appear mainly in one large brood annually (most of the troublesome species of *Aedes*), such measures should be carried out vigorously a few weeks before the adults begin to emerge. In this way the majority of the annual adult generation will be destroyed before emergence and the otherwise inevitable nuisance controlled or very greatly abated. On the other hand, with insects which have multiple broods during the spring, summer and autumn, anti-larval measures will usually need to be carried out every two weeks during the season when adults are emerging. It is in the latter case that any permanent reduction in the number of breeding places will be of greatest value. Even if only a little is done each year the time, material and money needed for anti-larval work will gradually decrease.

In the foregoing notes on the different species of mosquito, information has been given on the methods of control and the seasons at which these can be carried out to the greatest advantage. This information is summarised briefly later (pp. 27 and 28). Some practical information about the methods of application of the different anti-mosquito measures which have been used successfully in this country are detailed below.

Anti-Mosquito Measures.*

The measures of mosquito control may be directed either against the adult insect or its immature aquatic stages, mainly the larvae.

(1) Measures against Adult Mosquitoes.

Houses which are kept clean, well-ventilated and well-lit are much less likely to harbour mosquitoes than those which are dirty, dark and ill-ventilated, with many hangings and festooned with cobwebs. The principal measures employed against adult mosquitoes are spray-killing with insecticides and the use of repellents.

(a) *Insecticides.*

It is only in the case of those species of mosquitoes which tend to congregate inside buildings at certain seasons (usually for hibernation) that such measures are likely to have any appreciable effect on the prevalence of these insects. Species such as *A. maculipennis, T. annulata* and *C. pipiens* rest in cattlesheds, cellars, attics, etc., during the colder months, and at such times very large numbers of them can be destroyed. The adults of *A. maculipennis* can also be attacked at other times, since they frequent buildings at all seasons of the year.

The most effective insecticides are those containing pyrethrum, DDT (dichloro-diphenyl-trichlorethane) or BHC† (benzene hexachloride). Pyrethrum has a quick immediate knock-down, but practically no residual effect. DDT

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* An account of the methods of mosquito control is given in Govt. of India Health Bulletin No. 11, 7th Edition, 1946, entitled *Anti-Mosquito Measures with special reference to India* by Major-General Sir Gordon Covell. This pamphlet is obtainable through the High Commissioner for India, India House, Aldwych, London, W.C.2. Price 9d.

† The designation BHC includes a mixture of isomers of benzene hydrochloride. The gamma isomer, which is the most powerful insecticide, is also known as "Gammexane." (See footnote, p. 10.)

and BHC are very much slower in action, but possess a remarkable residual effect, so that insects alighting on surface sprayed with them are killed over a period of several weeks or even months after their application. Only a few minutes of contact is required, after which the insect will die within four to six hours. The duration of the residual effect varies according to the nature of the surface sprayed. Thus, a dose which is effective for months on rough wood, fabric or well-dried paint may persist on a freshly painted or enamelled surface or on one covered with dried mud for no longer than two weeks. Recently applied limewash has a marked neutralizing effect on DDT, so that it is useless to apply this insecticide immediately before, or for some days after, a building has been limewashed.

DDT and BHC may be applied either as an oily solution, a water emulsion or a water suspension. Emulsions and suspensions are made up as concentrates, which are diluted with water immediately before use. There are a number of proprietary preparations containing these insecticides, either alone or in combination, and for domestic use on a small scale it will probably be found convenient to use one of these. They are however comparatively expensive, and for large scale application a locally prepared spray such as those given below will prove very much cheaper:

Pyrethrum oil-soap emulsion spray.—Two parts by volume of one per cent. pyrethrum extract are mixed with two parts of ground-nut or other vegetable oil. The mixture is gradually added to one part of 20 per cent. soap solution (prepared by mixing 2½ lb. neutral soap in one gallon of water), thoroughly agitating all the time, to produce a uniform stock emulsion. This retains its full efficiency for about two months, after which it gradually deteriorates. Immediately before use, the stock emulsion is diluted with four times its volume of water. After dilution the emulsion deteriorates rapidly, and therefore only a single day's supply should be made up at one time.

DDT water suspension.—Dissolve five grammes of flake gelatin and 10 grammes of powdered gum acacia in 480 cc. of hot water. Allow to cool. Pour into a stone mortar and add 600 grammes of DDT powder. Grind the whole into a fine homogeneous paste with a stone pestle. This will take about 30 minutes. For use, for a five per cent. DDT spray, throughly mix with water to make 2½ gallons.

Emulsions and suspensions in water are particularly useful in such places as cellars or cattlesheds, where there are few articles liable to be damaged by their application, but they produce white spots on the surfaces sprayed, which are difficult to remove unless they are wiped off immediately after spraying.

Apparatus.—For all insecticides either hand sprayers, knapsack sprayers or power driven electric or petrol sprayers may be used. A stirrup pump with a modified nozzle and spray arm is a useful form of apparatus for the application of DDT as a water suspension. Pyrethrum sprays are applied as a fine mist or aerosol, with the sprayer directed upwards so as to fill the room with spray, and all apertures are kept closed at the time of spraying and for 20 minutes or so afterwards, the object being to kill insects which are resting or flying about at the time of spraying. Residual insecticides are applied as a coarser spray from a nozzle at least $\frac{1}{64}$th inch (but not greater than $\frac{1}{32}$nd inch) in diameter, held about 12 to 18 inches from the surface sprayed, the object being to cover this with a film. The dosage aimed at is about 150 milligrammes of DDT per square foot, which represents one

quart of a 5 per cent. spray per 500 square feet of surface. If BHC is used for this purpose it should be applied at the rate of one ounce per 500 square yards. Special attention should be given to ceilings, walls and cupboards and under surfaces of beds, tables and shelves in houses, stables, outhouses and other places where mosquitoes are most likely to rest.

Buildings in which mosquitoes are congregated for hibernation should be sprayed twice, once at the beginning of this period and a second time some weeks before the insects resume their activities in the spring.

(b) *Repellents.*

These are liquids or ointments applied to the exposed skin surfaces (ankles or legs; wrists or arms; back of neck and ears) to protect the individual against insect bites. Two of the most useful are oil of citronella and dimethyl phthalate (DMP), the latter of which was used extensively during the second world war, in liquid form. If applied as an ointment the DMP content of the preparation should be not less than 40 per cent. There are a number of proprietary preparations containing these or other repellent substances on the market. The period of protection afforded by any particular repellent varies very considerably with different individuals and under different climatic conditions. A good repellent, freely applied, will prevent mosquitoes from biting for from two to five hours.

(2) Measures against the Aquatic Stages of Mosquitoes.

Such measures may be divided into (*a*) those which aim at the prevention of the formation of breeding places and their abolition, if formed (mechanical measures); (*b*) those aimed at making water collections unsuitable for the breeding and survival of larvae (naturalistic measures); and (*c*) those aimed at the direct destruction of larvae and pupae (larvicidal methods).

(*a*) Mechanical Measures.

The ideal methods against mosquito larvae are those which either prevent the formation of breeding places or abolish these so rapidly that the insects have not time to multiply in them. Wherever possible the abolition should be permanent. These methods consist mainly of the drainage or the filling of actual or potential mosquito-breeding places.

Minor measures consist in burying old tins, pots and other potential water receptacles, which accumulate on rubbish heaps, and around houses. Water-butts, tanks, cisterns, bird-baths, etc., in gardens and green-houses often breed many mosquitoes. These should be emptied and brushed out about once every week. If they are fitted with tight covers to prevent the entry of mosquitoes to lay eggs, and the water is withdrawn by a tap from below the danger is lessened.

Holes in trees should be filled with earth, clinker or gravel and faced with cement, or better with asphalt, which is less liable to crack. Where breeding pools are few, small and localised, they should be filled in. When, however, there are old quarries, gravel sand and borrow pits, brick fields and similar excavations, this may be a formidable task. In some cases, the formation of such pools can be prevented to a large extent by the stoppage of flood water entering them from overflowing ditches and streams. The amount of filling needed to abolish the water can often be greatly diminished if this is combined with appropriate methods of drainage. In the vicinity of towns many such large or numerous excavations can be got rid of permanently at a

relatively low cost by filling with household rubbish. Swamps can sometimes be treated in a similar manner.

In many instances breeding places are formed by obstructions to drainage. It is essential, therefore, that all ditches, etc., which drain known breeding places, or which themselves act as breeding places, should be kept properly cleaned, graded and free from vegetation. This is especially the case just before and during the mosquito season.

In some cases a relatively simple system of drainage will abolish quite large breeding places if properly carried out.

The ground should be thoroughly studied beforehand, and appropriate line of drainage determined. The drains should be as few and as short as is consistent with efficiency. (Long drains often hold stagnant water and themselves act as breeding places.) Sharp bends should be avoided. The edges should be clean cut. The main drain and a few rough subsidiary drains should be made first and allowed to function for several weeks before any *large* system of secondary drains is installed. During this interval, much water will be drained off and the need for a large number of minor drains reduced. Work should always start from the outfall end of any drain.

There are, however, larger drainage schemes which will need expert engineering advice. These are usually in connection with the most serious mosquito nuisances in this country, namely, those caused by the mosquitoes which breed mainly in brackish water along the low-lying coastal areas (*e.g.*, *A. detritus* and *A. caspius*). When such breeding places are below the level of and are flushed by even the lowest spring tides, they seldom require attention, because the larvae are washed out at least once a fortnight, which, save in exceptionally warm weather, is too short an interval to allow of the hatching-out of adults. (See also the notes above on the control of *A. caspius* and *A. detritus*.)

Marshall has made a special study of these coastal-breeding mosquitoes and their control. He divides the areas into two groups—(i) those to which the sea has more or less direct access; and (ii) those lying behind the sea-walls bordering upon reclaimed areas.

(i) *Areas to which the Sea has Access.*—Here the spring tides often leave pools which may stagnate for long periods and in which mosquitoes breed until the water soaks away or evaporates. The duration of these pools may be shortened by drought or lengthened by rainfall. Such breeding places may be abolished by filling, or by drainage to lowest spring-tide level, or by a combination of these methods. As such measures may take some time to complete, it is usually necessary to use larvicidal measures (oil or cresol) to obtain an immediate destruction of the larvae, if these be present, otherwise they may hatch out in the interval.

(ii) *Areas behind Sea-walls.*—These areas are usually low-lying and their surface is often below the level of ordinary high tides. Large brackish stagnant pools may be formed here by percolation and by leakage through or over imperfect sea-walls. Defective drainage devices and accumulation of rain-water are other or additional causes of the formation of breeding places. In such areas repairs to sea-walls are often needed, but it is usually also necessary to instal some system of drainage leading to sluice valves or tidal gates, which are opened either automatically or by hand when the tide is sufficiently low to allow the accumulated water to run away. Such schemes usually require expert engineering advice. In some of these areas many depressions may be abolished by filling, while other breeding places may be treated periodically with larvicides.

Whenever the nuisance is a serious one it is always advisable to get the opinion of an expert as to the best method of dealing with the problem.

(*b*) Naturalistic Methods.

In many permanent water collections such as lakes, ponds and ditches, the breeding of mosquitoes is kept under control by the attacks of their natural enemies, which must destroy enormous numbers of larvae. Where, however, there is much aquatic vegetation, more especially that of a floating type, large numbers of the larvae may be protected from destruction.

Many small fish such as sticklebacks, gold-fish and the fry of larger fish, will eat larvae greedily. Small ornamental ponds in gardens can often be kept free of larvae if a few gold-fish are introduced into them. If, however, there be much vegetation, the shelter for the larvae may be so great that many escape destruction. Weedy ponds, lakes and ditches are often fruitful breeders of mosquitoes (especially of *A. maculipennis*). In such cases the vegetation should be removed or cut away below the water level so that the larvae are exposed to the attacks of their natural enemies or are washed into uncongenial surroundings.

In some weedy dykes where it was too expensive to cut the weeds and keep them cut, good results have been obtained by the use of sluice gates which allowed the water to be raised and lowered so that the larvae were washed out of their shelters. A similar method may be used with ornamental lakes if financial conditions permit.

When cresol larvicides or oiling are used extensively on lakes and ponds, it must be remembered that many natural enemies of the larvae may be killed off. This may leave the water more suitable for the breeding of mosquitoes after the temporary effects of these larvicides have passed off.

Marshall records that with *A. cantans*, a species which always breeds in densely shaded pools, the removal of trees and bushes around a very prolific breeding ground resulted in the disappearance of the larvae, which only reappeared when the bushes were allowed again to reform shade.

(*c*) Larvicidal Agents.

The *permanent* abolition of breeding grounds is the ideal to be aimed at in all anti-mosquito measures. Because this may not always be possible financially, and because such permanent works may take weeks or months to complete, it is often necessary to resort to more rapid but *temporary* measures of control.

Larvicides should never be used on any collection of water unless mosquito larvae are present in it. The best time for the application of larvicides is influenced largely by season, rainfall, flooding, temperature, etc. In the summary at the end of this section some indications have been given as to what are usually the most suitable times with the different species. The effect of larvicides should always be observed 24-48 hours after their application.

Such methods involve the use of agents which kill the larvae and pupae rapidly (usually within a few hours). These larvicides may be classified as follows:—(i) oils and (ii) chemical larvicides.

(*i*) *Oils.*

Oils act on larvae both by blocking their breathing tubes and by the direct poisonous effect.

Kerosene oil may be used to kill larvae but, as it evaporates very quickly and is expensive to use on a large scale, it is usually mixed with some heavier oil. A good preparation consists of a mixture of one part of crude heavy oil to four parts of kerosene. If to this mixture be added about 0.1 to

0.2 per cent. castor oil, its spreading power is increased enormously. Some workers say the toxic properties of the oil are increased by the addition of about 1 per cent. cresol to this mixture. The amount needed is about ½-oz. per square yard, or 15 gallons to an acre.*

Waste crank-case oil from motors can also be used instead of crude oil. It should be mixed with 10-20 per cent. kerosene and 1-2 per cent. castor oil added. Its efficacy can be greatly enhanced by the addition of a small quantity (1 to 2 per cent.) of DDT. The waste oil should be well strained before use, otherwise, if it is used in a sprayer, the impurities are liable to block the nozzle of the spray.

A long stick with a bundle of rags or sacking on the end may be used to spread oil on small pools. Where large areas have to be dealt with, the oil is best distributed by means of a knapsack sprayer (such as is used by gardeners) with a fine-spraying nozzle.

Oil does not spread well where there is much vegetation, and the surface layer may be disturbed by wind or heavy rain before it has time to act properly. It is also liable to kill fish and vegetation. Oil is very often useful in temporary ponds in woodlands where it is protected from wind. It is less suitable for pools in coastal areas, where the wind is often strong and displaces the oil film before it has time to act. The rapidity of its killing action can be increased, however, by the addition of 1 per cent. cresol, but cresol larvicide is often preferable in such situations. Oiling may also be used along the edges of deep ponds and lakes, when the breeding is confined to these situations. Oiling is also suitable for use on water stored for fire-fighting purposes.

As the action of oiling is only temporary, it may be necessary to repeat its application every two weeks, if the larvae attacked belong to a species which continues breeding during the summer months.

Oil may also be used on the surface of domestic water containers such as water-butts, cisterns, etc., but if the water employed is for domestic purposes or for gardening, this may be objected to by the users. In such cases about 4 tablespoonsful of petrol per sq. yd. of surface will kill the larvae, and if exposed to the air will evaporate in less than 24 hours without damaging the water. This must be repeated if larvae re-appear later. Where the liquid is stored in receptacles with taps at the bottom, the water may be covered with a thin layer of liquid paraffin (about 1½ teaspoonsful per sq. yd.) The effect of this will last for several months.

(*ii*) *Chemical Larvicides.*

DDT may be applied to water surfaces as a dust, but better results are achieved by using it in the form of an oily solution, a water emulsion or a water suspension, prepared on the same lines as described above for the destruction of adult mosquitoes. The dosage generally recommended for Anopheline larvae is one quart of a five per cent. solution, emulsion or suspension (=0.1 lb. DDT) per acre, as compared with the ten to twenty or even thirty gallons of oil required for the same breeding area. With untrained labour it is advisable to dilute the larvicide to about one per cent., applying it at the rate of 2½ gallons per acre. DDT is effective in all types of water collections, even if much vegetation is present, though if this is very dense it may be found necessary to increase the dose. For the destruction of Culicine larvae the emulsion is particularly effective, and for some

* Several of the large petroleum companies manufacture special oil mixtures for anti-mosquito work.

species a dosage as low as 0.05 per million of the volume of water treated has been found sufficient. The larvicide may be applied by means of a knapsack or hand sprayer or from a drop bottle (e.g., a beer bottle fitted with a perforated cork and quill), or by throwing sawdust or plaster of paris pellets soaked in the oily solution into breeding places.

BHC is applied by the same methods as are used for DDT, at the rate of 0.02-0.04 lb. of the gamma isomer per acre.

Paris green (copper aceto-arsenite) and *cuprous cyanide* are used either as dusts or water suspensions. As dusts they are applied mixed with an inert vehicle such as french chalk, in a dilution of 2½ to 5 per cent. by means of a mechanical blower or hand bellows, or they may be simply thrown into the air by hand. The powder is carried over the surface of the water by air currents, and with a slight wind will be effective at a distance of several hundred feet from the point of application. Water suspensions may be prepared by mixing 2½ lbs. of paris green or cuprous cyanide, half a gallon of kerosene, one ounce of castor oil and the whites of four eggs, shaken up in a can and used in a dilution of one ounce to the gallon of water. These two larvicides may also be mixed with water only and thrown on to the surface of the breeding place. They are very effective against Anopheline larvae, but do not kill the eggs or pupae, and have no effect on any of the aquatic stages of Culicine mosquitoes, which are the chief source of the mosquito nuisance in Great Britain. They are therefore of limited application in this country.

Cresol (saponified cresylic acid) is useful for destroying mosquito larvae in containers such as fire buckets, from which water is not used for drinking by man or animals. A sufficient quantity should be added to render the water slightly milky. This amount is more than sufficient to kill all the larvae, but is convenient for inspection purposes.

Work in the United States has shown that the killing power of oil can be greatly increased if an extract of pyrethrum be added to it. The larvicide recommended consists of a pyrethrum-kerosene-oil-soap emulsion, which is diluted 10 times with water before use. This larvicide is said to be harmless to fish, waterfowl and plant life, and to have been used successfully at sewage-disposal works, and in bathing pools. The concentrated stock emulsion consists of:—

	Parts by volume
Light fuel oil	95
Concentrated pyrethrum extract (containing 2½ grms pyrethrins per 100 c.c.)	5
Coconut-oil-potash liquid soap	5
Water	45
Total	150

In making the mixture, the soap is agitated with the water until the mixture begins to foam. This can be done with an ordinary bucket pump. The pyrethrum extract is added to the oil and thoroughly mixed with it. The oil mixture is then added gradually to the soap solution with constant stirring and pumping. When all the oil has been mixed, the agitation is continued for 5 to 10 minutes, or *until a homogeneous emulsion results*. This forms the stock emulsion, which should be freshly prepared and is diluted in the proportion of one quart to 4 gallons of water just before use.

It is effective in water of salinity not over 5 per cent. It is applied by spraying, usually in amounts equivalent to 1½-2 gallons of the stock emulsion

per acre, but as it does not spread well where there is much vegetation or floating debris, as much as 6 gallons may be needed to produce a high degree of efficiency. The minimal amount of oil to produce the same effect would be at least 12 gallons.

This larvicide does not seem to have been tried in this country, but might prove very useful in sewage disposal works, on flooded meadows or on permanent pools and lakes breeding mosquitoes.

CONTROL OF STATIC WATER TANKS.

To reduce the risks of mosquito nuisance, tanks and other collections of stored water should be inspected at least once a month. Vegetation and floating matter should then be removed and from the beginning of April to the end of September if mosquito larvae are found the surface of the water should be sprayed with one of the thick oils which are specially prepared for this purpose. As oil damages asphalt and bitumen the water in tanks lined with these coatings may have to be treated with a larvicide.

If, for some special reason, a tank has to be emptied, it must be completely drained. If any water is left at the bottom of the tank, mosquito larvae may survive and hatch out in a few days. Small collections of water, therefore, which remain and cannot be brushed out, should be treated with one of the cresol larvicides, which should be allowed to act for at least half an hour before the tank is refilled.

From time to time green *algae*, on which mosquito larvae thrive, may appear in the water. Growths of this nature can be kept under control by adding in solution sufficient copper sulphate to give a concentration of 3½ lbs. of the salt to a million gallons of water. Such treatment destroys the aquatic vegetation that *Anopheles* larvae prefer but does not destroy the larvae themselves nor prevent some species of *Culex*, such as *Culex pipiens*, from breeding.

In the planning of static water supplies it should be borne in mind that deep and large tanks or dams situated in exposed situations away from trees are least favourable to mosquito breeding and that conversely, shallow sectional tanks under trees the most favourable.

BRIEF SUMMARY OF THE MOST SUITABLE METHODS, AND THE BEST SEASONS FOR CARRYING OUT ANTI-MOSQUITO MEASURES.

Below are summarised the outlines of the methods which have been found most suitable for the control of the different species of mosquito recorded from Great Britain. For fuller details the worker should always refer to the "control" notes given under each species, and the section on "Mosquito Control in Great Britain" for the methods of applying the measures.

With regard to the best season at which to apply certain measures, especially larvicidal ones against the spring generations of the *Aedes* group, no rule-of-thumb data can be given, as these vary with the weather conditions. If the winter and spring be dry and the latter cold larvae may not reach their maximum prevalence till some weeks later than indicated below, and so larvicides need not be applied until a couple of weeks later. On the other hand, if the winter and spring be wet and the warmer weather commences abnormally early, adult insects may begin to emerge earlier and it will then be advisable to commence larvicidal operations a couple of weeks sooner. The dates given in the summary are applicable to normal seasons and also allow considerable latitude to cover many abnormal conditions. It must again be emphasised, however, that *larvicides should not be employed unless larvae are present* in the water collections it is proposed to treat.

Anopheles claviger.—Remove aquatic vegetation where possible. Apply larvicides in February and October.

An. algeriensis.—As for *An. claviger.*

An. maculipennis.—Where adults are numerous in buildings (animal houses mainly), spray walls and ceilings with insecticides in October to kill the wintering adults, and repeat in March to destroy the remaining adults before they leave their shelters to lay eggs in the spring. If adults are troublesome spray also in July and August.

To kill larvae remove aquatic vegetation in breeding places, and introduce small fish if these be absent. If breeding be extensive use suitable larvicides or mechanical methods.

An. plumbeus.—Fill holes in trees with earth, gravel or clinker, and face with asphalt or cement.

Culex pipiens.—Attack hibernating adults in dwellings, cellars and outhouses with insecticidal sprays in December and January, and repeat in March. Abolish breeding places by getting rid of old tins, pots, cans, etc. Empty water-butts, tanks, cisterns, etc., every two or three weeks from March to October, or cover with tight-fitting lid and insert tap at bottom or use petrol or liquid paraffin to kill larvae. Abolish other breeding places or treat with suitable larvicide.

C. molestus.—Examine and treat underground collections of stagnant water.

C. apicalis.—No action needed.

Theobaldia annulata.—As for *C. pipiens,* with special attention to liquid manure collections. Larvicides to be used every two or three weeks from March to October, when breeding detected. Sewage disposal works may need special measures of alternate irrigation or possibly treatment with pyrethrum larvicide.

T. subochrea.—As for *T. annulata,* when larvae found.

T. alaskaensis.—Probably as for *T. annulata,* but information limited.

T. fumipennis.—No action needed.

T. morsitans.—No action needed.

T. litorea.—No action needed.

T. longiareolata.—No action needed.

Orthopodomyia pulchripalpis.—No action needed.

Taeniorhynchus richiardii.—Uproot and remove aquatic plants and reeds to which larvae are attached.

Aedes geniculatus.—As for *An. plumbeus.*

Ae. cinereus.—Measures to prevent and diminish duration of flooding; suitable larvicides used in April.

Ae. vexans.—Fill or drain breeding places; suitable larvicides used in late spring (May) and repeated two or three times during the summer.

Ae. rusticus.—Fill or drain breeding places; suitable larvicides used in January or February.

Ae. cantans.—As for *Ae. rusticus,* but larvicides are used in March, and may need to be repeated if many new pools form later.

Ae. punctor.—As for *Ae. cantans.*

Ae. communis.—No action needed.

Ae. sticticus.—No action needed.

Ae. leucomelas.—No action needed.

Ae. annulipes.—As for *Ae. rusticus,* but larvicides used in March.

Ae. flavescens.—Use suitable larvicides in April.

Ae. dorsalis.—Abolish breeding places if possible: treat with larvicides in April, and, if possible, at least once monthly until end of September.

Ae. caspius.—Limit, reduce and abolish breeding grounds by embankment, drainage, filling, etc.; treat these with suitable larvicides in late March or early April, and at least once monthly until end of September.

Ae. detritus.—Limit, reduce and abolish breeding grounds by drainage, filling, etc.; major engineering works may be needed; limited breeding places treated with suitable larvicides in February and at least once monthly till October.

APPENDIX I.

BRIEF DESCRIPTION OF THE DIFFERENT STAGES IN THE LIFE HISTORY OF MOSQUITOES.

(Plate II)

Adult mosquitoes, popularly known as " gnats " are small winged insects varying in length from $\frac{1}{8}$ to $\frac{1}{4}$ inch. They vary greatly in colour but the commoner species are usually light or dark brown. Only the females are capable of biting. The body consists of a small rounded head, a larger thorax and a cylindrical abdomen. The thorax carries two long membranous wings, which are folded over the abdomen when at rest, and six slender legs.

Mosquitoes can usually be differentiated from most other two-winged, six-legged insects by (*a*) the presence of a long proboscis, (*b*) the character of the wing venation, and (*c*) the presence of scales on the veins of the wing and along its posterior margin (*vide* Plate II).

Mosquitoes, in common with most other insects, go through various distinct stages in the course of their development from egg to adult. The forms shown by the insect during these stages may be so unlike each other that they may easily be mistaken for quite different creatures unrelated to each other (*vide* Plate II). The stages in the life history of mosquitoes can be compared with the egg, the caterpillar and the chrysalis in the life history of the butterfly or moth. The corresponding stages of the mosquito are the egg, the larvae and the pupa.

Water is *essential* for the development of the immature stages of mosquitoes.

The eggs are tiny structures, usually oval in shape.

The larvae, often referred to as " wrigglers," pass their whole existence in water. This is the active growing stage of the insect in which the size varies from about $\frac{1}{16}$ of an inch long when they hatch from the egg to about $\frac{1}{2}$ an inch in the large, full-developed ones of some species. The body of the larva is made up of three parts, the head, the thorax, and the abdomen. The head is small and globular and has numerous hairs. The thorax is rounded and usually wider than the head. The abdomen is narrower than the thorax. It is cylindrical and is divided into a number of segments.

Although the whole of this stage of the insect is passed exclusively in water, the larvae are true air-breathers. They inhale air through two small openings near the end portion of the abdomen. In some species (the Culicines), the body wall around these openings is prolonged so as to form a distinct tube (the " siphon ") set at an angle with the abdomen. In some other species (the Anophelines), no such tube exists. Those which possess breathing tubes hang down suspended from the surface film of the water by the tip of the tube when taking in air. Those species without a siphon lie parallel to, and close beneath, the surface of the water.

The colour of the larvae varies considerably. Some are dark brown or almost black, others are greenish or yellowish, while some are a dirty milky white. They are never bright red. The so-called " blood worms " often seen in water are the larvae of *Chironomus*, a non-biting insect.

The pupa or " tumbler " is the stage intermediate between the larva and the adult. It is a comma-shaped animal, having a large rounded portion above (head and thorax) and a small tail (abdomen) below.

Differentiation of Anophelines and Culicines.

Mosquitoes may be divided into two main groups—the Anophelines and the Culicines. The chief differences at various stages of their life cycles are shown in the following table and in Plate II.

	Anophelines.	Culicines.
Eggs	Laid separately and provided with floats.	Often laid in large masses (rafts), sometimes separately (*e.g*, *Aedes*); not provided with floats.
Larvae ...	Without respiratory siphon and lying parallel with and close to the surface of water.	With respiratory siphon and hanging down from surface of water.
Pupa	Respiratory trumpet more conical.	Respiratory trumpet more cylindrical.
Adult ...	Females with palps as long as proboscis. Usually sits with head, thorax and abdomen in straight line at acute angle to resting surface.	Females with short palps. When at rest humped up with abdomen parallel to resting surface.

APPENDIX II.

THE IDENTIFICATION AND COLLECTION OF MOSQUITOES AND THEIR LARVAE.

Mosquitoes are identified either in their adult or their larval stages, and various methods are used for their collection and transportation. A careful record should always be kept of the location and the conditions under which the specimens were collected, as well as of the time and date. Such information is needed in deciding upon the nature and extent of the anti-larval measures to be carried out.

(1) Identification of Mosquitoes.

Specimens will be identified free of charge either by the Ministry of Health's Malaria Laboratory, Horton Hospital, Epsom, or by the Entomological Dept., British Museum (Natural History), London, S.W.7. Workers are recommended to send their specimens to one of these places for identification and record.

(2) Collection and Transportation of Adult Mosquitoes.

Collection.

Wherever possible collect insects while biting. When complaints are received that mosquitoes are biting people in houses, a thorough search should be made for them there, and also in adjacent animal houses (stables, byres, pig-sties, etc.). The work is greatly aided by the use of an electric torch, because the insects usually rest in dark corners, all of which should be very carefully examined.

In dwellings, search near the ceilings (especially on the surface of old cobwebs), behind pictures, on and behind curtains and clothing hanging up (especially if they be dark-coloured), inside cupboards and wardrobes, etc., under beds clinging to the mattress, etc. Some species like *T. richiardii* may bite in houses during the night and leave again before day-light. With such species it may be necessary to try to capture them in the houses (bedrooms) during the night hours.

In animal and other outhouses, they are found most abundantly on old cobwebs, and on the ceilings, in old boxes, in rabbit hutches, and in dark corners where they are not much disturbed by either wind or human activities.

During the winter months when species like *An. maculipennis, T. annulata, C. pipiens,* and probably *C. molestus,* seek the shelter of buildings, specimens may often be captured in large numbers on the ceilings of animal houses, cellars, attics, outhouses, etc.

There are many " wild " species of mosquito which rarely if ever bite man indoors. The mosquitoes are best caught in the open just after sunset on a still evening. To capture such insects the best plan is to sit down very quietly in the woodland or open country where the insects have been reported biting. A bare leg or arm is exposed, and if man-biting mosquitoes are present at the time and in the vicinity, they will usually soon come and settle upon the limb or clothing, where they can be caught, usually before they suck blood.

The commonest way to collect adult mosquitoes is with an ordinary laboratory test-tube about 4 in. by half an inch. While the insect is resting on a wall, ceiling, window, or better still while biting, the open end of the tube is slowly placed over it. The mosquito usually flies towards the closed end of the tube in its efforts to escape, and is easily captured by placing a finger over the mouth of the tube. If, however, it remains near the mouth, a thin piece of cardboard or stiff paper may be inserted between the mouth and the surface on which the insect is resting, so confining it inside. When the insect is imprisoned the tube is closed with a small tight plug of cotton wool. If it is desired to catch several specimens in the same tube, the wool plug is pushed down with a pencil until only sufficient space is left for the mosquito to move about. A second, third and fourth specimen may then be caught in the same tube and each confined separately by a plug of wool.

If a number of test tubes are not available, each insect may be killed when captured by blowing in a whiff of tobacco smoke and allowing it to act for several minutes. The dead mosquitoes are then transferred to a dry test tube, or stored in a match- or pill-box as described below.

Care should be taken that the specimens are as little damaged as possible, but even damaged ones can be identified in many instances.

Transportation of Specimens through the post.

The following method may be used to send dead specimens through the post for identification:—A thin layer of cellulose wadding is spread *evenly* on the bottom of a pill-box. The dead insects are distributed over this; another thin layer of wadding placed on top of them and the box closed. The details of the place of collection, etc., are written on the bottom of the box. A match box may be used similarly.

(3) Collection and Transportation of Mosquito Larvae.

Collection.

If the species of mosquito responsible for the nuisance has been collected in the adult stage and identified, a reference to the details given above will indicate the type of breeding place in which its larvae are most likely to be found. The seasonal prevalence is indicated in Plate I.

In looking for the larvae of any particular species, always commence the search in suitable water collections nearest to the place where the nuisance is occurring.

The searcher should familiarise himself with the appearance of mosquito larvae before he starts searching. The larvae of Anophelines and Culicines have been shown diagrammatically in Plate II. The larvae of Anopheline mosquitoes lie flat below the water surface, while those of the Culicines hang down from it. When disturbed the larvae usually sink or swim to the bottom and may lie there for several minutes before coming to the surface again. The pupae usually bob up and down frantically.

Do not forget that larvae live *only* in water, and that any water collection, however small, may form a suitable location for those of some species of mosquito. Small collections of water only half an inch deep may breed mosquitoes, and such pools may be concealed by grass and bushes and so are overlooked. Empty tins, etc., are often hidden in similar position and may prove a fruitful source of domestic mosquitoes. The majority of larvae are found, however, in streams, lakes, ponds, pools, tanks, cisterns, flooded areas, etc.

The larvae can be collected by "dipping" for them with an ordinary white-enamelled soup ladle. Cups, saucers, photographic trays or saucepans with a white interior can also be used.

When collecting, commence at some central point and start examining all suitable collections of water near at hand. Search these carefully and do not hurry over the examination. When approaching any breeding place never let your shadow fall on the water, otherwise the larvae will be disturbed and go to the bottom, where they may stay for some time, the duration of which may be several minutes with some species. For the same reason it is useless to search while rain is falling at all heavily. When collecting in bright sunlight a pair of glare glasses, if not too dark, is useful.

Dip for larvae with a rapid skimming motion, allowing the surface water to run into the dipper, and then bringing it to the level. Do not dip deeply and do not splash. If, however, this be done too slowly the larvae may sink to the bottom before the dipper reaches them. The contents of the dipper are then searched for larvae. Usually these are easily seen, but sometimes, if there is much debris or mud in the water, it may be difficult. In that case if none are seen, stir up the water and the vigorous movements of the larvae usually betray their presence. If any larvae are detected they are removed with a wide-mouthed teated pipette (like a fountain pen filler with a wide opening) and transferred to a wide-mouth glass receptacle such as a jam jar.

In the case of streams, large ponds and lakes, it is not sufficient to examine only a small area, and, if no larvae be found after one or two dips, to conclude that they are absent. Samples of water should be taken along the edges every few yards. If one part is shaded by trees or bushes and another freely exposed, treat these two places as if they were separate pools.

It is seldom necessary to examine more than a yard or so away from the edge of a lake or other permanent pond, unless the vegetation extends further out. If, however, there is aquatic vegetation or floating debris further out, this should be searched as it may be a fruitful source of larvae. In temporary pools, in which there are no natural enemies of the larvae, the latter may be found more widely distributed, but are usually more abundant near the edges or around floating debris.

If the opening be large larvae can be collected from some tree-holes with a ladle, but if they are disturbed they are very liable to sink to the bottom and thus escape capture. In such cases and with tree holes with smaller openings, the contents should be well-stirred up to mix the sediment thoroughly, and then siphoned off. Refill the hole with water and repeat the procedure.

In searching for Anopheline larvae, especially if none are found by dipping or with the net, the water in places where there is vegetation should be well muddied. This may be done by pulling up plants, stirring up by hand, or walking about in the water. If one then waits for a few minutes Anopheline larvae (if present) come to the surface, and are easily seen lying on the surface in contrast with the muddy water. They can then be collected with a dipper or a large metal spoon.

Transportation of Larvae through the Post

When captured, larvae should be brought alive to the office or laboratory in some of the water in which they were found. The larvae are then transferred from the jar by means of a teaspoon or a wide-mouthed pipette to a small dish such as a petri-dish.

Most of the water is removed, and a 2 per cent. solution of formalin added. The larvae are then transferred in the formalin solution to a small wide-mouthed bottle or glass tube provided with a tightly fitting cork. Fill up with formalin and cork tightly. It is a good plan to tie down the cork with a string and dip the cork and neck of the bottle in melted wax (candle wax is suitable). The bottle is then securely packed and sent through the post for identification of the larvae. Larvae can also be preserved in 70 per cent. alcohol, but it is not permissible to send this through the post, as it is inflammable.

APPENDIX III.

Two-Winged Blood-Sucking Insects other than Mosquitoes.

In addition to the mosquitoes or " gnats " there are other two-winged blood-sucking insects which are troublesome to man in Great Britain*. The smaller kinds are popularly known as " midges "; the two commonest genera being *Simulium* and *Culicoides*.

Simulium are small, blackish, stumpy insects, often mistaken for mosquitoes. They are very troublesome in some localities, their bite being painful and often producing large swellings which may persist for several days. The larvae are found on water weeds and on stones in running water.

Culicoides is another genus of tiny insects, not more than a quarter the size of the smallest species of mosquito, which are serious pests in many gardens during the summer months. They breed, amongst other places, in the soft damp earth round the bases of trees.

The mosquito-like flies of the family *Chironomidae*, of which the best known belong to the genus *Chironomus*, may also be a nuisance, although they do not bite. They breed in the soft mud at the bottom of streams, ponds and canals and domestic water containers. The larvae of one species, often seen in water butts, are commonly termed " blood worms ". At times they may appear in dense clouds at sunset.

Prevention of bites.

The only effective anti-midge measure yet devised is the application of repellents, of which dimethyl phthalate (DMP) is the most popular. This may be applied as a liquid or in the form of a cream containing not less than 40 per cent. of DMP by volume. A useful formula is:—

Lanette wax	5 gm.
Triethanolamine	9 cc.
Oleic acid	27 cc.
Dimethyl phthalate	100 cc.
Water	100 cc.

Wide mesh head veils, soaked in DMP and then wrung out and hung in the open air, are even more effective, affording complete protection against bites for five or six days.

Other flies that need mention are—

Stomoxys calcitrans—often called the Stable Fly, which closely resembles the House Fly. It has sharp piercing organs which enables it to bite and suck blood. It readily attacks man but usually is not of much consequence where animals are present on which it can feed. It breeds in manure heaps and commonly feeds on horses and cattle.

Tabanidae—commonly known as " clegs " or " horse flies "—attack horses and cattle, but occasionally bite man. The bite is painful, but on account of its large size the insect cannot be confused with the mosquito.

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* *British Blood-Sucking Flies*, by Edwards, Oldroyd and Smart (British Museum (Natural History), S. Kensington, S.W.7, price 15/-) contains a full descriptive and illustrated account of all the species briefly alluded to in this Appendix.

APPENDIX IV.

MAPS SHOWING DISTRIBUTION OF INDIGENOUS MALARIA IN ENGLAND AND WALES.

About 1860. After the 1914-18 war.

The distribution of indigenous malaria was about the same in the two periods and there are sufficient reasons for believing that the density of *A. maculipennis* offers the most likely explanation.

There are only four species of *Anophelines* indigenous in Great Britain, and only one species, *A. maculipennis*, lives in close association with man. This species is known to have a number of sub-species, of which two only have been recorded in this country, namely, var. *atroparvus* and var. *messeae*. *Atroparvus* prefers brackish water in which to breed and if found in fresh water is never very numerous. *Messeae*, however, is seldom found breeding in brackish water. Whilst *atroparvus* feeds readily on the blood of man, *messeae* prefers to feed on domestic animals and only in the absence of suitable animals reluctantly feeds on man. In localities where more than five cases of indigenous malaria have occurred in any one year since 1917 *atroparvus* was always present in the houses in large numbers. In districts further inland where only one or two indigenous cases of malaria occurred it has never been possible to determine whether they were infected by *atroparvus* or by *messeae*, but it is believed that *atroparvus* was responsible and the reason why the disease did not spread was because this sub-species was not sufficiently numerous in the locality.

PLATE I

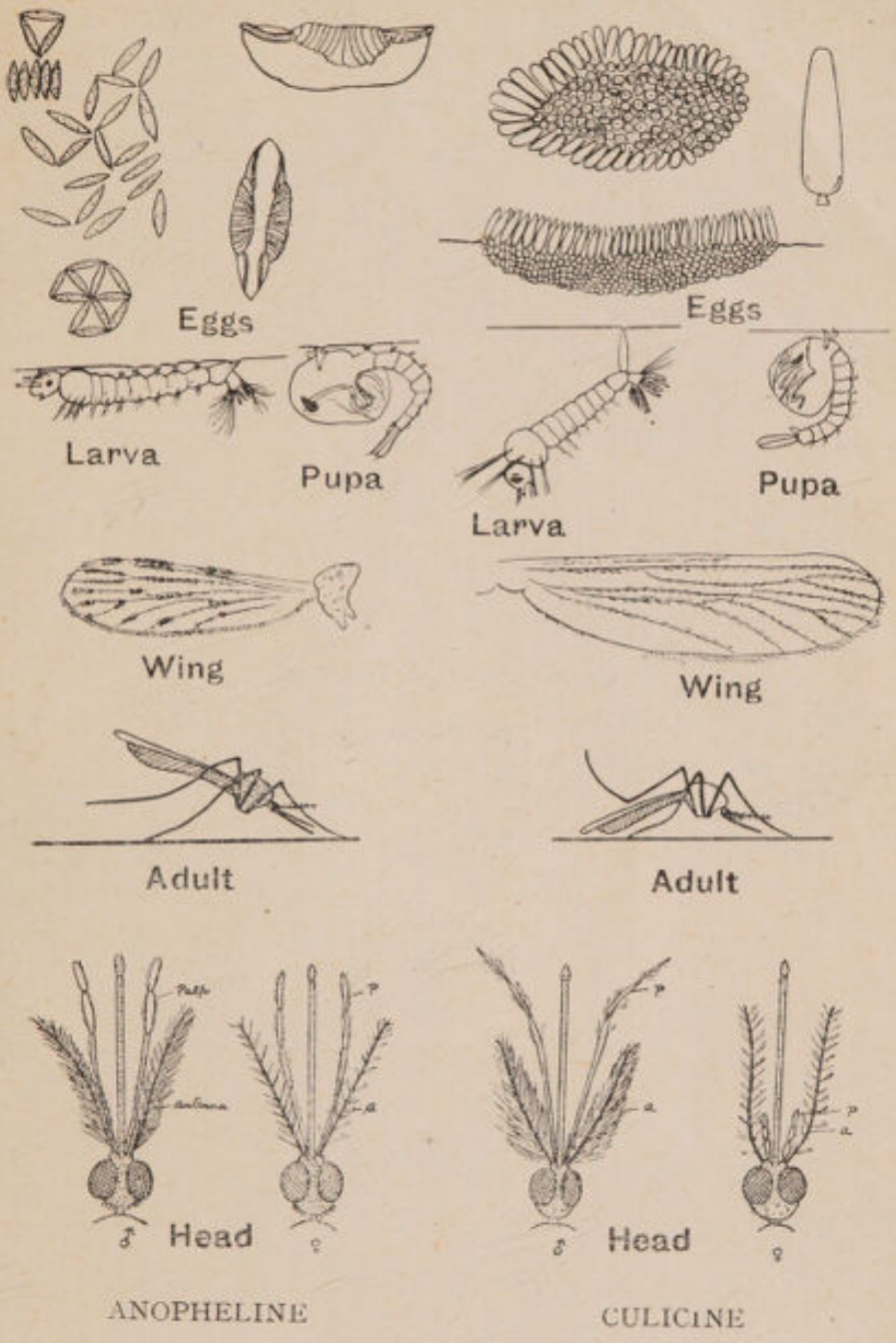
BIOLOGY OF BRITISH MOSQUITOES

	JAN.	FEB.	MAR.	APRIL	MAY.	JUNE	JULY.	AUG.	SEPT.	OCT.	NOV.	DEC.
ANOPHELES ALGERIENSIS.	—	—	—	— +	·— +	·— +	·— +	·— +	·— +	—	—	—
ANOPHELES CLAVIGER.	—	—	—	— +	·— +	·— +	·— +	·— +	·— +	—	—	—
ANOPHELES MACULIPENNIS.	✱	✱	✱	✱·—	✱·—	·— +	·— +	·— +	·— +✱	✱	✱	✱
ANOPHELES PLUMBEUS.	·—	·—	·—	·—	·— +	·— +	·— +	·— +	·— +	·—	·—	·—
CULEX APICALIS.	HABITS UNKNOWN.											
CULEX PIPIENS.	✱	✱	✱	✱·—	·— +	·— +	·— +	·— +	·—+✱	— ✱	— ✱	✱
CULEX MOLESTUS.	·—+	·—+	·—+	·—+	·—+	·—+	·—+	·—+	·—+	·—+	·—+	·—+
THEOBALDIA ANNULATA	—✱	—✱	—✱	·— +	·— +	·— +	·— +	·— +	·— +	— +	—+✱	—✱
THEOBALDIA ALASKAENSIS.	HABITS UNKNOWN.											
THEOBALDIA SUBOCHREA	—✱	—✱	—✱	·— +	·— +	·— +	·— +	·— +	·— +	·— +	—+✱	—✱
THEOBALDIA MORSITANS.	—	—	—	— +	·— +	· +	· +	· +	·— +	—	—	—
THEOBALDIA FUMIPENNIS.	—	—	—	— +	·— +	· +	· +	· +	·— +	—	—	—
THEOBALDIA LITOREA.	—	—	—	— +	·— +	· +	· +	· +	·— +	—	—	—
ORTHOPODOMYIA PULCHRIPALPIS.	HABITS UNKNOWN.											
TAENIORHYNCHUS RICHIARDII.	—	—	—	—	— +	·— +	·— +	·— +	·— +	—	—	—
AEDES CINEREUS.	·	·	·	·—	·—	·— +	· +	· +	· +	·	·	·
AEDES VEXANS.	HABITS UNKNOWN											
AEDES GENICULATUS.	·—	·—	· +	— +	·— +	·— +	·— +	·— +	·— +	·—	·—	· —
AEDES RUSTICUS.	—	—	—	— +	· +	· +	· +	· +	·— +	·— +	—	—
AEDES PUNCTOR.	·—	·—	·—	·— +	· +	· +	· +	· +	· +	·	·	·
AEDES ANNULIPES.	·	·—	·—	·— +	— +	· +	· +	· +	· +	·	·	·
AEDES CANTANS.	·—	·—	·—	·— +	— +	· +	· +	· +	· +	·	·	·
AEDES COMMUNIS.	HABITS UNKNOWN.											
AEDES STICTICUS.	HABITS UNKNOWN.											
AEDES LEUCOMELES.	HABITS UNKNOWN.											
AEDES DORSALIS.	HABITS UNKNOWN.											
AEDES FLAVESCENS.	·	·	·	·—	·— +	· +	· +	· +	· +	·	·	·
AEDES CASPIUS.	·	·	·	·— +	·— +	·— +	·— +	·— +	·— +	·	·	·
AEDES DETRITUS.	·— +	·— +	·— +	·— +	·— +	·— +	·— +	·— +	·— +	·— +	·— +	·— +

KEY.

· = EGG.
— = LARVA.
+ = ACTIVE ADULTS.
✱ = HIBERNATING FEMALE ADULTS.

PLATE II



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