Bull. Org. mond. Santé
Bull. Wld Hlth Org. } 1963, 28, 811-823

Tsetse-Fly Control and Eradication *

K. S. HOCKING,[1] J. F. LAMERTON [2] & E. A. LEWIS [3]

In many instances the cheapest and quickest way of controlling trypanosomiasis is to reduce the number of vectors and the opportunities for contact between man and vector. For permanent results, moreover, eradication of the vectors is necessary, since eradication of trypanosomiasis by chemotherapeutic means has so far not proved feasible.

For a variety of reasons, game destruction as a method of fly control is gradually being replaced by other methods. Of these, the complete removal of bush cover will always effectively eradicate tsetse flies, but in order to save time, labour and money, partial clearing (selective or discriminative) is more usually resorted to. Provided this is preceded by extensive and accurate surveys of fly infestation, it is generally successful.

Blanket applications of insecticides from aircraft or from ground aerosol machines can give good and rapid results ; however, as knowledge of the habits and behaviour of Glossina *species grows, the discriminative application of insecticides can be made more precise, economical and effective. This method of using the residual insecticides seems to be the most promising for the future.*

Tsetse flies are important only as vectors of diseases, human and animal, and hence the only reason for controlling them is to reduce or eliminate these diseases and thus enable man, with or without cattle, to occupy land previously held by some species of *Glossina*. Generally the diseases can be prevented or cured by the administration of drugs. Repeated survey and constant surveillance with mass treatment have reduced the incidence of human trypanosomiasis to a very low level. Treatment of the disease is readily available and highly effective; a large proportion of infections can be cured, and the mortality rate from human sleeping-sickness has been diminished to a very appreciable extent. The situation with regard to animal trypanosomiasis (nagana) has also improved. Curative treatment with trypanocidal drugs has been increasingly successful; a degree of protection against heavy infection and high mortality is conferred, especially when the fly density and fly infection rate are relatively low. Here, however, it seems that the risks of drug resistance are greater and tend to complicate the problem of control by chemotherapy and chemoprophylaxis if herds of cattle, for instance, are exposed for unduly long periods in the presence of continued fly and without close expert supervision.

Eradication of the diseases by chemotherapeutic means has not proved possible and hence for a permanent effect it is necessary to eradicate the vector. In many cases also, reduction in the numbers of the vectors, or reduction in the contact between man and fly or cattle and fly, is the cheapest and quickest way of controlling the diseases.

CONTROL BY GAME DESTRUCTION

In the late nineteenth century it was observed in South Africa that game, tsetse flies and trypanosomiasis generally go together (Bruce, 1895), and natural events, such as the rinderpest epidemic that occurred shortly afterwards, demonstrated that the elimination of game could lead to the disappearance of tsetse flies and trypanosomiasis (de Sousa, 1960; du Toit, 1954).

Game can be exploited both as a source of meat, hides and skins and as an attraction for big-game hunters and other tourists. The profitability of tourism has been demonstrated too often to require further comment, and it has been shown of game animals that they are resistant to many diseases that

* Revised version of papers submitted to the WHO Expert Committee on Trypanosomiasis, June, 1962.

[1] Director, Tropical Pesticides Research Institute, Arusha, Tanganyika.

[2] Veterinary Research Station, Mpwapwa, Tanganyika.

[3] Consultant to the World Health Organization.

affect cattle and that they can thrive in and utilize marginal country much more efficiently than can domestic stock. Game farming is already a profitable business in parts of South and Central Africa; in East Africa population studies have allowed cropping-rates to be suggested for a number of species (Harthoorn, 1961; Lamprey, 1961; Pereira, 1961).

Every government in Africa should be aware by now of the potentialities of its game stock and of the necessity for slowing down destruction while the best ways of exploiting its value are worked out. We may expect general acceptance, and implementation where possible, of the principle that when destruction measures are taken the game policy should include compensatory efforts towards game conservation.

In tsetse-fly control work, an example of this is the exemption from destruction of species close to extinction and of those that are not the essential hosts of tsetse flies, including migratory animals or those which are not fed upon by the tsetse fly. Where the numbers of certain species do have to be lowered to a point at which they will not generally support tsetse flies, it is fortunate that game can usually regenerate rapidly, once the remaining fly has been eradicated by other means, so that game control can be relaxed (Ashcroft et al., 1959; Lamerton, 1960; Potts & Jackson, 1952; Weitz et al., 1958).

Game destruction has been used as a routine method of tsetse-fly control in Southern Rhodesia, Uganda, Portuguese East Africa, Northern Rhodesia and Bechuanaland and many thousands of square miles have been cleared of fly. A controlled experiment at Shinyanga in Tanganyika in 1952 demonstrated clearly that game elimination resulted in the complete disappearance of *G. morsitans* Westw., *G. swynnertoni* Aust. and *G. pallidipes* Aust. from 600 square miles (1500 km^2) of country (Potts & Jackson, 1952). The method as used in Uganda has been described by Robertson & Bernacca (1958). The species of fly with which the Uganda schemes were chiefly concerned was *G. morsitans*; but *G. pallidipes* was also involved in certain areas. Initial tsetse-fly surveys were carried out and the situations ascertained by periodical fly-rounds and reconnaissances during the course of control operations. There was a carefully planned and well-organized system of hunting. The country is naturally divided into a number of virtually discrete blocks more or less isolated from one another by large rivers and lakes and stretches of swampland which provide effective barriers to most game animals. Game fences to prevent reinvasions of the cleared areas were therefore unnecessary. In general, the stretches of swamp and open water have also made it possible to limit the " shooting front " to not more than 70 miles (110 km), whereas in Southern Rhodesia it extended to 300-400 miles (or nearly 650 km) or more. The authors were convinced that in the circumstances prevailing no other known tsetse-fly control measures could have achieved so much in so short a time, nor could any other method have been successfully applied at so low a cost.

Judiciously applied, game destruction has been, and still in some conditions may be, an economical and practical means of trypanosomiasis control. However, several other methods of control, mostly chemical, have recently been developed which are already in most circumstances as effective as and cheaper than game destruction, and they will probably become even more efficient as time goes on.

Further, the preservation and exploitation of game, discussed at several recent conferences, has been shown to be profitable.

For these reasons, most countries which practise game destruction for the control of trypanosomiasis are substituting other methods. The status of game destruction is in rapid decline, and that decline may be expected to continue.

CONTROL BY CLEARING OF VEGETATION

Sheer clearing of bush

The clearing of vegetation that entails the removal of all woody growth in a fly-infested area of land is not normally employed as a tsetse-fly control measure, although there are instances where extensive stretches appear to have been denuded for this purpose. Where such exist, it seemed at the time that drastic measures were necessary, and essential, to cope with emergencies associated with serious outbreaks of tsetse-borne trypanosomiasis among the human population or to preserve valuable grassland for cattle.

It has been, and is still, customary to clear all—or almost all—the shrubs and trees in selected bands or strips of country in border to check tsetse-fly encroachment or dispersal and so provide efficient barriers and defence or consolidation lines; or in order to reduce the contact of fly and man at river-crossings where riverine tsetse flies occur, and along the main routes of communication or of cattle movements.

Similar thorough measures are also employed for the isolation of blocks of fly-infested woodland or forest in which the removal of the vegetation is reduced to the minimum consistent with the requirement of effective tsetse-fly control or eradication.

The clearing of all woody vegetation for a few hundred yards on each side of river-crossings, and at watering-places, frequented by people was one of the earliest methods used to reduce man-fly contact and the incidence of human *Trypanosoma gambiense* trypanosomiasis. These clearings varied in length and were extended as a result of field observations on their efficacy under different conditions against the riverine species *G. palpalis* (R.-D.) and/or *G. tachinoides* Westw. Instead of a few hundred yards, the length was increased to a mile or two as in Nigeria, Ghana, East Africa and the Sudan. If the clearings were for purposes of isolation or barriers, the clearing was sometimes continuous for several miles. These clearings were made across the riverine vegetation at established fords and at road crossings. They served their purpose admirably; and have been of practical value also in dividing riverine blocks conveniently for eradicative measures—by hand-catching (as in Kenya and the Sudan) or by additional, partial bush-clearing. Protective barriers in the Lake Victoria region of Kenya, to prevent re-invasion of areas cleared of *G. palpalis* by insecticides, are from eight to 10 miles (12-16 km) long (Whiteside, 1958).

Somewhat similar sheer clearings are used against dispersal and encroachment of *G. morsitans*, *G. swynnertoni*, *G. pallidipes* and—in parts of Kenya—*G. longipennis* Corti. These are usually many miles long, and one or two or more miles wide. In Kenya, for example, the lengths range from four to 17 miles (6-27 km); and in the south-east of Southern Rhodesia, a barrier of about two miles (3 km) wide is 60 miles (nearly 100 km) long (Ford—personal communication, 1962). A width of not less than two miles is considered to be desirable, but may have to be increased (or slightly reduced) according to circumstances. Clearings along main roads, as a safeguard against accelerated fly advance—and as a convenient line of defence—have been used against *G. morsitans* and *G. swynnertoni* in Tanganyika. They have proved to be of considerable benefit in Zululand, Southern Rhodesia, Ngamiland, Kenya, Uganda and Tanganyika. Their efficacy as defence measures are sometimes reinforced by discriminative clearing in the forward, fly-infested area, or by agricultural settlements.

One of the major disadvantages of these ruthlessly cleared barriers is that they are costly to make unless the work is carried out by unpaid communal labour, as in Tanganyika up to a few years ago; they have to be maintained in such a condition that they remain effective against reinvasion for a considerable period. Re-slashing the regeneration is necessary, or well-organized burning has to be arranged and supervised. It has been shown that close cultivation or grass planting discourages re-growth of woody vegetation in suitable riverine barriers; and that thorough bush-clearing by mechanical means (bulldozing by blade and chain) encourages good grass-cover in other areas.

The maintenance of these sheer clearings is a thorny subject: it calls for the active co-operation of the local authorities and the inhabitants; and for the assistance of the Administration. That they have, hitherto, been maintained more or less satisfactorily in some areas is due largely to the vigilance and efforts of the technical and professional officers concerned with fly control. There is some evidence that the situation in this respect is deteriorating due, in part at least, to the lack of interest by the settlers themselves and to the want of staff to advise on and to supervise the work.

A progressive reduction of the fly population in the forward areas may well relieve pressure on the barrier and its flanks; if the vegetation in the forward infested country was so modified as to be inhospitable to tsetse flies, the barriers would not require attention for prolonged periods of years. It is in this connexion, as well as in effecting more lasting control and eradication, that discriminative and partial clearing of infested bush is of value.

Discriminative, selective and partial clearing of bush

Studies of the distribution and habits of different species of tsetse flies in relation to the vegetation have shown that the fly population tends to concentrate periodically in certain identifiable plant communities that comprise a comparatively small proportion of the bush or woodland as a whole. This tendency is influenced by the climatic conditions which, during the hot and dry seasons, are unfavourable to wide dispersal throughout the woodland; and the fly population retreats to the cooler, shaded shelter of the type of vegetation which provides a micro-climate more suitable to the survival of the fly. At the onset of more favourable conditions generally, the flies again disperse widely and infest large areas of the woodland.

This contraction and expansion of infestation varies in different parts, and is dependent on the distribution of the vegetation of the locality, and of the particular plant community essential to the survival of the tsetse fly in adverse seasons; it depends also on the range of temperature, humidity, dryness and light that is not inimical to the tsetse-fly species concerned.

The requirements, in these respects, of the commoner tsetse-fly vectors of trypanosomiasis have been described and explained in numerous publications; and the types of vegetation most favourable as a refuge or " concentration site " are determined before tsetse-fly control measures are undertaken. Thus, studies of the vegetation are necessary in addition to those of the fly and its habits.

It is not possible to define precisely the terminology of the methods of bush-clearing employed in anti-tsetse measures. They include " discriminative ", " selective ", " partial ", " spot " and " rod " clearing. Each has been described and is applicable to the species of tsetse fly involved and the nature of the vegetation and habitat. Swynnerton (1936) defined " discriminative clearing " as " the complete removal of the vegetation from the only sites that are essential to a species of tsetse or other animal for the fulfilment of one of its requirements at one time of the year, or the mere removal of certain vegetation elements from such favoured sites or from the country as a whole ". Bax (1944) draws an arbitrary distinction between the hitherto analogous terms of " discriminative clearing " and " selective clearing ": the former applied to the removal of a definite vegetational type consisting of different species of trees right through the bush, thus reducing the vegetation to one or more species of trees. Selective clearing, according to Morris (1946), is that used for the eradication of *G. palpalis* and *G. tachinoides* (in Ghana) by making untenable their dry season habitats over a complete river system; and he associated these habitats with certain species of trees which are indicative of fly concentration sites. Nash (1960) explains " partial " clearing in connexion with the same two species (in Nigeria) as the removal of only the undergrowth and low-branching trees of the riverine vegetation so as to permit the entry of the hot dry wind from the adjoining savannah, and thus modify the insulating effect of the habitat.

There are different degrees of " discriminative ", " selective " and " partial " clearing—the terms usually employed nowadays. In Tanganyika, the first two have been carried out against *G. morsitans*, *G. swynnertoni* and *G. pallidipes*. Separately, or in combination, they have been successful in effecting substantial reductions, and subsequent elimination, of infestation in many parts of the territory.

There are several points of particular interest in connexion with the tsetse-fly situation in Tanganyika. Among these is the concentration of *G. morsitans* in the " interzonal " vegetation of the extensive *mbuga* (seasonal swamp) systems. This may take the form of a single strip of favourable vegetation or of two or more infested " interzones " which increase the amount of clearing required for fly control. Another common practice is that of " defence in depth " as a protective measure: it is a form of discriminative or selective clearing along the front of a fly advance to a depth of about five miles (8 km). It is said that this is less costly to clear than a clean barrier, and that regeneration of the vegetation need not be cut back for possibly ten or a dozen years; maintenance, therefore, is less expensive.

A similar claim is made for discriminative clearing in which only the top-canopy trees of *G. morsitans* habitats were felled, on the principle adopted by the East African Tsetse and Trypanosomiasis Research and Reclamation Organisation in Ankole, Uganda (Ford, 1954), and which Lloyd (1957) describes as discriminative clearing of a selective nature. This type of clearing resulted in a sharp drop in fly numbers, but subsequent " mopping-up " procedure was necessary, or, in some cases, the remaining flies gradually disappeared.

It seems that both discriminative and selective clearings are required against *G. morsitans* and *G. swynnertoni* and that, not infrequently, some thicket also needs to be cleared in the case of the latter species. *G. pallidipes*, too, favours thicket-forming vegetation; its control calls for discriminative clearing by the removal of such vegetation either as patches of thicket with a relatively tall tree or merely as undergrowth.

Perhaps the best example of discriminative clearing and its effect is an experiment near Abercorn in Northern Rhodesia carried out by the Tsetse Research Department, Shinyanga. Subsequent to a term of fire-exclusion, the habitats or concentration sites of *G. morsitans* were found to be well marked. When these were cleared, the fly infestation disappeared; and according to recent reports (Swan, 1961), the situation is still satisfactory.

In the Ankole scheme, the removal of the top-canopy trees of *G. morsitans* habitats, at first distributed over an area estimated at 250 square miles

(650 km²), brought a substantial reduction of fly, but seems not to have been carried out over a sufficiently large area of infested bush in the time required to affect the situation as a whole, or to prevent further advances on sections of the perimeter. In fact, additional areas were infested to the extent of 700-800 square miles (1800-2000 km²). In these circumstances, game elimination was adopted to prevent further deterioration and as a means of fly eradication. The position improved considerably; and fly catches dropped, in two years, to less than 5%, whereas discriminative clearing had continued for about five years. A fly advance in one section of the perimeter was not arrested, and a system of insecticide spraying was ultimately adopted to cope with this situation.

A serious set-back is reported by Robertson in the scheme of *G. morsitans* control which had been achieved by " selective bush-clearing " in 1947-53. It was clear, about five years later (Robertson & Bernacca, 1958), that a " barrier-clearing zone " had become ineffective against a southward advance of the fly, or that residual fly foci within the protected area had not previously been detected. Resurveys revealed an increased infestation, but confirmed the view that the primary habitat of *G. morsitans* in this area comprises *Acacia gerrardii* (*hebecladoides*) as a dominant top-canopy tree—as in Ankole—but that a favourable habitat was also provided by two other species of trees.

These experiences do not indicate that discriminative or selective clearings are ineffective. Rather do they emphasize the importance of extensive and accurate surveys of the fly infestation and of the principal and alternative habitats of the tsetse-fly.

Discriminative clearing has also been attempted in the Lambwe Valley as a measure to control *G. pallidipes*, which is considered to be the most widespread and most important species of tsetse fly in Kenya. The type of clearing in this case consisted of cutting out the thicketed undergrowth and leaving the tall clean-boled trees. It was effective; but only temporarily, because the width of the clearing was far too short. A similar experiment was conducted in the *pallidipes-brevipalpis-longipennis* locality of Kiboko in the Central Province, and in a *G. austeni* Newst. belt of forest in Kilifi on the Kenya coast. Apart from these trials, discriminative clearing has not been adopted in large-scale reclamation schemes in Kenya. It is, however, a method often used in settlement schemes, a feature of the territorial policy of fly control, where the main object is to prepare land for crops and mixed farming. The emphasis is also on the making of efficient barrier clearings against the dispersal of *G. pallidipes*, which occurs in all the fly-belts in the territory and is able to survive in very small patches of thicket. The amount of bush-clearing required to eliminate this fly approaches close to sheer destruction of all thickets and a large proportion of trees. Considerable acreages have, therefore, been cleared by machinery —as in similar country in Tanganyika. Two methods of mechanical clearing have been employed; namely " blading " and " chaining ". The former is the more suitable for heavy bush; it removes all the vegetation and leaves the land clear for a good grass cover. " Chaining " is ineffective in areas where the rainfall exceeds 30 inches (760 mm) annually because regrowth tends to become profuse; and the " chaining " does not always uproot the smaller bushes. More than 44 900 acres (16 500 ha) of land were cleared by machinery between 1952 and 1959.

Tsetse-fly control by bush clearing in Kenya is directed against *G. pallidipes*, *G. austeni* (in the coastal district only), *G. longipennis* and *G. brevipalpis* Newst. *G. swynnertoni*, in about 600 square miles (1500 km²) of the Masai Reserve adjoining Tanganyika, appears to have reached its limit where a barrier clearing has been made. *G. morsitans* occurs only in a very small area in the north-west corner of the territory, and does not constitute a problem.

Kenya is, perhaps, fortunate in that the problem of tsetse-fly control is not so vast as in many other African territories. Yet the maintenance of the progress so far made in the several limited projects is presenting difficulties on account of regeneration in the cleared areas and the reluctance of African settlers to undertake the task of keeping down the re-growth or of conforming to the requirements in regard to controlling late burning. There is also the need of administrative co-operation in insisting on organized settlement and land usage.

The situation in Nyasaland has not warranted much in the way of tsetse-fly control measures (Borley—personal communication, 1962). Human trypanosomiasis is not common. In 1954, 27 cases (presumably of *T. rhodesiense* sleeping-sickness) were reported (Aspinall et al., 1960) and three from 1955 to 1960: some of the infections were believed to have been acquired outside the territory. Animal trypanosomiasis is seemingly of great importance, chiefly in the southern districts and near the Tanganyika border in the north.

Bush-clearing has, however, been undertaken against *G. brevipalpis* in the Karonga District near the northern territorial boundary, resulting in an appreciable reduction of fly over about 20 square miles (50 km²). The method was based on felling on hillside gullies and streams, the known foci of the fly in this locality. Complete elimination was not achieved; and bush-clearing has been superseded partly by the application of insecticides.

The reclamation of tsetse-fly-infested land in Nyasaland is being attempted by the gradual and judicious canalization of settlement; but here, too, difficulties are encountered in that the people prefer to spread in an unorganized fashion, neglecting the areas that have been arranged for their reception.

The discriminative method of bush-clearing consists in removing the vegetation from drainage lines, thinning out mixed woodland to a tree density inimical to the continuation of a fly population, clearing of thicket "ecotone", destroying the vegetation in fly-concentration sites, and partially clearing the lighter vegetation in some parts by ring-barking. It also comprises the removal of thicket edges and strips of vegetation along the base of hills and, in special cases, burning large *mopani* trees to break up the upper or top canopy of the fly habitats.

By thus attacking the primary and the subsidiary foci of *G. morsitans* alone, or of mixed *G. morsitans* and *G. pallidipes* infestations, a reduction of up to 95% of the original fly density is fairly easily achieved, but the last 5% has proved to be more difficult, especially where human settlement cannot be incorporated in the scheme.

Anti-tsetse measures are also actively pursued in Mozambique where the species of tsetse flies concerned in the transmission and spread of human (*T. rhodesiense*) and animal trypanosomiasis is *G. morsitans. G. pallidipes*, *G. austeni* and *G. brevipalpis* are vectors of the disease in cattle. In addition to game eviction with organized settlement as a measure to control *G. morsitans* in the Mambone scheme of rehabilitation, discriminative clearing, following the isolation of the area to be treated by wide barriers and game fences, is a method commonly used in this territory. Against *G. pallidipes*, partial clearing of riverine vegetation is combined with discriminative clearing of the most favourable areas of infestation and with game control. Insecticides are applied in order to reduce the numbers of both these species, and for the elimination of residual fly foci (Serrano—personal communication, 1962).

Santos Dias (1954) describes earlier observations on the effect of discriminative clearing, by machines and hand-labour, in the control of *G. austeni*. All the shrubs and undergrowth were removed; and large trees were thinned out, so that they were not less than about 10 m apart. The fly density and activity increased in the immediate forward area to such an extent that the labourers were pestered where, previously, no flies approached the tsetse-control personnel. On completion of the clearing work, fly eradication had been achieved and cattle could be grazed in the area.

Other schemes of tsetse-fly control have been and are being, pursued. The majority are directed to the reduction of animal trypanosomiasis and to check the advance of fly on to tsetse-free country. In only one area, at present, are anti-tsetse measures directed to the control of human sleeping-sickness. The total area of land covered by tsetse-fly control schemes is about 2700 square miles, or nearly 7000 km² (excluding the Govuro scheme of approximately 1900 square miles, or 2330 km²). Two additional protective-reclamation schemes are being undertaken in other areas of nearly 3860 and 3700 square miles (10 000 km² and 9580 km²), with a frontage and depth of 74 and 50 miles (120 km and 80 km) respectively. The eradication of *G. austeni* in another locality was suspended, and that area has now become reinfested in places.

With the abolition of game destruction as a tsetse-fly control measure in Southern Rhodesia, discriminative clearing of bush is being carried out along the fly-fronts so as to provide for an adequate defence against reinfestation of land reclaimed by game elimination, to reinforce barrier clearings, and to exterminate fly infestations that have been located within the protected areas. Goodier (1961) has described the kind of discriminative clearings, by bulldozers and hand-labour, in the south-eastern portion of the territory adjacent to Mozambique. *G. morsitans* had been extending from across the border into Rhodesia, where it continued to spread westwards. The barrier clearing had successfully checked appreciable extensions of *G. brevipalpis*, *G. austeni* and *G. pallidipes*. *G. morsitans* and *G. pallidipes* continued to invade the territory along strips of vegetation, and were responsible for the persistence of trypanosomiasis among the cattle-which were estimated at about 350 000 in the locality and adjacent farms. Following detailed studies of the distribution of these two species of fly, of their habitats, and of the incidence of bovine trypanosomiasis, clearing of the riverine fringe and ecotone vegetation was undertaken where favoured habitats were discovered. *Acacia* and *mopane* woodland and certain other woodland trees and thicket were removed for about 50 to 200 yards on each side of the drainage lines. Ring-barking of the harder-wooded trees was considered to be better than felling with mechanical saws; it saved time and lessened regeneration. A similar and successful scheme of clearing had previously been carried out in a drainage system in the northern fly-belt where the decline in fly-rounds which began within a month was attributed to the onset of the cold season and the effect of ecological methods of control in areas where the climate is near the limits tolerated by flies. Considerable use is made of fences to exclude the larger game animals from areas where anti-tsetse operations are in progress; and aerial photographs are utilized to map out the vegetation and to plan fly-control operations and reclamation schemes which are to be carried out progressively and with concurrent treatment of cattle and agricultural development. Where the land is unsuitable for settlement, periodical insecticide attack on near-by tsetse-fly concentration areas and discriminative clearing are planned. Subsidiary methods may include game fences to prevent too rapid a reinvasion of game in areas formerly cleared, and the continued use of pickets and deflying chambers on roads (Ford—personal communication, 1962).

The primary habitats or concentration sites of *G. morsitans* in Ngamiland are closely associated with a plant community in which *Acacia giraffae*, chiefly, forms the top-canopy. Other species of *Acacia* provide a harbour for smaller fly numbers and seem to serve a subsidiary refuge in the dry seasons. Discriminative clearing of these habitats has therefore been the principal fly-control measure to supplement and to consolidate the substantial reduction of the fly population and densities effected by game eviction. On some parts of the perimeter of the fly-infested country, the favoured vegetation forms somewhat extensive habitats whereas on other parts it is linear, marginal and ecotonal. Felling in the former approaches near to sheer felling, but in the latter a large amount of the woody vegetation, including almost all *mopane* trees, is untouched.

These measures have undoubtedly stopped fly encroachment on the southern front, and have resulted in a considerable reduction of fly. The infestation is very low, but has not yet been eradicated. Strong indications of advancing fly in other sections of the long perimeter are being dealt with by felling actually infested top-canopy habitats and potential concentration areas or suitable sites; and barriers are being cleared by felling supplemented by strips of ring-barked *Acacia* trees.

With further reference to selective clearing in Ghana, Morris (1944) gives a detailed account of the method used in a large-scale experiment to eradicate *G. palpalis* and *G. tachinoides*; and later (1953), reports that the early success of the fly control measures was followed up by an extension of selective clearing to an area which was nearly 3000 square miles (7770 km^2). This method was adopted by the French Sleeping-Sickness Service in combination with their well-organized mass treatment in the Ivory Coast. The fly population declined rapidly as the clearing operations on each stream of the river system progressed, and the incidence of the disease became less and less. By 1950, ten years after the start of the work, eradication was almost complete and the disease had been virtually eliminated.

The clearing had been done by communal labour; and those who had been compelled to leave their ancestral land and homes on account of human trypanosomiasis were persuaded to return, voluntarily, to the riverine homesteads and hamlets where, with a little assistance in the maintenance of roads, river crossings and the conservation of water for the dry season, the human population could settle, produce crops on the river banks and keep down re-growth of bush. The complete control of intruding *G. morsitans* by game disturbance supported by settlement enabled cattle also to be grazed in the reclaimed area.

The method of selective clearing employed by Morris is now being continued by the specialized units of the Ministry of Health in Ghana. Tsetse-fly eradication measures in schemes begun late in 1957 comprise clearings of stream systems in the epidemic foci of South Mamprussi in northern Ghana where the area already cleared covers, in all, about 2000 square miles (5200 km^2). A second scheme, along the east bank of the Black Volta—including the related tributaries—involves a similar area of country. Protective measures at several river crossings and major roads are also being made and maintained (Scott—personal communication, 1962).

In discussing the role of bush clearing in Northern Nigeria, Glover (1961) considers that, although insecticides have been so successful, clearings cannot yet be discarded as they are still useful for protecting roads and river crossings and in creating fly-free flanks on which to base insecticidal projects when these are necessary.

Generally it may be stated that in schemes of bush-clearing accurate and detailed surveys are essential before plans of fly control are drawn up; and observations need to be continued during the operational period and for some time afterwards. Constant and expert supervision and experience are necessary in conducting the ecological studies required and in interpreting the results. The tsetse-fly control aspect occupies the whole-time attention of the entomologist/ecologist, who is also responsible for acquiring the fullest possible knowledge of the flies, their habitats and habits, and, to some extent, of the role of the flies, under local natural conditions, as vectors of the trypanosomes affecting man and his stock. The major problems in regard to practical tsetse-fly control, following virtual or actual elimination, are to prevent reinfestation from adjoining infested country, and to stop any advance of fly at an early stage.

CONTROL BY THE USE OF INSECTICIDES

To be acceptable, suggestions for control of tsetse flies by chemical means must show some advantage, in cost or speed of action, over methods of control by total or partial clearance of bush habitat of the flies. In all methods of control by insecticides, isolation of the tsetse-fly habitat is essential for a permanent result as the habitat is not made unsuitable for the flies; this is not, of course, necessary if only a short-term reduction in numbers is required—for example, to stop a sleeping-sickness epidemic.

Application by aircraft

Some species of tsetse flies, such as *G. morsitans*, *G. swynnertoni* and *G. pallidipes* in East Africa, occur over wide areas of country, often many hundreds of square miles in extent, and for the control of such species, the use of aircraft for the application of insecticide has obvious advantages, the chief of which is, of course, their ability to cover large areas quickly. Against the more confined riverine species, such as some *G. palpalis*, ground methods of application are often adequate and much cheaper. Application from the air has been found to be uneconomic, even where it is possible, against species living in high forest, such as some *G. palpalis* and *G. brevipalpis* (Hocking & Yeo, 1953).

Savannah woodland, even if containing evergreen thickets, can, however, be successfully treated; though it is preferable that the leafless period of the year be chosen. The only effective applications have employed the insecticide in the form of a coarse aerosol containing as much as possible of its volume in droplets between 5 μ and 50 μ in diameter. Larger droplets are unable to bypass obstacles such as leaves and branches and penetrate to the resting sites of the tsetse flies, and smaller droplets do not deposit very effectively on the insects themselves. Under tropical conditions applications of coarse aerosols are effective only for a limited period (one to two hours) just after dawn and, unreliably, for an even shorter period before dusk. At other times, meteorological conditions are so unstable that rapid diffusion of the aerosol occurs (Yeo & Thompson, 1954).

Aerosols have been produced from aircraft emitting an oil solution of insecticide under high pressure through fine nozzles on an extended boom, by injection of the solution into the exhaust of the aircraft, or by various types of rotary atomizers. It has not been possible to reduce the mean mass diameter of the aerosol below about 70 μ by the first method and even this is possible only on a reasonably fast aircraft as the speed of the aircraft is needed to assist the break-up. An aerosol of approximately the same droplet spectrum, or perhaps rather finer, can be produced on light aircraft by the Micronair spinning cage produced by Britten-Norman Ltd. Injection into the exhaust system involves some decomposition of the insecticide by heat but the use of a suitable solvent and care in selection of the point of injection can reduce this to a minimum and droplets of the desired size can be produced.

The first practical control of tsetse flies by applying insecticides from aircraft was in the eradication of *G. pallidipes* from Zululand in South Africa, which took seven years to achieve and where the method was combined with other methods of application. Pupal surveys had revealed that the breeding areas and permanent haunts from which the fly dispersed at favourable seasons occupied only 200 square miles (520 km^2) out of 7000 square miles (over 18 000 km^2) of seasonal fly-belts. The breeding areas were treated from the air with many applications of exhaust-generated aerosol containing DDT and certain mountainous or rugged localities were treated from the ground with DDT or BHC smoke-generators. The cost of the operation was very heavy, well over £2 000 000 (or over £10 000 for every square mile treated) but only about 10/– for each acre rendered fly-free (du Toit, 1954).

In East Africa, a suitable aerosol was produced from Avro Anson aircraft by emitting an oil solution of insecticide under a pressure of 150 pounds per square inch (10.5 atm.), through Bray nozzles pointing forwards, with an air speed of approximately 120 m.p.h. (190 km/hour). An effective procedure has been to use a 10% solution of DDT in oil at one quart per acre (approx. 2.7 litres/ha) with a swath width of 50 m. Eight such applications at fortnightly intervals have eradicated *G. morsitans* and *G. pallidipes* from a 16-square-mile (41-km^2) block at a cost of about £1000 per square mile (Hocking & Yeo, 1956) and radically reduced the tsetse-fly population in other cases (Hocking, Yeo & Anstey, 1954). The fortnightly intervals were based on the need to kill newly emerged adult flies before they produced new larvae, and the eight applications were to cover two pupal periods.

Calculations by Yeo & Simpson (1960) have shown that, with applications giving a 90% kill of adults, monthly intervals between applications should be more effective than two-week intervals if the same number of applications are made, thus enabling a light aircraft to be used for larger areas. An attempt to eradicate *G. morsitans* and *G. pallidipes* from a 12-square-mile (30-km^2) block with 380 ml per acre (912 ml/ha) of γ-BHC applied from an Auster aircraft through Britten-Norman Micronair equipment was not successful. This was probably because the kill of female flies was considerably lower than that of males (on the susceptibility of which the dosage was based) and there was not therefore sufficient margin for contingencies, the kills being considerably reduced when, for example, meteorological conditions were not ideal or the spraying equipment was not working at full efficiency (Foster, White & Yeo, 1961). The experiment repeated the following year with 560 ml per acre (1.3 litres/ha) of 2.5% dieldrin applied in the same way eight times at monthly intervals was very successful and cost about £350 per square mile (Burnett et al., 1961).

The experimental insecticide Telodrin of the Shell Chemical Company is two or three times as toxic to tsetse flies as is dieldrin and is being used with apparent success at a volume dosage as low as 57 ml[1] per acre (136 ml/ha) in Ruanda-Urundi. Exhaust injection equipment on a Cessna aircraft can produce an aerosol with a mean mass diameter about 30 μ, and using Telodrin through that equipment at a dosage equivalent to that of dieldrin (i.e., one-half to one-third of 0.03 pound per acre) the theoretical cost would be as low as £150 per square mile.

[1] After evaporation of the volatile part of the solvent; the application rate is 450 ml per acre.

All these chlorinated hydrocarbon insecticides are much less effective against pregnant female tsetse flies than they are against the rest of the fly population (Burnett, 1961). In practice, therefore, an insecticide such as fenthion, which does not have this disadvantage, might be more economical.

Ground aerosol machines

Under this head can be included such machines as the T.I.F.A. and the Swingfog, which use a blast of hot air to produce aerosols, and canisters which produce insecticidal smokes by the burning of combustible mixtures containing insecticides.

Experimentally, and on a limited scale, smoke canisters have been used with some success by the Tropical Pesticides Research Institute against *G. palpalis* in Uganda[2] and by the East African Trypanosomiasis Research Organization against *G. swynnertoni* in Tanganyika (Crawford, 1949), and they were used to supplement the aerial spraying in Zululand (du Toit, 1954). The chief difficulties in their use are connected with getting adequate and uniform distribution of the smoke under varying wind directions and meteorological conditions.

Ground aerosols could compete directly with aircraft applications for the destruction of savannah tsetse-fly species but would need a more elaborate organization to cover an extensive area. The T.I.F.A. has been used with good results in Northern Rhodesia to apply a thermal aerosol containing 1.5% γ-BHC to eradicate *G. morsitans* from isolated pockets, the cost of the insecticide being about £100 per square mile (Aspinall et al., 1960). The Swingfog has been tried in Rhodesia to prevent the carriage of tsetse flies by road traffic, and in Kenya the T.I.F.A. has been used to disinfest trains in a similar way (Fairclough, 1956).

Residual treatment of vegetation

In East Africa the riverine *G. palpalis* is apparently dependent on vegetation at the water's edge for its feeding area. Treatment of this vegetation with an emulsion of a residual insecticide so that it remains lethal to the fly on short contact for more than a pupal period (say, for two months) is generally sufficient to control this species and possibly to eradicate it. This method was developed by the

[2] Hocking, K. S. (1947) *The use of smoke generators to control* Glossina palpalis, Arusha, Colonial Insecticides Research Unit (*Miscellaneous report No. 33*—unpublished).

Tropical Pesticides Research Institute in 1948,[1] and adopted by Kenya as a control measure from 1951 (Wilson, 1953). The earlier control measures of this nature were carried out with 5% DDT emulsion applied at about 15 Imperial gallons (68 litres) per mile of river, four times at two-weekly intervals, which cost about £42 per mile. It was later found that 1.5% dieldrin emulsion applied twice with a month's interval, or 5% dieldrin emulsion applied once, both at the same rate, were more effective (Burnett, Robinson & Le Roux, 1957). In Uganda the standard method is now to apply 5% dieldrin emulsion once only to selected portions of the riverine vegetation at a total cost of £20 per mile. In Kenya, where a scheme to eradicate *G. palpalis* from the colony is more than half completed (Glover & Trump, 1960), the standard method was to apply four applications of 1.8% Dieldrex at a cost of about £60 per mile, but the cheaper method as used in Uganda has now been introduced.[2] *G. palpalis* has also been eradicated experimentally by this method in Northern Nigeria (Mahood, 1960).

These costs compare with an average cost of bush clearing on these rivers of £200 to £300 per mile, but may be more than doubled by the cost of the necessary surveillance to determine whether any fly remains. In most of this control work the insecticide has been applied with knapsack or compression sprayers by labourers walking down the river-bed, but in some larger streams a more effective method has been found to be application by a power sprayer from a punt which is poled down the river.

The control of the riverine species *G. tachinoides* Westw., in Northern Nigeria is a similar but rather more complicated problem. More extensive spraying is required but, because there is a long completely dry season, DDT wettable powder can be used instead of dieldrin emulsion with a great saving in cost of insecticide. The cost per mile of river is about £15 (Kernaghan, 1960).

A considerable amount is now known about the resting-places of the savannah species of tsetse fly in East Africa, i.e., *G. morsitans* and *G. swynnertoni.* In a block of 15 square miles (38 km²) of isolated *G. morsitans* habitat in Uganda an experiment has been carried out in which dieldrin emulsion was applied to the lower side of the branches of *Acacia gerrardii* trees in fly-concentration areas, these being the putative daytime resting-places of the flies. The apparent density of *G. morsitans* was reduced by over 99% and the method, when applied over a sufficiently large area, would probably be effective in eradicating the fly at a cost of about £250 per square mile (Hocking, 1961). It is now being applied to 1000 square miles (2600 km²) of fly-bush in Ankole in Uganda with the assistance of funds from the United States of America.

In areas with a very severe dry season *G. morsitans* becomes effectively a riverine species, and in the north of the Northern Region of Nigeria, for example, where the relative humidity is down to about 5% for most of the day during several months of the year and the maximum temperatures are well over 100°F (37.8°C), this fly is confined during the heat of the day to the lowest part of the trunk of the well-shaded trees along the river banks. Treatment of those places with residual insecticide, which is a comparatively cheap and rapid procedure, is sufficient therefore to eradicate *G. morsitans.* The Veterinary Department of the Northern Region of Nigeria is treating effectively areas of the order of 100 square miles (260 km²) in a season at a cost of about £100 per square mile (Blasdale, 1960). In a part of Southern Rhodesia with a similar severe dry season dieldrin was applied to *vlei* edges and major drainage lines throughout a fly-block of 108 square miles (280 km²), particular attention being paid to the selective spraying of known tsetse-fly resting-places in these areas. About 5% of the total area was sprayed with very satisfactory results at an over-all cost of about £50 per square mile.[3] A later attempt to cheapen the operation still further by relying on systematic band spraying of specific vegetation types gave disappointing results (Lovemore—personal communication). Much detailed information is now being obtained about the resting-sites of *G. morsitans* in Southern Rhodesia.[4] Experimental eradication of *G. morsitans* over 120 square miles

[1] Woodcock, K. E. (1949) *Peripheral vegetation spraying —Ziribanje island* (unpublished document No. 79 of the Bureau Permanent Interafricain de la Tsé-tsé et de la Trypanosomiase).

[2] Glover, P. E. (1962) *A further note on the extermination of* Glossina palpalis *in Nyanza Province of Kenya* (unpublished document ISCTR(62)37 submitted to the ninth meeting of the International Scientific Committee on Trypanosomiasis Research, Conakry, 21-25 August 1962).

[3] Lovemore, D. F. & Pilson, R. D. (1960) Unpublished report from the Tsetse and Trypanosomiasis Control Branch, Federal Department of Veterinary Services, Salisbury, Southern Rhodesia.

[4] Ford, J. (1962) *Microclimates of tsetse-fly resting sites in the Zambezi Valley, Southern Rhodesia* (unpublished document ISCTR(62)4 submitted to the ninth meeting of the International Scientific Committee on Trypanosomiasis Research, Conakry, 21-25 August 1962).

(310 km^2) has been carried out in Northern Rhodesia at a cost of £130 per square mile.[1]

Other methods of control by chemical means

Attempts have been made to control tsetse flies by the use of treated traps and treated screens in both East and West Africa. Eradication has not been achieved and it is not likely by these means, but they have their use in the reduction of tsetse-fly numbers in such places as river-crossings and watering-places in sleeping-sickness areas, and thus in reducing sufficiently the man-fly contact. Attempts have been made in Kenya to improve the efficiency of the method by the addition of attractants to the traps. If successful, the development of attractants might also be of value in increasing the contact between the fly and treated stretches of vegetation, and present work by the Veterinary Department in Kenya gives promise of success with various animal extracts (Langridge, 1960). Conversely, repellents might be of use in enabling cattle to cross narrow fly-belts without acquiring trypanosomiasis.

An interesting control method which has been tried experimentally and has shown promise is the use of insecticidally treated cattle as lethal bait for tsetse flies (Whiteside, 1949; Burnett, 1954). The main difficulties in the method are in dispersing the cattle in such a way that a high proportion of flies contact them rather than the natural game hosts in the area for food, and also in keeping the insecticide deposit on the cattle at a lethal level for a sufficient length of time. Attempts have been made to solve the second difficulty by feeding insecticides to cattle and thus making their blood toxic to blood-sucking insects but this is not yet a practical proposition, although insecticides such as dimethoate (Rogor) have been used on a field scale to control warble-fly larvae in cattle in this way (see, for instance, Marquardt & Lovelace, 1961). Recently, experiments in Uganda involving the spraying of cattle with a very dilute emulsion of dieldrin have given very promising results (Rennison, 1960).

Conclusion

To sum up, under suitable conditions blanket applications of insecticide from aircraft or from ground machines can be effective in eradicating tsetse flies and, with recent advances in insecticides and dispensing equipment, aircraft applications can be made very economical. As, however, knowledge of the habits and behaviour of the various species of *Glossina* grows, the discriminative applications of insecticide to eradicate these species can be made more precise, more economical and more effective, and this method of using the persistent insecticides would seem to be the most promising line for the future. Applications from aircraft should be considered when a quick result is required, as, for example, when there is an outbreak of trypanosomiasis. Other methods of application, such as the use of sprayed cattle, may have their uses in special circumstances.

BIOLOGICAL CONTROL

Observations have been made and experiments conducted on the role of parasites in the control of tsetse flies and on the practical possibilities of sterilizing flies by hybridization or by the irradiation of pupae from radioactive cobalt. None of these has been adopted in any routine measures of practical control.

There are many records of parasitic *Hymenoptera* and *Diptera* in tsetse-fly pupae from almost every fly-infested territory in Africa. Observations on parasitized pupae of *G. morsitans* in Southern Rhodesia (Chorley, 1929), of *G. pallidipes* and *G. brevipalpis* in Zululand and of *G. brevipalpis* and *G. fuscipleuris* in Kenya (Lewis, 1939) have shown that the percentages of wild pupae were high in those instances and indicate an influence on the fly population that may be of significance in control. However, large colonies of *Syntomosphyrum glossinae*, for instance, have been produced with the object of implementing tsetse-fly control by parasitization, but the results have not warranted further endeavours in this direction (Lamborn, 1925; Nash, 1933).

Trials on hybridization by cross-mating closely related species with a view to producing a high degree of sterility in a fly population were also abortive as a practical measure of control in the field (Vanderplank, 1944).

Sterilization of tsetse flies by irradiation of pupal stages has been the subject of initial laboratory investigations from which it has been tentatively concluded that with a reasonably high degree of sterilization of both sexes of emerged flies, their release in sufficient numbers might result in a large measure

[1] Gledhill, J. A. & Caughey, W. (1962) *Report on a field trial in the use of dieldrin for the control of* G. morsitans *in the Zambezi Valley, 1961* (unpublished document ISCTR (62)36 submitted to the ninth meeting of the International Scientific Committee on Trypanosomiasis Research, Conakry, 21-25 August 1962).

of control in an isolated locality. It is clearly necessary, however, to obtain more information by laboratory study and field trials on this particular aspect of tsetse-fly control. It is also possible that sterilization by chemical means holds out more promise than sterilization by radioactive cobalt.

ACKNOWLEDGEMENT

We wish to acknowledge our gratitude for the help we have received from numerous colleagues throughout Africa; not one failed to respond to our request for up-to-date information.

RÉSUMÉ

La destruction des animaux sauvages a été couramment utilisée dans la lutte contre la tsé tsé, et ceci dans plusieurs pays. Il s'agit là d'un procédé économique et pratique, mais cette destruction est de moins en moins populaire; d'autre part, l'existence d'autres moyens de lutte a relégué au dernier plan cette méthode.

La destruction complète de toute végétation est utilisée pour barrer la route à la tsé tsé ou pour protéger hommes et bêtes contre tout contact avec les mouches. Il est en général difficile et coûteux de maintenir ces barrières, à moins qu'elles ne fassent partie d'un plan d'ensemble. Dans la lutte contre la mouche tsé tsé, l'on procède généralement à une destruction sélective de la végétation; l'on détruit les arbres ou les plantes qui favorisent le développement de la mouche. Les relations entre la mouche et son habitat varient selon l'espèce considérée et selon la région; cette méthode doit donc se fonder sur des enquêtes complètes et précises sur l'habitat et la répartition des mouches. Les destructions partielles de végétation ont été utilisées très souvent et avec des fortunes diverses; les échecs étaient dus à un manque de préparation et de renseignements au départ.

Les méthodes chimiques de lutte contre la tsé tsé doivent, pour être adoptées, faire la preuve de leur supériorité — rapidité d'action ou prix de revient — sur les méthodes de destruction totale ou partielle de la végétation. Lorsque l'on s'adresse aux insecticides, l'isolement des habitats de tsé tsé est une nécessité si l'on veut obtenir un résultat définitif, mais non s'il s'agit seulement d'arrêter une vague épidémique. Dans des conditions favorables, une pulvérisation égale d'insecticides à partir d'un aéronef ou d'un camion automobile peut assurer l'éradication des mouches tsé tsé; les progrès réalisés dans le domaines des insecticides et dans celui de l'équipement sanitaire permettraient de considérer comme réellement économiques les pulvérisations aériennes. Cependant, comme l'on connaît de mieux en mieux le comportement et l'évolution biologique des différentes espèces de *Glossina*, les applications sélectives d'insecticides peuvent être rendues plus précises, plus économiques et plus efficaces. L'utilisation d'insecticide résiduel semble à cet égard la méthode donnant les plus beaux espoirs. L'on doit faire appel à la pulvérisation aérienne lorsque l'on désire un résultat rapide, par exemple lorsque survient une flambée de trypanosomiase. D'autres méthodes telles que celles utilisant le bétail ayant reçu des pulvérisations d'insecticides peuvent être employées dans certains cas assez spéciaux.

Des méthodes biologiques de lutte (par exemple stérilisation des mouches tsé tsé par hybridisation ou par irradiation des nymphes au cobalt radioactif) ont été envisagées; elles n'ont, pour le moment, aucune application pratique.

REFERENCES

Apted, F. I. C. (1962) *Trans. roy. Soc. trop. Med. Hyg.*, **56**, 15

Ashcroft, M. T., Burtt, E. & Fairbairn, H. (1959) *Ann. trop. Med. Parasit.*, **53**, 147

Aspinall, K. W., Ford, J., Steel, W. S., Steele, B. & Swan, J. F. C. (1960) *The control of trypanosomiasis in the Federation of Rhodesia and Nyasaland.* In: International Scientific Committee for Trypanosomiasis Research, *Eighth meeting*, *Jos*, Commission for Technical Co-operation in Africa South of the Sahara (Publication No. 62), p. 77

Bax, S. N. (1944) *E. Afr. agric. J.*, **9**, 2

Blasdale, P. (1960) *The development of a practical means of eradicating* Glossina morsitans submorsitans *Newst. and* G. tachinoides *West. in the Sudan savannah zone of Northern Nigeria.* In: International Scientific Committee for Trypanosomiasis Research, *Eighth meeting*, *Jos*, Commission for Technical Co-operation in Africa South of the Sahara (Publication No. 62), p. 295

Bruce, D. (1895) *Preliminary report on the tsetse fly disease, or Nagana, in Zululand*, Durban, Bennett & Davis

Burnett, G. F. (1954) *Bull. ent. Res.*, **45**, 411

Burnett, G. F. (1961) *Bull. ent. Res.*, **52**, 763

Burnett, G. F., Robinson, J. & Le Roux, J. G. (1957) *E. Afr. agric. J.*, **22**, 142

Burnett, G. F., Yeo, D., Miller, A. W. D. & White, P. J. (1961) *Bull. ent. Res.*, **52**, 305

Chorley, J. K. (1929) *Bull. ent. Res.*, **20**, 279

Crawford, J. (1949) In: East African Trypanosomiasis Research Organization, *Annual report 1949*, Nairobi, Government Printer, p. 15

Fairclough, R. (1956) *Bull. ent. Res.*, **47**, 193

Ford, J. (1954) *Discriminative treatment of bush against* G. morsitans. In: International Scientific Committee for Trypanosomiasis Research, *Fifth meeting, Pretoria*, p. 90 (BPITT Publication No. 206)

Foster, R., White, P. J. & Yeo, D. (1961) *Bull. ent. Res.*, **52**, 293

Glover, P. E. (1961) *The tsetse problem in Northern Nigeria*, Nairobi, Patwa News Agency

Glover, P. E. & Trump, E. C. (1960) *Span*, **3**, 117

Goodier, R. (1961) *Rhod. agric. J.*, *58*, 262

Harthorn, A. M. (1961) In: *Proceedings of the Lake Manyara Conference*, East African Common Services Organisation, Nairobi

Hocking, K. S. (1961) *Bull. ent. Res.*, **52**, 17

Hocking, K. S. & Yeo, D. (1953) *Bull. ent. Res.*, **44**, 589

Hocking, K. S. & Yeo, D. (1956) *Bull. ent. Res.*, **47**, 631

Hocking K. S., Yeo, D. & Anstey, D. G. (1954) *Bull. ent. Res.*, **45**, 585

Kernaghan, R. J. (1960) *Some aspects of the insecticidal control of* Glossina tachinoides *in Northern Nigeria.* In: International Scientific Committee for Trypanosomiasis Research, *Eighth meeting, Jos*, Commission for Technical Co-operation in Africa South of the Sahara (Publication No. 62), p. 285

Lamborn, W. A. (1925) *Bull. ent. Res.*, **15**, 303

Lamerton, J. F. (1960) *Game, tsetse and trypanosomiasis ; preliminary results of an experiment in Central Tanganyika.* In: International Scientific Committee for Trypanosomiasis Research, *Eighth meeting, Jos*, Commission for Technical Co-operation in Africa South of the Sahara (Publication No. 62), p. 179

Lamprey, H. F. (1961) *Annual report, Game Division, Tanganyika, for 1960*, Dar es Salaam

Langridge, W. P. (1960) *Scent attractants for tsetse flies.* In: International Scientific Committee for Trypanosomiasis Research, *Eighth meeting, Jos*, Commission for Technical Co-operation in Africa South of the Sahara (Publication No. 62), p. 235

Lewis, E. A. (1939) *Bull. ent. Res.*, **30**, 345

Lloyd, H. M. (1957) *Annual report, Tsetse Survey and Reclamation Department for 1956*, Dar es Salaam

Mahood, A. (1960) *An experiment on the control of* Glossina palpalis *(R.-D.) in Southern Zaria Province, Northern Nigeria, by chemical means.* In: International Scientific Committee for Trypanosomiasis Research, *Eighth meeting, Jos*, Commission for Technical Co-operation in Africa South of the Sahara (Publication No. 62), p. 269

Marquardt, W. C. & Lovelace, S. A. (1961) *J. econ. Ent.*, **54**, 252

Morris, K. R. S. (1944) *Farm & Forest (Ibadan)*, **5**, 149

Morris, K. R. S. (1946) *Bull. ent. Res.*, **37**, 201

Morris, K. R. S. (1953) *J. roy. Soc. Arts*, **101**, 733

Nash, T. A. M. (1933) *Bull. ent. Res.*, **24**, 107, 163

Nash, T. A. M. (1960) *Trop. Dis. Bull.*, **57**, 974

Pereira, H. C. (1961) *E. Afr. agric. J.*, **27**, 40

Potts, W. H. & Jackson, C. H. N. (1952) *Bull. ent. Res.*, **43**, 465

Rennison, B. D. (1960) In: East African Trypanosomiasis Research Organization, *Annual report, 1959*, Nairobi, Government Printer, p. 54

Robertson, A. G. & Bernacca, J. P. (1958) *E. Afr. agric. J.*, **23**, 254

Santos Dias, J. A. T. (1954) *Quelques réflexions sur la lutte contre la* Glossina austeni Newst. *fondées sur la connaissance de son écologie.* In: International Scientific Committee for Trypanosomiasis Research, *Fifth meeting, Pretoria*, p. 148 (BPITT Publication No. 206)

Sousa, A. E. de (1960) *The advance of* Glossina *in Southern Mozambique.* In: International Scientific Committee for Trypanosomiasis Research, *Eighth meeting, Jos*, Commission for Technical Co-operation in Africa South of the Sahara (Publication No. 62), p. 203

Swan, J. F. C. (1961) *Annual report, Department of Veterinary and Tsetse Control Services, for 1960*, Lusaka

Swynnerton, C. F. M. (1936) *Trans. roy. ent. Soc. Lond.*, **84**, 1

Toit, R. du (1954) *Onderstepoort J. vet. Res.*, **26**, 254

Vanderplank, F. L. (1944) *Nature (Lond.)*, **154**, 607

Weitz, B., Langridge, W. P., Napier Bax, P. & Lee-Jones, F. (1958) *The natural hosts of* Glossina longipennis *Corti and of some other tsetse flies in Kenya.* In: International Scientific Committee for Trypanosomiasis Research, *Seventh meeting, Brussels*, Commission for Technical Co-operation in Africa South of the Sahara (Publication No. 41), p. 303

Whiteside, E. F. (1949) *Bull. ent. Res.*, **40**, 123

Whiteside, E. F. (1958) *The control of animal trypanosomiasis in Kenya.* In: Inter-African Advisory Committee on Epizootic Diseases, *Symposium on Animal Trypanosomiasis, Luanda, 1958*, Commission for Technical Co-operation in Africa South of the Sahara (Publication No. 45), p. 81

Wilson, S. G. (1953) *Bull. ent. Res.*, **44**, 711

Yeo, D. & Simpson, H. R. (1960) *Bull. ent. Res.*, **51**, 631

Yeo, D. & Thompson, B. W. (1954) *Bull. ent. Res.*, **45**, 79