been greater in Ntambanana than in Umfolozi. In spite of this greater apparent density, no evidence of breeding in the settlement area could be demonstrated by means of carefully conducted searches for pupae or pupal casings.

From the evidence accumulated from all sources, the general picture regarding the habits of *G. pallidipes* has emerged, that the flies make use of certain specific areas for breeding, but disperse from these sites into the surrounding territory from time to time. As Jack (1919) has so ably stated: "the whole movement is analogous to that of a rising flood flowing along favourable channels and gradually extending the flooded area". In other words, the outward movement of flies commences from specific areas. These are the permanent breeding sites and when contraction occurs, the movement is again towards these sites.

To prove this contention, a survey of breeding sites with the object of demonstrating pupae and pupal casings was commenced in January 1947. As the aerial application of the synthetic insecticides DDT and BHC was extended, tsetse fly densities were markedly reduced. The result was that unhatched pupae soon became comparatively difficult to find. It was soon realized, however, that pupal casings would serve as an even more reliable guide in establishing the actual permanent breeding grounds. Previous observations had shown that pupal casings, protected as they are to a great extent from weathering in their sheltered situations in soil, remain clearly recognizable for a period of several years. It was held that in the permanent breeding sites of the flies, pupal casings would accumulate progressively over a period of years. If searches for them were conducted in a systematic manner by well organized teams, their relative abundance would indicate the sites most favoured by the flies for depositing their larvae.

Teams of from six to eight natives, all trained in the methods of search and recognition of puparia, were set to work to systematically survey the whole of the potential fly area. Work was commenced in the game reserves where, generally speaking, the highest densities of flies were known to exist. From these centres the surveys were extended outwards until areas were reached in which no evidence of breeding could be established.

The method adopted consisted of the slashing away of vegetational cover where overhanging canopy formation impeded entrance into thickets. Surface debris in the form of twigs and leaves was removed by hand and the search for casings conducted by carefully drawing the fingers through the overlying layer of humus-bearing soil and thus exposing them. Experience soon served to indicate those situations in which pupal casings were likely to be encountered. By systematically working through the various areas, the survey was completed in just over two years, i.e. from January 1947 to March 1949.

Recordings were made of the daily totals of casings taken by each team, the number of natives employed and the time worked. From this data the relative density, in terms of casings per boy per day, was calculated for the various areas surveyed. The density so obtained was plotted on a map of the area.

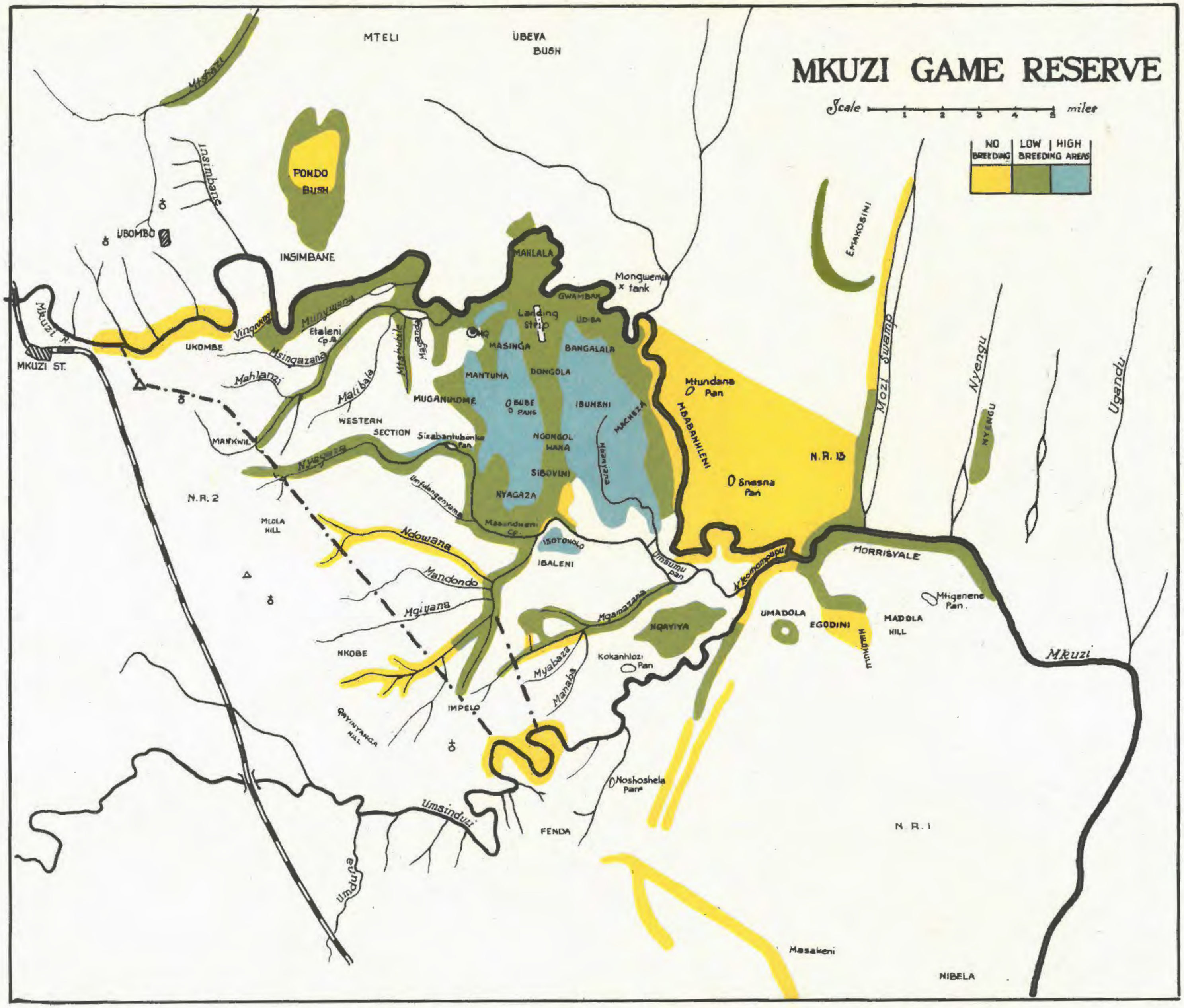
Map 3 represents the breeding areas of *G. pallidipes* in the Mkuzi game reserve in terms of pupal casings per boy per day. High breeding area denotes 10 to 50 casings per boy per day, low breeding area denotes 1 to 10.

The Mkuzi game reserve is situated within the coastal plain of Zululand and consists of flat country heavily bushed in parts. It carries a very high density of game, the bulk of which are impala and nyala with, however, many kudu, wildebeest, small game and a few black rhino. [*Diceros bicornis* (Lin.].

MAP 3.

Breeding areas of *G. pallidipes* in the Mkuzi game reserve asrevealed by the density of pupal casings.

MAP 3.



In comparison with the other game reserves the density of pupal casings found was not high, but it must be borne in mind that owing to the flat nature of the country and the more or less uniform density of the bush, breeding was dispersed over a considerable area. However, the tendency for breeding to be confined to certain specific areas was clearly manifest. As the surveys extended outwards from these localities, the density decreased rapidly until no further evidence of breeding could be found. In many such areas high densities of adult *G. pallidipes* could often be demonstrated.

In Map No. 4 (appended), the breeding areas of *G. pallidipes,* in terms of the pupal casing survey for the whole of the fly-infested areas of Zululand, is given.

By way of comparison, the distribution of the three species of tsetse flies in Zululand is given in Map 5 (appended).

The two maps show very clearly the extreme limitation in extent of the actual breeding areas of *G. pallidipes* in comparison with the distribution of the flies. Breeding has been confined largely to the three game reserves which represent the habitat of the bulk of the game antelopes. These serve as the permanent readily available hosts of the flies and ensure their continued existence. From these reserves dispersion has occurred into the surrounding areas which carry large numbers of cattle. They serve as hosts of a more temporary nature and afford a less reliable source of food, due to their susceptibility to Nagana and consequent mortality.

In the heavily bushed and, for the most part, narrow valleys constituting the tributaries and feeder channels of the Mkuzi and Pongola rivers to the north-west, as well as along the courses of many small rivers and streams entering St. Lucia Lake, small areas of breeding, as evidenced by low densities of pupal casings, were found.

Some of these areas must be looked upon as probably constituting localities in which breeding of a permanent nature has occurred, and in which *G. pallidipes* has been able to maintain itself without reinforcement of additional numbers from the larger breeding centres. Papert (1930) has shown that *G. pallidipes* was present in the valley of the Pongola river near the railhead at Gollel as far back as 1928, and there is no reason to believe that the flies have not persisted and bred in the area since that time. On many of the farms in this area game has been preserved and the fact that these antelopes have been confined to comparatively small localities where they would fulfil the function of reliable permanent hosts, seems to account for the occurrence of the more or less circumscribed scattered breeding areas.

VII. The Use of the New Synthetic Insecticides for the Control and Eradication of Tsetse Flies.

The first of the new synthetic insecticides to become available in quantity in the Union of South Africa was DDT. In 1945, reports from the war office of the United Nations were received which recorded the successful application of this insecticide. It was applied by means of aircraft to the control of the vectors of malaria and muscid flies, connected with outbreaks of dysentery, amongst troops in the Pacific theatre of operations. Nagana was at its height in Zululand at the time and as little if any success had attended the efforts made in the past to control the disease or the principal tsetse fly transmitting it, *G. pallidipes,* serious consideration was given to the possible use of DDT as a means of combating the vector.

Preliminary experiments conducted at the field laboratory [Kluge (1945) unpublished reports] in the Umfolozi game reserve indicated that *G. pallidipes* and *G. brevipalpis* showed a high degree of susceptibility to DDT applied as a space spray in organic solvents or to contact with residual deposits applied to dry grass. The tests indicated that the insecticide could possibly be applied with advantage to combating the flies, provided some practical means of applying it over extensive areas could be found.

No details were available of the apparatus used for distributing the insecticide from aircraft in the above-mentioned war office reports and it became necessary, therefore, to devise some suitable method of atomizing the insecticide so as to apply it successfully by means of aircraft.

The problem as it presented itself at the time comprised an area of approximately 7,000 square miles. Nagana was rife amongst the numerous herds of cattle in both European farming areas and native reserves, in the greater portion of which *G. pallidipes* were abundant. (See Map No. 5 appended.)

The description of the life history and habits of *G. pallidipes* makes it clear that the application of insecticide could be directed against the adult flies only. A fog or cloud of finely divided particles, which would remain airborne for as long as possible so as to exert the maximum effect upon the highly mobile adults, seemed to be called for. The covering of vegetation with a residual film of insecticide which might or might not exert its effect, should flies alight upon it, appeared less desirable.

1. *Methods of applying insecticide by aircraft.*

(a) *Insecticides in atomized liquid droplet form.*

With the object of producing a cloud or fog of finely divided particles of insecticide in a liquid base, an apparatus embodying the principle of the venturi tube was constructed. Figure 3 illustrates diagramatically the atomizer finally adopted. The liquid insecticide was fed by gravity into an annular space in a brass casting surrounding the constricted throat of the venturi. From here it flowed through a series of radially placed $\frac{1}{8}''$ holes into the actual throat. A funnel of sheet metal, situated anteriorly, directed the airstream caused by the forward motion of the aircraft into the throat where, due to compression, it was accelerated. Behind the throat a second longer sheet metal funnel, having an angle of 14° internally, created a partial vacuum which further accelerated the airstream at the throat. Atomization of the impinging liquid streams took place in the throat but it was found that the droplets tended to coalesce against the sides of the posterior funnel. To overcome this difficulty a cone of sheet metal was attached, as illustrated, over the end of the posterior funnel and the accelerated airstream from this cone completed the process of atomization. Tests of the apparatus set up in a wind tunnel by the military personnel of the South African Airforce, with the airstream set to 120 m.p.h., gave the readings at the various positions in the apparatus indicated.

Each of six Anson aircraft was fitted with two atomizers mounted beneath the fuselage at the trailing edge of the wing. The liquid insecticide was carried in tanks of 200 gallons capacity in the fuselage, and emission into the atomizers was effected by gravity through a partially flexible pipeline and a cock controlled by the pilot.

The insecticide consisted of a base of furnace oil containing dissolved technical DDT to give a final concentration of 5% of the para para isomer. Rate of

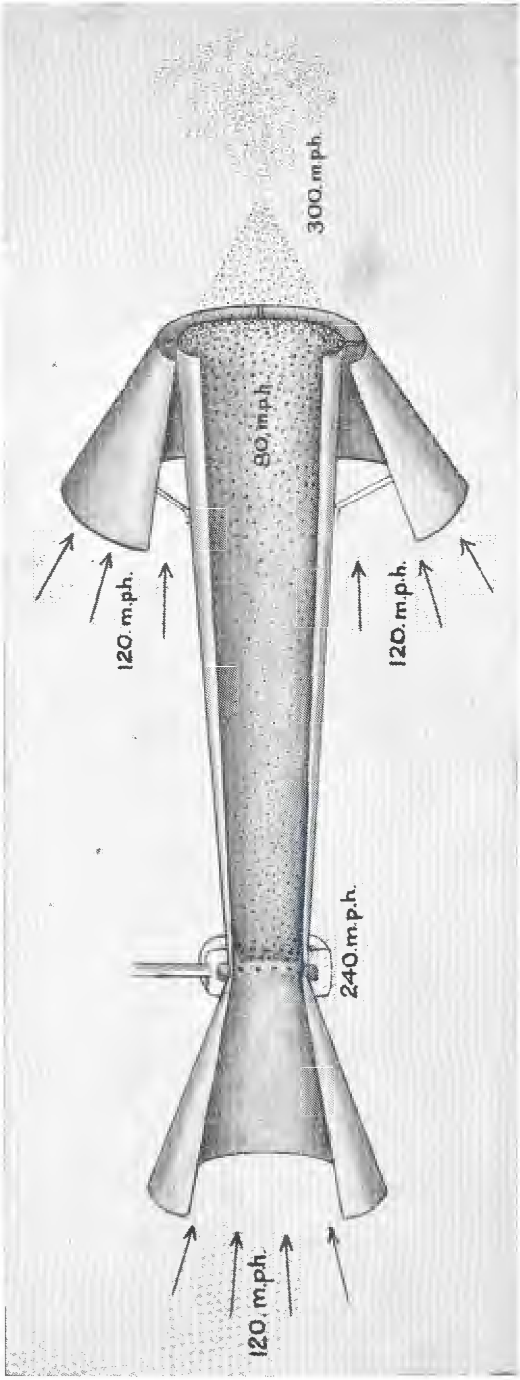


FIG. 3.—Venturi-type atomizer as fitted to Anson aircraft. (Diagramatic)

flow was adjusted to between 12 and 13 gallons of liquid insecticide from each atomizer per minute, or 24 to 26 gallons per aircraft per minute.

Experimentation under field conditions revealed that satisfactory results were obtained by operating the aircraft at a height of between 50 and 75 feet above ground level at right angles to the wind of a velocity not exceeding 10 m.p.h. Under these conditions a swathe of atomized insecticide of about 70 yards, giving a satisfactory cover and allowing a reasonable overlap between swathes, was obtained.

The methods of operation and means of assessing swathe width of satisfactory concentration are illustrated diagramatically in Figures 4 and 5.

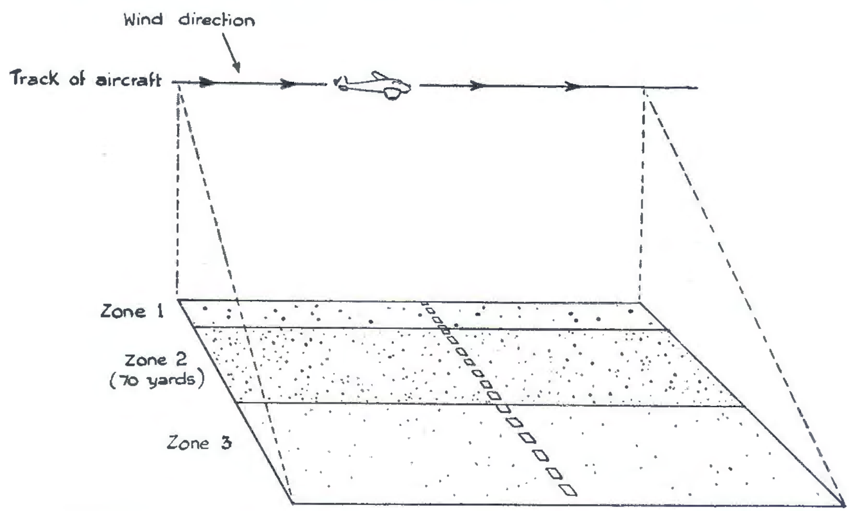


FIG. 4.—Diagramatic representation of spray pattern from aircraft. Squares indicate test cards placed are right angles to the line of flight.

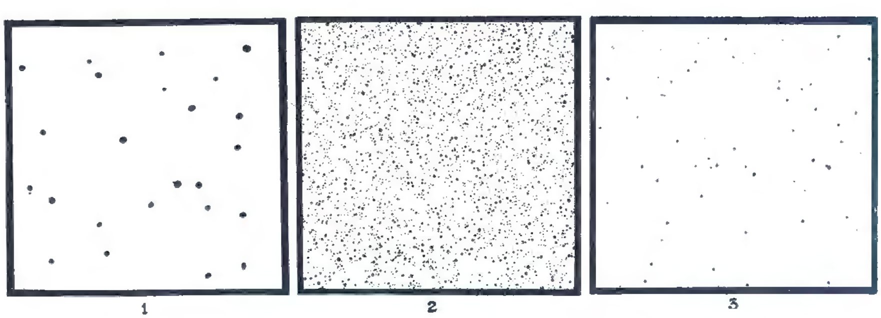


FIG. 5.—Representative cards from each of the zones indicated in Fig. 4.

Many difficulties were encountered in applying insecticide by aircraft in atomized liquid form. The chief of these was the fact that the atomized insecticide became invisible upon leaving the aircraft. This was due to dispersion of the droplets in the air and the pilot was dependent, therefore, upon fixed ground marks in order to fly parallel reciprocal courses spaced 70 yards apart.

With the comparatively short runs necessary in most areas, which rarely exceeded a maximum distance of eight miles, it was found that the usual magnetic and gyro compasses showed too great a lag. The result was that even when the run was commenced over fixed points 70 yards apart on a single base line, the reciprocal course set on the return run was often too wide of the mark and unsprayed gaps between swathes occurred.

To overcome this, a system of marking both the commencement and end of each run was introduced. Where undulating country was encountered, it was frequently necessary to introduce a marker somewhere between these two points in order to give the pilot some fixed point on which to fly.

The system finally adopted was to fix two base lines, one at either end of the area to be sprayed. The run was commenced over a flag on a tall mast carried on a motor vehicle. The end point was indicated by means of a chemical smoke generator. This had to be visible to the pilot when he commenced his spray run. While the aircraft was turning, the smoke marker would be replaced by a flag 70 yards further along the base line and, simultaneously, a smoke marker on the initial base line would indicate the course to be set by the pilot on his return run. In this way the pilot alternated his spray runs between a flag and smoke marker.

The system was extremely laborious, entailed considerable staff, and was possible only where the terrain and bush conditions were accessible to personnel to mark off swathe widths and set the necessary markers.

The successful application of insecticides in highly potent form over the trackless, and frequently featureless bush, constituting the habitat of tsetse flies, called for some method obviating the necessity for ground markers so as to enable the pilots of aircraft to successfully cover any area independent of such ground aid. Furthermore, the extensive areas to be covered demanded greater speed and the utilisation of several aircraft simultaneously in order to allow of a fixed programme being adhered to.

(b) *Insecticides in smoke or thermal aerosol form.*

Tests were undertaken in which insecticide in liquid form was introduced directly into the engine exhaust stacks. The formulation used is described later. Use was made of the blast of hot exhaust gases to break up the liquid into droplet form and the heat was found to be sufficient to partially crack the solvent and vaporize the insecticide. It emerged from the exhaust stacks in the form of a dense white smoke.

Types of aircraft and methods employed.

Ansons.—The installation as finally fitted to Anson aircraft consisted of the same type of fuselage tanks of 200 gallons capacity as used for the venturi spray method. The flexible emission pipe passed through each engine nacelle. It was attached by means of a union to a short socket of $\frac{5}{8}''$ inside diameter welded into the exhaust stack at a point approximately 4 inches behind the confluence of the two arms of the ring exhaust. This point of introduction of the insecticide was chosen empirically after some experimentation, and the temperature of the exhaust gases here during actual operational conditions was found to be 710° C. Although this temperature is capable of breaking down the chemical structure of both D.D.T. and B.H.C., it will be appreciated that, dissolved in the solvent, the insecticides are protected to a considerable extent against thermal disintegration. Furthermore, the rate of flow is such that the insecticides are subjected to only momentary contact with a temperature of 710° C. and extremely rapid cooling occurs as vaporisation takes place. Almost negligible disintegration of insecticide is caused as will be shown by the biological evaluation of potency carried out by means of exposure tests on insects. The exhaust stacks themselves were extended by means of sheet-metal flues for a distance of approximatelv eight feet. The posterior ends were in line with the trailing edges of the wings and were directed downwards in order to escape the slipstream of the air screws.

Figure 6 illustrates one of the modified exhaust stacks as fitted to an Anson aircraft.

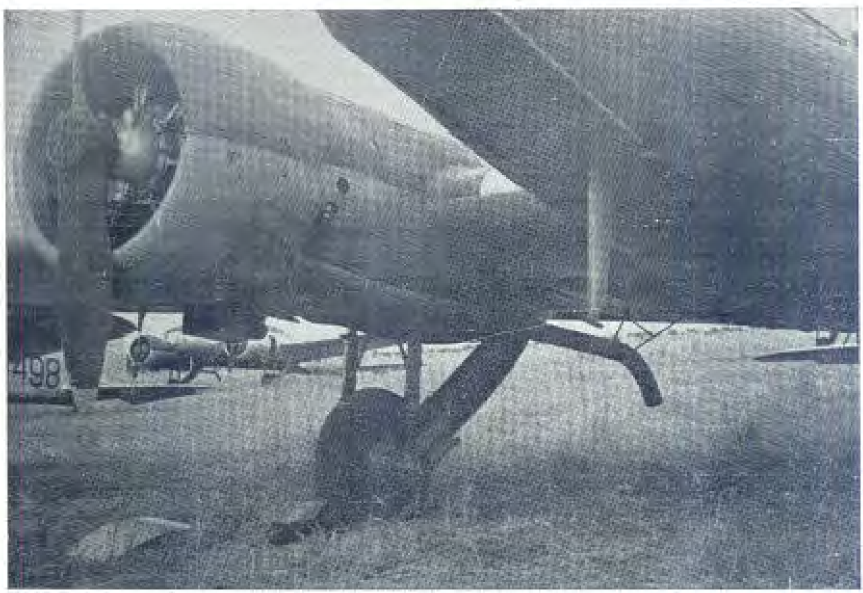


FIG. 6.—Modified exhaust stack of Anson aircraft for the production of insectidical smoke or thermal aerosol. Note tube carrying insecticide entering exhaust.

In the case of the Anson aircraft, fitted with a 7 cylinder Gypsy IX radial engine, the rate of flow of insec.icide was adjusted to 5 gallons per engine per minute. It must be mentioned here that as the insecticide was fed into the exhaust stacks by gravity, the rate of flow varied considerably during flight. Gravitational forces created by the position of the aircraft varied the pressure exerted upon the insecticide and consequently its flow rate. It could be observed clearly that when an aircraft descended obliquely during spraying operations, the volume of smoke decreased and increased considerably as the aircraft ascended. This variation in rate of flow caused difficulties in operating in broken or hilly country. In many heavily bushed valleys, an adequate dosage of insecticide could only be applied if the aircraft could be flown from the lower to the higher points. This was often beyond the operational capabilities of the aircraft.

Piper Cruisers.—At a later stage the Anson aircraft were replaced by a very much lighter type, the Piper Cruiser. These single engined aircraft, with horizontally opposed four cylinder engines of 115 h.p., were fitted with an adjustable type fuelline pump capable of feeding the insecticide into the exhaust stack at a constant rate. The reduced amount of heat generated by the smaller engine

FIG. 6 (*a*).—Anson aircraft in eschelon formation applying smoke in the Mkuzi game reserve. Note smoke covering bush in background.

FIG. 6 (*b*)—Piper cruisers applying smoke. Forced feeding insecticidal solutions enables columns to be laid in all flying positions.

13665–2

and the smaller amount of exhaust gas emitted, limited the amount of insecticide which could be introduced into the exhaust stacks. The insecticide was fed into each of the four exhaust manifolds at a point about 3 inches from the actual exhaust port where the temperature, taken by means of a special thermocouple pyrometer, gave a reading approximating that of the Anson aircraft, namely, 710° C.

Rate of flow of the insecticide was adjusted by experimentation under actual flight conditions so as to produce the optimum amount of white smoke. It was noted that if the rate of flow was too great, the exhaust stack tended to cool off with the result that the smoke assumed a brownish colour, indicating that a portion of the insecticide solution was being emitted as a liquid. If the insecticide was fed too slowly, the smoke volume was reduced and assumed a bluish colour. The optimum flow rate of insecticide for the Piper Cruiser was found to be 1·3 gallons per minute.

The method of operation consisted of utilising several aircraft simultaneously. Depending upon the size of the area to be treated up to eight aircraft were used together. So large a number was purely a matter of convenience in order to accelerate the treatment and complete a single large area in one operation. The leader of a flight, who was chosen usually on his knowledge of the area to be treated, commenced his initial run on the leeward side of the area so that the smoke from his aircraft would not interfere with the visibility of those following. The second and subsequent aircraft took up a position in eschelon formation to windward. The parallel distance, which represented the 70 or 25 yard swathe width, depending on the type of aircraft, could be arrived at by visual judgment. On completing the forward run the leader would so adjust his turn that his return run would commence immediately the last aircraft had completed his forward run. The swathe width could be judged by the smoke trail of the preceding aircraft which had flown parallel and to windward.

It will be appreciated that the smoke volume emitted by an aircraft at the commencement of a run has moved downwind for a distance proportional to the speed of the wind when the run has been completed. The return run will not be parallel to the track originally followed, as the aircraft is flying parallel to the moving smoke column. This is compensated for, however, by the next run as is illustrated diagramatically in Figure 7.

Complete cover of an area is achieved by this method and the operation may be left entirely in the hands of the pilots; the smoke columns serving as a visual guide. Due to the rapid dispersion of the smoke under adverse conditions, however, the applications must be applied only during favourable weather conditions. This restricts the use of the method to certain hours only when conditions are suitable.

Applications of insecticide by the smoke or exhaust aerosol method are best conducted at dawn, preferably on windless days, but successful results are obtained with wind speeds up to five or six m.p.h. Furthermore, conditions of inversion or a static condition of the atmosphere are necessary. As soon as the ground heats up due to solar radiation, thermal air currents are set up which tend to carry the smoke upwards and disperse it too quickly.

In practice it has been found that, on an average, under the climatic conditions encountered in Zululand, successful operation is possible on about four mornings per week. More or less ideal conditions allow for approximately 30 hours per aircraft per month. In terms of the Anson aircraft, which cover 50 acres per minute while spraying or the Piper Cruisers which cover 15 acres per minute, this permits of approximately 30,000 acres and 13,500 acres coverage per aircraft per month, respectively. The calculation of the spraying is based on one third of the actual flying time for the Ansons and one half for the Piper Cruisers. The figures given are approximate and depend upon such factors as distance from base, which determines the amount of dead flying necessary, turning range of aircraft, efficiency of pilots, climatic conditions, etc., but are given to serve as a guide to reflect the experience over seven years of operations in Zululand.

Helicopters.—In the hilly portions of the area, such as in many parts of the Hluhluwe game reserve, large sections of heavily bushed country were quite inaccessible to the fixed wing type of aircraft. In order to treat these areas with insecticide simultaneously with the more level portions accessible to the conventional types of aircraft, helicopters were introduced. The first of these came into operation in December 1948, followed by two additional machines put into service in April 1949.

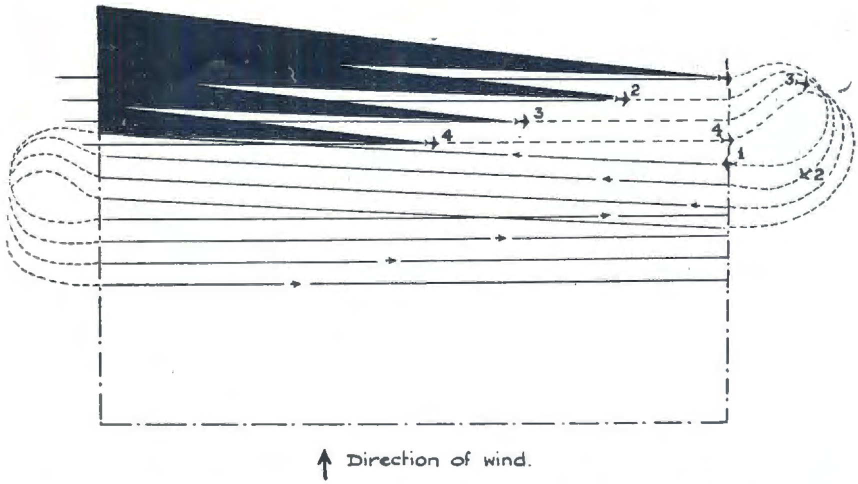


FIG. 7.—Diagramatic representation of flight pattern for the laying down of smoke or thermal aerosol. Note the widening and coalescence of the smoke columns behind the aircraft and the effect of the wind upon them.

The type introduced was the Sikorsky S.51, 4 place helicopter powered by a Pratt and Whitney 450 h.p. radial engine. The insecticide was carried in two tanks of 40 gallons capacity each, mounted externally at the centre of gravity of the aircraft. The insecticidal solution was fed by gravity through interconnecting pipes into the single exhaust stack at a point at which the temperature of the exhaust gases under normal operational conditions recorded 710° C. The exhaust stack was extended by means of a sheet metal flue as indicated in Figure 8.

As the helicopter is capable of being flown at varying forward speeds, the rate of flow of insecticide was controlled by means of a cock operated by the pilot. This permitted him to vary the flow rate according to the forward speed. Thus, at 60 m.p.h., the flow rate was adjusted to 5 gallons per minute, or half that of the Anson aircraft flying at twice this speed.

The rather unconventional design of the helicopter and its phenomenal rate of climb at low altitude, necessitates its being flown with safety in a definite manner when covering steep valleys or hillsides in rugged country. As with all

FIG. 8.—Sikorsky S51 helicopter showing modified exhaust stack and point of entry of insecticidal solution.

FIG. 8 (*a*).—Helicopter applying insecticidal smoke in *G. brevipalpis area* in Hluhluwe game reserve.

types of aircraft emitting insecticide in thermal aerosol form, the aircraft should be flown as close to treetop height as possible. The pilot should have unrestricted visibility, which is best achieved by facing the nose of the machine to the hillside. At the same time, this position ensures that the tail rotor will be well clear of any obstructions. By commencing the spray run at the base of the hill and ascending parallel with its slope, the gravitational force acting upon the fluid insecticide tends to promote a steady sustained flow. No definite swathe width can be given and coverage of steep bushed valleys and hillsides is judged by the pilot on visual observation and experience.

The smoke or thermal aerosol method of insecticide dispersion has certain very definite advantages from the point of view of adult tsetse fly eradication. Apart from ease of application, rapidity with which a given area may be covered and the fact that the method facilitates complete coverage, penetration of heavily bushed regions down to ground level is assured. Whereas the amount of any atomized liquid spray deposited upon foliage stands in direct proportion to the density of vegetational canopy, the semi-gaseous smoke penetrates effectively to the lower levels where the major portion of the tsetse flies occur. Under good conditions the smoke from the fixed-wing type of aircraft descends to ground level within seconds and this effect is even more pronounced in the case of the helicopter where the large horizontal rotor assists in forcing it downwards.

Tsetse flies can be destroyed by aerial application of insecticides in the adult stage only. It is obviously of advantage to apply insecticides at a time when mass hatching has occurred and the maximum number of adults are present with the minimum number of pupae in the ground, where the latter are inaccessible. As has been shown this is the position in early spring at the onset of the warm weather. This period represents the late dry season in most parts of Africa when vegetational cover is at a minimum pending the onset of the summer leaf flush. Fly eradication must now continue uninterruptedly throughout the summer months in order to achieve really effective control or complete eradication and a method capable of remaining fully effective throughout the period of ever-increasing overhead leafy canopy possesses very obvious advantages.

(i) *Insecticide formulations used for the production of smoke or thermal aerosol.*—To start with, technical DDT was dissolved in compression-ignition fuel oil (diesel oil) to give a content of 16% of the para para isomer. This required the addition of toluol to hold this amount in solution at temperatures as low as 32° F.—approximately the lowest temperature recorded during transit of the material by rail from the factory to the site of operation.

At a later date DDT was replaced by benzene hexachloride (BHC) principally for reasons of economy. In the preparation of the solution the technical BHC was dissolved in diesel oil by heat. On cooling a large quantity of the less soluble alpha and beta isomers were precipitated from the solution and the gamma isomer content was adjusted to 4%.

(ii) *Estimation of dosage of insecticide applied.* It will be appreciated that in attempting to arrive at an estimate of the actual dosage of insecticide per application over a given area of bush, no more than an approximate figure can be arrived at.

In the case of the liquid spray where the rate of flow of the 5% DDT-furnace oil solution was adjusted to 26 gallons per minute, the dosage applied was estimated on the basis of a 70 yard swathe width. Spraying was carried out at

120 m.p.h. This meant that the aircraft covered the ground at approximately 50 acres per minute depositing the solution in atomized form at half a gallon per acre, or approximately 23 mgm. per square yard.

When the smoke or thermal aerosol method was used with the Anson aircraft, the insecticide was emitted at the average rate of 10 gallons per aircraft per minute. The speed of the aircraft remained the same and an effective swathe width of 70 yards was assumed. It must be realized that the column of smoke which descended to ground level remained suspended in air and moved over the ground at the speed of the prevailing wind. Assuming deposition of the insecticide over a 70 yards swathe width, this would give a figure of roughly 29 mgm. p.p. DDT per square yard. In the case of the BHC thermal aerosol, the concentration of 4% of the gamma isomer in the solution was arrived at on the assumption that this insecticide was approximately four times as effective as DDT. The dosage, therefore, in this case was approximately 7 mgm. per square yard.

The Piper Cruisers, with a speed of 100 m.p.h., were flown so as to give a swathe of 25 yards in width. This represents a coverage of approximately 15 acres per minute. The rate of flow, as stated, was adjusted to 1·3 gal. per minute. This gave an estimated dosage of 2·6 mgm. of the gamma isomer per square yard, which is less than half that given by the Anson aircraft.

(iii) *Methods of assessing the potency of the insecticidal solutions applied.*—A number of attempts were made to arrive at a satisfactory method of determining the concentration of the atomized insecticide close to ground level by means of chemical assay. Results were so variable, however, due to the difficulties experienced in obtaining standard samples of the mist or smoke under the varying climatic conditions prevailing, that the attempts were ultimately abandoned.

A method which served as a sufficiently accurate guide to the potency of the insecticide applied consisted of the exposure of insects in specially constructed cages of 16 mesh wire gauze. The exposure cages consisted of a circular base of sheet-metal $3\frac{1}{4}''$ in diameter provided with a flange to which was wired a dome of wire gauze $2''$ in depth. The flies were introduced into the cage through a half inch hole in the centre of the base which could be closed with a cork stopper. These small cages had the advantage of being cheap, easily constructed, easy to handle and could be immersed in organic solvents after use in order to remove all traces of insecticide prior to being used again.

In making the exposure tests, various methods of spacing the cages were employed. When it was desired to determine whether sufficient overlap of swathes was being maintained, or when the effective swathe width of an individual aircraft had to be determined, the cages were spaced linearly at set intervals at right angles to the line of flight. To note whether any area was being adequately covered, check exposures were frequently conducted without the knowledge of the pilots. In such cases the cages were handed to assistants to select whatever sites in the bush they wished, in order to obtain randomized spacing.

It was found, during the course of large numbers of exposure tests, that tsetse flies were considerably more susceptible to insecticides than were blowflies. The former became increasingly difficult to obtain as the campaign progressed. They were eventually replaced by blowflies, which could be bred in abundance and were readily available and easily handled.

After exposure, readings were taken at hourly or two hourly intervals until no further mortality could be noted, generally up to the twelfth hour after exposure. The mortality in the exposure cages was compared with that in two or more cages of unexposed flies retained at a site well away from the treated area.

In selecting sites for exposing flies in cages, various factors were taken into consideration, such as overhead leafy canopy, direction of wind, height above ground, etc. It was found that the mortality of flies in stationary cages was frequently considerably less than in cages held in the hand and moved gently so as to cause air to flow through the meshes of the gauze. Especially was this the case in still air. It became apparent that wire or fabric gauze retarded the flow of air and might even prevent suspended particles of insecticide from reaching the insects exposed within the cages, unless some movement of air was induced.

The results obtained from many exposure tests, conducted under a variety of climatic conditions, invariably gave mortalities amongst blowflies in excess of 90% in cages which had been moved. In the case of stationary cages mortalities varied considerably, but in the aggregate generally exceeded 60%. Such results were accepted only when no mortality had occurred amongst the unexposed control flies.

It is believed, and there is some evidence to substantiate this, that a mortality rate of 90% amongst blowflies corresponds to 100% mortality amongst tsetse flies exposed under the same conditions, as the degree of susceptibility to DDT and BHC of the latter is so much greater than the former.

(c) *The application of insecticides by means of chemical smoke generators.*

In mountainous areas where the hilly nature of the terrain precluded the use of fixed-wing type aircraft and prior to the acquisition of helicopters, thermal smoke generators, embodying DDT as the active principle, were employed on a large scale.

The chemical composition of the thermal mixture consisted of the following:—

DDT containing 75% p.p. isomer	52%
Sugar (icing sugar)	36%
Sodium chlorate	12%

The ingredients were intimately mixed by mechanical means and compressed, under a pressure of one ton per square inch, into cylindrical tin-plate containers 5″ in diameter by 2¼″ in depth. The contents of each container averaged 1 lb. in weight. Compression of the mixture at 1 ton per square inch was necessary to produce a firm consistency of the thermal mixture and to ensure slow and uniform burning, without danger of enflaming, for a period of four minutes. Into the upper surface of the compressed mixture was pressed a disc of match head composition roughly 1″ in diameter by ⅛″ in thickness to serve as igniter. The tin container was provided with a lid containing five ½″ holes in the form of a cross. The central hole afforded access to the igniter of match head composition which was lit by means of a safety match. Masking tape or adhesive cellophane was used to seal the holes in the lid during transit.

Experimental exposures of tsetse flies and blowflies in wire gauze cages demonstrated a fairly high degree of efficiency over a range of approximately 35 yards surrounding the generator. The latter was placed upon the ground. Mortality amongst the tsetse flies varied considerably depending upon climatic and wind conditions at the time of exposure. Under ideal conditions, such as those occurring frequently just before and after sunrise and often during the late afternoon, when inversion conditions were encountered, mortalities approaching 100% were usually recorded over an area of about one acre when the generators were spaced 70 yards apart. In still air the smoke from a generator rises to a height of 12 or 15 feet where it cools rapidly and sinks to ground level. There is a tendency for a large proportion of the vaporized DDT to become deposited within a radius of about 10 yards around the generator. A sufficient concentration remains to produce a satisfactory mortality, however, up to a distance of 35 yards on all sides.

The method of applying the smoke generators in the heavily bushed valleys amongst hills was to use natives, each of whom carried 16 generators in a canvas carrier on his back. The generator boys were spaced at 70 yard intervals from each other. At intervals of 70 yards a generator was placed and ignited as the operators progressed. This gave a coverage of approximately one generator per acre. Assuming an even distribution of the smoke this represented about half a pound of technical DDT per acre, or 34 mgm. p.p. isomer per square yard.

The smoke generator method of applying insecticides had certain serious disadvantages from the practical point of view. Each generator had to be placed by hand, frequently on steep hillsides covered by almost impenetrable bush, and much time was expended in reaching the various sites. Once liberated from the generator the smoke could not be controlled. This restricted the application of the method to certain favourable sets of climatic conditions and these were met with only in the early mornings and late afternoons of favourable days. Katabatic action of air frequently caused the smoke to flow into the low lying parts of valleys. These could be completely blanketed with smoke, leaving the hillsides inadequately covered.

(d) *Application of insecticides in dust or powder form.*

An alternative means of applying insecticide in areas inaccessible to fixed-wing aircraft consisted of applications in dust or powder form. Two methods were adopted, depending upon the nature of the terrain to be negotiated.

In the low-lying more level areas of valleys, a mechanical type of duster powered by means of a $1\frac{1}{2}$ h.p. air cooled engine was employed. The hopper, sirocco-type fan and engine were mounted on a tubular metal frame with one pneumatic-tyred wheel slightly forward of the centre of gravity. Two wheel-barrow type handles enabled the contrivance to be held in position and guided along game paths and narrow tracks cut in the bush. These constituted the only means of negotiating the dense thickets. The dust was emitted through a length of flexible 3″ rubber hosing.

This apparatus is illustrated in Figure 9.

On steep hillsides dust was applied by means of hand operated bellow-type dusters carried upon the backs of natives, as illustrated in Figure 10.

A dust containing 5% technical DDT (75% p.p. isomer) was applied at the rate of 5 lb. per acre or approximately 17 mgm p.p. isomer per square yard.

Exposures of blowflies and tsetse flies, conducted in the manner described for the smoke generators and aircraft, gave mortalities averaging 70% to 90%. These were considered sufficiently high to justify the application of the method on an extensive scale.

Although this method of applying insecticide had similar disadvantages to that of the smoke generator method in being slow and necessitating the negotiation of large inaccessible areas on foot, it represented an improvement on the former method. In dense bush the dust was less affected by adverse climatic factors

FIG. 9.—Mechanical duster mounted on single wheel.

FIG. 10.—Team of boys with bellows type dusters. Note carrier boys with additional DDT dust for replenishment.

than the heated smoke from the thermal generators, which had to cool before descending to ground level. Furthermore, dust could be directed with a fair degree of accuracy into thickets and remained airborne for a reasonable period. Finally, it could be applied for the most part throughout the day and was less affected by wind. Thus a considerably larger area could be treated daily than was possible by the smoke generator method.

(e) *The application of insecticides to cattle.*

In the native reserves and European farming areas situated around and away from the known areas of high concentration of tsetse flies, Nagana was extremely prevalent during the early stages of the campaign in 1947. *G. pallidipes* were present throughout the area, but varied considerably in density from place to place.

At the time, the application of insecticides by aircraft and DDT smoke generators was being concentrated in the known breeding areas. The extent of the dispersion areas, in which the flies occurred in low density, was such as to preclude the use of aircraft. In these areas, game had been eliminated to a considerable extent. The result was that the tsetse flies were subsisting largely on the herds of cattle. These had been drastically reduced in numbers by Nagana from 1945, and losses were still occurring. This indicated that cattle undoubtedly formed an important, if not the principal, source of food for the flies.

A preliminary cattle census was taken in native reserve No. 12 to the west of the Hluhluwe game reserve in October 1947. In an area served by 7 dipping tanks for the control of East Coast Fever, 8,070 head out of a total of 21,600 two years previously, remained. This signified a reduction of 63%, most of this mortality being attributable to Nagana. In some areas mortality had been as high as 90%. Tests conducted in the Umfolozi game reserve, in which DDT in emulsion form had been sprayed onto cattle, had demonstrated a lethal effect upon tsetse flies for a period of from 5 to 6 days. In these tests the flies were allowed to alight and partially engorge themselves, but were captured for subsequent observation before leaving the host.

In 1949, a large number of dipping tanks, serving practically all the country surrounding the more heavily fly infested areas, was cleaned and refilled with dipwash. This consisted of a solution of 0·16% sodium arsenite (expressed as As_2O_3) with 0·1% of para para DDT added as a 20% emulsion. Replenishments of the dipwash were made at the rate of 0·2% p.p. DDT. This ensured a constant concentration of 0·15% p.p. DDT, as had been determined in other parts of the Union previously. (Graf and Bekker, 1952). A mayonnaise type DDT emulsion concentrate was used. It contained 20% p.p. DDT in toluol with a casein resin-soap emulsifier. Initial filling required 1 gallon of the concentrate to every 200 gallons dipwash and replenishment 1 gallon per 100 gallons dipwash.

The dipping tanks selected, 144 in all, and their approximate positions are reflected in Map 6 (appended).

Dipping was carried out at weekly intervals. In view of the low density of *G. pallidipes* to start with, it was apparent that actual figures of mortality amongst the tsetse flies would be extremely difficult to obtain. A fairly good method of judging results was obtained indirectly. The regular dipping of cattle in DDT profoundly affected the incidence of biting flies, e.g. *Stomoxys, Siphona, Tabanidae,* etc., and taking into consideration the extreme degree of susceptibility of tsetse flies to DDT, it was accepted that the latter were at least equally affected.

FIG. 10 (*a*).—Hand operated dusters in operation.

FIG. 10 (*b*).—Mechanical duster operating in dense bush.

The dipped herds became practically fly-free after two to three weekly dippings and it was noted that a marked reduction in the presence of house flies in farm houses followed the disappearance of flies, both biting and non-biting, upon the cattle.

This freedom from fly worry was maintained until the cessation of the DDT dipping campaign towards the end of 1950. The incidence of Nagana dropped rapidly, which could be largely attributed to the effect of DDT upon the tsetse flies present in small numbers throughout these dispersion areas.

VIII. Bush Clearing.

Reference has already been made, in the earlier portions of this report, to the creation of barrier clearings surrounding portions of the Umfolozi and Hluhluwe game reserves. The results obtained could not be regarded as very favourable. Nagana continued to spread and exact a very heavy toll from the cattle population of the whole area.

1. The widening and extension of the existing barrier clearings.

In May 1946, a commencement was made with the widening and extension of the barrier clearings to a width of two miles. This distance was considered to be adequate in preventing flies from crossing such artificially opened country.

The work fell under the control of the Division of Soil Conservation and Extension. Preliminary experimentation involving various types of mechanical equipment was undertaken. Compressed air driven chisels, for the cutting of roots below ground level and hand operated " monkey winches ", operating on the steel cable and drum principle to uproot trees bodily by traction, were tested. Finally a type of cable-operated tractor-driven stump-puller was employed.

Map No. 6 indicates the course and extent of the barrier clearings created.

The work was completed at the end of December 1949, when a total length of 94 miles by two miles in width was completed.

The barrier clearing traverses many types of terrain, which vary from comparatively sparsely covered flat country to extremely precipitous valleys and hill slopes covered by dense forest, with trees up to 50 and 60 feet high.

In certain areas with almost perpendicular hill slopes, frequently of a very rocky nature, hand clearing had to be resorted to. Here it was found impossible to operate the tractor-driven stump-pullers. Undergrowth was cleared by means of machetes and corn knives and felling by means of axes resorted to. Undergrowth and brush was stacked over the stumps and subsequently burned.

Surprisingly little difficulty was encountered in keeping the cleared areas free of bush. Although dense growths of weeds, various climbing plants and seedling trees made their appearance shortly after clearing, sufficient grass established itself to make good burns possible before the advent of the spring rains. These effectively disposed of most of the new growth and afforded the grass an even better chance of establishing itself during subsequent summer seasons. Regular burning of this grass during the late dry season ensured the maintenance of the bush free barriers.

2. Thicket or discriminative clearing.

In the northern portions of the fly infested areas, in particular along the bush fringed "leaders" or tributaries of the Pongola and Mkuzi rivers to the west of the Ubombo mountains, fairly heavy concentrations of *G. pallidipes* were encountered. Breeding, as evidenced by the presence of accumulations of pupal casings, was shown to be present as reference to Map No. 4 will indicate. The rugged nature of the country with narrow tortuous valleys made the application of insecticides from the air a difficult matter and it was found impossible to ensure uniform coverages of insecticide in a number of areas. DDT smoke generators were applied, but again the smoke cover was not considered to be entirely satisfactory owing to the tendency of the smoke to collect in the lower parts of the valleys leaving the sides or slopes partially uncovered.

Discriminative or thicket clearing by means of hand labour was undertaken to render the heavily bushed areas untenable to fly. In all, an area of 4,700 acres was cleared of undergrowth and thicket. This permitted desiccation to occur to a degree sufficient to prevent the fly from maintaining itself.

During the course of the work, it was observed repeatedly that as a clearing advanced in a linear fashion along the course of a valley, concentrations of fly occurred ahead of the clearing operations. This constituted a hazard in that, as this type of clearing advanced slowly, flies could disperse over considerable areas ahead of the clearing gangs to set up foci of infection amongst cattle and establish themselves on adjoining farms.

To counteract this menace, DDT smoke generators were used extensively to cope with such concentrations of flies. The measure proved highly effective and by the time the discriminative clearings were completed towards the end of 1949, fly had been practically entirely eliminated.

The costs connected with the bush clearing operations will be dealt with later.

IX. The Principles Governing the Eradication of Tsetse Flies in Zululand.

In attempting the eradication of tsetse flies from so extensive an area as Zululand by means of the application of insecticides it was obvious, that for reasons of economy, their use over the whole of this area would be impossible.

The work of Harris (1930) appeared to indicate that the extensive epizootics of Nagana of the past had their origin in the game reserves. From these reserves flies dispersed into the surrounding country during periods of peak abundance, only to recede to the sanctuary afforded by them during periods of adverse climatic conditions. The disease, at such times, declined almost to the point of total disappearance.

No very clear picture of such a cycle of events had emerged, however, from the observations of the past. The tendency always existed on the part of native herdsmen surrounding the reserves to encroach with their stock into the better grazing close to their periphery. When this occurred Nagana would inevitably result, even during times of freedom of the disease in epizootic form from the remainder of the region.

To prove whether such more or less circumscribed sources of tsetse flies did exist and, at the same time, to determine the efficacy of applications of the new synthetic insecticides upon a known high concentration of flies, an experiment was conducted in the Mkuzi game reserve in 1945.

DDT in liquid form, according to the method described in Chapter VII, was applied three times between December 1st 1945 and January 12th 1946, to an area 30 square miles in extent within this reserve. This section contained a very high concentration of *G. pallidipes*. (Map 3.)

The first application to the area occupied five days. The second application commenced ten days later and also took five days to complete and the third application, which took six days, was commenced 19 days later. The spacing between applications was based upon the principle that the normal gestation period of the female *G. pallidipes* varies between 10 and 12 days. Any newly emerged females, therefore, would not be given the chance of maturing and depositing larvae.

In view of the fact that the insecticide was applied in liquid droplet form, it was thought that a fairly effective residual deposit of DDT would remain upon the bush as a result of the first two sprays. This deposit would remain effective for some time to deal with all flies alighting upon the treated vegetation so that a longer period appeared permissible before applying the third spray. The additional deposit of DDT applied by the third spray upon the two previously applied, would give a total period of between six and eight weeks, during which DDT would remain effective as a residual deposit. In this way it was anticipated that a very material reduction of *G. pallidipes* would result, if not perhaps something approaching eradication. Sufficient time would have elapsed to permit of pupae in the ground hatching and being destroyed as adults either by the second or third spray or by the residual deposit upon the vegetation. At that time the information regarding the greatly extended pupation period was not available.

At the time that applications of DDT were being conducted in the known high fly-concentration centres of the Mkuzi game reserve, fly surveys by means of Harris traps were extended to cover large tracts of country surrounding the reserve. In particular, densely bushed areas separated from it by open country were surveyed. Many of these bushed areas were found to harbour high concentrations of *G. pallidipes,* but it was found to be impossible to include them in the spraying programme at the time.

When the three applications of DDT were completed, a period of observation of 39 weeks ensued during which no further applications of insecticide were undertaken. In the meantime pupal-casing surveys, as described in Chapter VI, were undertaken and it was found that the areas of known high fly density in the reserve represented the actual breeding areas. The areas separated by open country from the reserve proper showed the presence of little breeding activity. These were subsequently referred to as dispersion areas. (Map 3).

The reduction in fly density following the three applications of DDT in liquid droplet form, as revealed by Harris trap surveys, have been reflected in Figure 2 for the two types of areas referred to, namely breeding and dispersion areas.

The results obtained from this initial experiment in the Mkuzi game reserve were of the very greatest significance in planning the subsequent campaign.

It was concluded that what applied in the Mkuzi reserve would apply equally well to the rest of the fly infested portions of Zululand. It was necessary, therefore, to determine accurately the actual breeding areas for the remainder of Zululand. The only method which proved satisfactory and gave a clear picture of these areas was that described as pupal-casing surveys under Chapter VI. Once established, the breeding areas could be concentrated upon from the point of view of eradicating the flies within them by means of applications of insecticide. A marked reduction of flies in the breeding areas would lead to a cessation of dispersion into the surrounding country. The fly population in these dispersion areas would die out in time in the absence of reinforcement by dispersion from the breeding centres.

That this contention is correct, namely, that the fly-infested areas are made up of primary breeding areas, in which *G. pallidipes* is able to maintain itself under all conditions, and dispersion areas, appears to have been borne out by the results obtained during the course of the campaign.

It must be conceded that during consecutively favourable years secondary breeding areas are established. This appears to have been the case in certain of the heavily bushed valleys leading into the Mkuzi and Pongola rivers. In these areas fair numbers of game exist, principally impala and vaal rhebok, *Pelea capreolus,* (Bechst) and here *G. pallidipes* appears to have established itself. From the infested valleys associated with the Pongola river, extensions of fly took place into Swaziland and small centres of breeding of a low grade were demonstrable in the south eastern portion of this territory. As will be shown, however, the extermination of *G. pallidipes* in the breeding centres near the Pongola river appears to have had a profound effect upon the incidence of flies in Swaziland, into which considerable dispersion had occurred. The process of elimination was accelerated by applications of insecticide to the infested areas in Swaziland, but in the light of the experience gained in the area of the Mkuzi game reserve, it is contended that the flies would have disappeared from these areas in the course of time. A year or more may have elapsed, however, before final disappearance of all flies could have occurred.

In relation to the actual primary or permanent breeding grounds of *G. pallidipes* in Zululand, the areas into which the flies had dispersed and in which the disease Nagana was rife, were extremely extensive. To accelerate the process of the disappearance of the flies from these dispersion areas and in this way terminate, in as short a time as possible, the incidence of Nagana in the livestock, DDT in dipping tanks, as previously outlined, was used. At the same time, however, applications of insecticide by means of aircraft and DDT smoke generators were undertaken wherever any local concentrations of flies were found by means of trap or bait animal surveys. These measures were applied, however, only when the course of insecticide applications in the breeding areas proper was not interfered with, as the destruction of these flies remained the first consideration.

X.—The Results Achieved in the Eradication of Tsetse Flies in Zululand.

The progress achieved during the course of the campaign, designed primarily to put an end to the catastrophic stock losses by an attempt to eradicate the principal vector, *G. pallidipes,* has brought to light one fact of great significance, namely the clear division of its habitat into breeding and dispersion areas. Surveys showed the presence of very high densities of flies in the three reserves, but equally high densities were demonstrable in many areas far removed from them. In fact, depending upon the criteria used for assessing its prevalence, e.g. bovine mortality or adult fly abundance, the impression gained was that the species was established throughout the area. As the work progressed and the adult flies were systematically reduced in number, a clearer picture of their distribution emerged.

1. *The Mkuzi game reserve.*

The initial progress achieved in the control of *G. pallidipes* in the Mkuzi game reserve, as a result of the application of DDT in liquid droplet form, has been described. The conclusion drawn, that the reduction in the density of *G. pallidipes* in the breeding area profoundly affected the incidence of this species in the dispersion areas, supports the view that only the principal breeding areas required attention.

Further support was afforded to this theory when, in 1946, the central part of the Mkuzi reserve was subjected to a series of eight applications by aircraft of DDT in smoke or thermal aerosol form. (For the sake of convenience in recording the flies caught in Harris traps, this central portion was subdivided into what became known as the " high density area " to the east and the " low density area " to the west. The former section harboured a greater concentration of game and somewhat higher densities of flies were generally recorded).

The applications of insecticide were spaced at roughly 10 to 14 day intervals and covered a period of almost four months, namely, from the 7th August to the 30th November, 1946.

A sudden and spectacular drop in the incidence of *G. pallidipes* occurred after the first application and the Harris trap catches reflected a steady sustained drop in fly incidence thereafter with fluctuations of a minor nature only.

At the completion of this series of applications a period of observation followed during which no further insecticide was applied. The weekly totals of flies fluctuated between nil and six or seven during the ensuing six months, averaging three to four per week. It was believed, to start with, that a threshold might have been reached which would no longer permit an insect with so limited a breeding potential as *G. pallidipes* to maintain itself. This was not the case, however, and it was suspected that the Harris traps were not reflecting the true density of fly still remaining in the reserve.

In July 1947, bait cattle were introduced. This had the effect of increasing the weekly totals of flies captured to around 30, most of which were being taken in the " high density area ".

In order to determine whether some breeding was still occurring within a confined area within the " high density area ", as was suspected from the locality in which the greater numbers of flies were being caught, DDT was applied to an area of three square miles by means of thermal smoke generators. Six applications, spaced at three weekly intervals, were made between the 27th August and the 20th December, 1947. This had the effect of reducing the catches within the " high density area ", from around 25 or 30 per week to six or seven. At the same time, however, the weekly totals of flies caught in the " low density area " showed an upward tendency.

It was realized that complete eradication within the breeding areas had not been achieved, although complete absence of all flies in the dispersion areas surrounding the reserve had taken place some time previously.

In January 1948, a final series of nine applications of insecticide by aircraft commenced. In the case of this series the applications were spaced at three-weekly to monthly intervals and covered a period of eight months from the 20th January to the end of September 1948. The spacing of the applications in this series was based upon the principle that with each application the coverage of the bush with insecticide would ensure almost 100% kill of all adult flies present.

Any females hatching from pupae present in the ground would require a period of from 23 to 28 days before depositing the first larvae, after which subsequent larvae could be deposited every 10 to 12 days. A three-weekly interval between sprays would ensure, therefore, that no female which hatched from a pupa present in the soil would be able to deposit a larva. It was not always possible, however, at the time to adhere strictly to a three-weekly cycle, due to other commitments, and occasionally intervals of a month between applications occurred. The longer interval between applications had the advantage that, for a given number of such applications, a longer period would be covered. This ensured that all pupae would hatch and the resultant flies would be dealt with.

Figure 11 represents graphically the various phases in the campaign which has led to the final eradication of *G. pallidipes* from the Mkuzi game reserve and surroundings. In the lower portion of this graph the fate of the flies present in two of the so-called dispersion areas outside the borders of the reserve is portrayed.

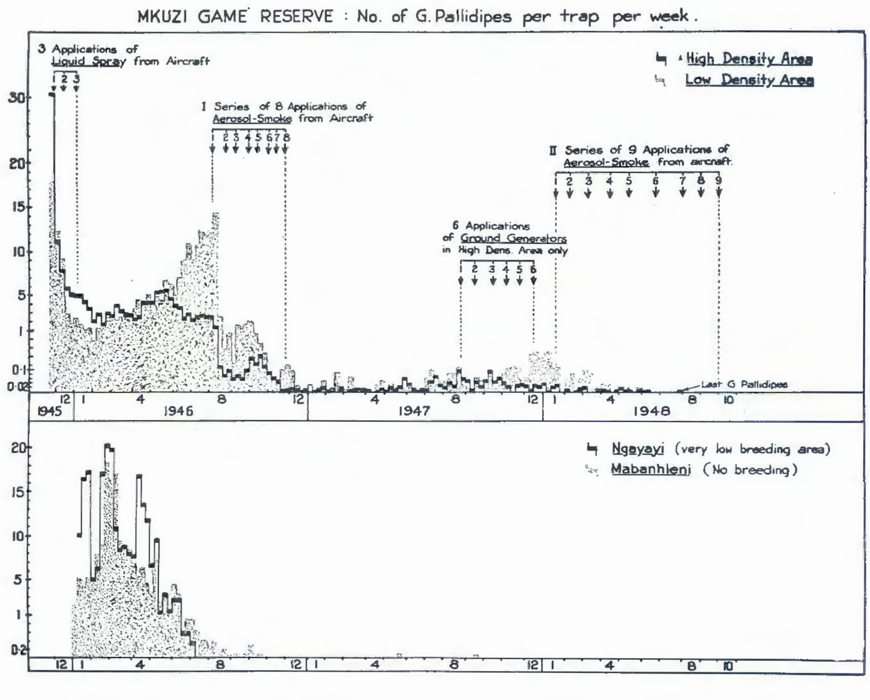


FIG. 11.

2. *The Magut area between the Pongola and Mkuzi rivers west of the Ubombo mountain range, including southern Swaziland.* (*See Maps* 2, 4 *and* 5 *appended*).

The extremely heavy mortality amongst cattle due to Nagana in the area between the Pongola and Mkuzi rivers and in the Mkuzi settlement to the south, which commenced late in 1945 and reached its peak during 1946, necessitated attention to this area at a relatively early stage of the campaign.

Aircraft were diverted from the Mkuzi game reserve whenever opportunity offered and applications of insecticide were undertaken in the densely bush-covered sections of the country to the west of the Ubombo (or Lebombo) mountain range. A schedule of three-weekly intervals between applications was adhered to as far as this was possible. The country is extremely rugged to the west with narrow densely bushed valleys leading into the Pongola and Mkuzi rivers, and it was found impossible to adequately penetrate many of these areas with insecticide in smoke form by means of aircraft.

Combined operations were ultimately resorted to. As has been stated, these comprised applications of insecticide by aircraft, discriminative or thicket clearing, the use of DDT thermal smoke generators, and the use of DDT in dipping tanks.

At the same time aerial applications of insecticide were undertaken in the bush-covered valleys comprising the fly-infested portions of Swaziland.

In the accompanying graph, Figure 12, the total monthly catches of *G. pallidipes* are plotted. The trends in fly reduction for the period 1947 to 1949, as represented by the means between actual catches, are shown in the areas adjacent to and between the Pongola and Mkuzi rivers to the west of the Ubombo range, together with those taken in the infested portion of Swaziland contiguous with this area. Final disappearance of the species occurred in 1949.

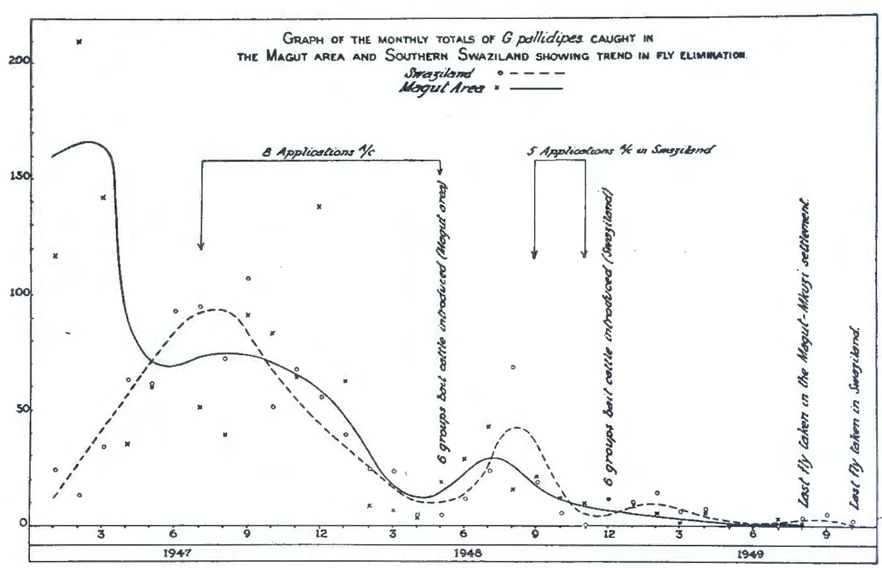


FIG. 12.

The various measures employed in the rugged Pongola-Mkuzi area were responsible for considerable fluctuations in catches. These fluctuations were accentuated by the introduction of bait cattle in six groups of two each into each area, as this improved means of survey had the effect of increasing the apparent density of flies.

It will be noted that in the Swaziland area a minor, but well defined peak in fly incidence took place between June and September 1948. This may be