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The Effects of Helicopter Applied Adulticides for Riverine Tsetse Control on *Simulium* Populations in a West African Savanna Habitat. I. Introduction, Methods and the Effect on Biting Adults and Aquatic Stages of *Simulium damnosum* s.l.

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Abstract. Helicopter applied insecticides used for tsetse control were investigated for their potential to reduce populations of *Simulium damnosum* s.l. in riverine forest in the Guinea savanna zone of southwestern Upper Volta. Populations of aquatic stages and biting females were sampled before and after spraying. Deltamethrin applied at 12·5 g a.i./ha to a 30 km length of riverine vegetation almost eliminated adults for a period of about nine days. Residues which fell into the water killed all larvae in the river. Endosulfan at 100 g a.i./ha applied to a similar stretch of vegetation caused a reduction of over 60% in biting adults for 11 days, but residues falling into the river killed only young larvae. Neither dieldrin at 400 g a.i./ha, endosulfan at 10 g a.i./ha nor deltamethrin at 12.5 g a.i./ha applied to a 5 km insecticide barrier between the experimental blocks and the untreated river appeared to have much effect. This suggests that most *S. damnosum* were traversing the barrier without coming into contact with the insecticides.

Introduction

The WHO Onchocerciasis Control Programme in the Volta River basin (OCP) seeks to reduce the transmission of onchocerciasis by lowering the density of the vector *Simulium damnosum* s.l. (Theobald) to a level where the transmission of the disease is no longer of socioeconomic importance (Davies *et al.*, 1978; Le Berre *et al.*, 1978). To achieve this objective, the aquatic larval stages of the vector are subjected to weekly applications of insecticide to the rivers in which they live. The insecticide is applied by helicopters and fixed-wing aircraft to a maximum of 18,000 km of watercourse in an area of *c.* 764,000 km² (Walsh *et al.*, 1981).

In a large part of the OCP area the results of the first three years of larviciding were satisfactory, but in some places the level of vector control was disappointing due to the invasion of the periphery of the area by adult *S. damnosum* originating from uncontrolled rivers to the south and west (Le Berre *et al.*, 1978). These adults were restricted to the riverine forest of the invaded rivers and did not disperse as far as normal populations (Garms *et al.*, 1979). Attention was therefore directed towards the possibility of applying adulticides in the reinvaded zones, either as placement or space sprays at times of heavy infestations, or to protect areas of high man-fly contact.

Very little has been published on the use of adulticides against *Simulium* in Africa. The first and most notable account was that of Wanson *et al.* (1949) who treated the Congo River (River Zaire) near Leopoldville (Kinshasa) with a fog obtained by injecting DDT in xylene and diesel oil into the exhaust of a fixed-wing aircraft. The vegetation on islands and both banks of the river was treated at a dose of 200 g a.i./ha during the wet season (September to December 1948), resulting in almost a complete kill. Ten years later helicopters were being used in the same area to disperse 4% HCH (McMahon, 1967).

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In the dry season (February to April) of 1955 2% lindane in diesel oil was applied ten times as an aerosol from the exhausts of two helicopters along the river Mayo Kebbi in Chad. As this was combined with manual larviciding operations the effect of the aerial application could not be assessed separately, although the combined operation reduced fly densities to almost zero (Taufflieb, 1955, 1956).

An attempt to control *S. damnosum* from the air (presumably by fixed-wing aircraft) at the Owen Falls near Lake Victoria in 1950 is reported by McMahon (1967). DDT was sprayed along 8 km of river bank at a swath dose of 200 g a.i./ha. The successful results were believed to be largely due to the larvicidal effect of that part of the spray which fell on the surface of the water. This operation is presumably the same as that reported by Prentice (1974) as taking place in January 1951.

In North America, where many of the nuisance species of *Simulium* breed in small forest streams, adulticiding has been more widely employed at times of maximum biting. Some of the earliest successes are described by Jamnback and Collins (1955). Peterson and West (1960) also reported that in 1958 11% DDT in diesel at a dose of 213.6 g a.i./ha 'significantly reduced' biting in the forests of eastern Canada, while in 1956 247 g a.i./ha reduced the number of biting flies for more than ten days. Winmill and Brown (1961), also using DDT, reported an initial 100% control in eight out of 13 operations using 270 g a.i./ha. More recently, in New York State Carestia *et al.* (1975) evaluated aerial applications of malathion and dibrom at 506 g a.i./ha and 112 g a.i./ha, respectively. They decided that the 12.8 km² blocks used for the trials were too small to reduce the effect of reinvasion and considered that areas of the order of 125 to 150 km² would be required in order to obtain meaningful results.

A series of anti-tsetse insecticide trials were carried out in the River Komoe valley, Upper Volta in 1977 by the WHO Applied Research Programme on African Trypanosomiasis Control. The aims of the trials were to test new helicopter application techniques and to screen a number of insecticides. Considerable success was achieved against the riverine *Glossina tachinoides* Westwood using very low dosages (Baldry *et al.*, 1978; Molyneux *et al.*, 1978). A further series of trials was planned for the River Komoe valley in early 1978 and since the site of the trials lay within the OCP area it was decided to monitor their effects on the local *S. damnosum* population. It was accepted that the insecticide applications would be designed to kill tsetse, either by direct knock-down of flying and resting adults or by providing residual deposits on vegetation upon which tsetse would alight. Since both *Glossina* and *Simulium* are diurnal, there seemed to be a reasonable chance that space sprays used for tsetse control might also be effective against *Simulium*.

Methods

Description of the site

A detailed description of the experimental site has been given by Molyneux *et al.* (1978). The trials described below were carried out on the riverine forest of two adjacent 33 km lengths of the River Komoe, called Blocks N (north) and C (central), in the vicinity of Folonzo in the Guinea savanna zone of southwestern Upper Volta (Fig. 1). An insecticidal barrier 5 km in length, designed to prevent the southwards migration of tsetse into the experimental blocks, was located upstream of Block N.

The River Komoe had been treated with temephos* on a weekly basis since February 1975 as part of the OCP routine control effort. No resident larval population existed in the river, but occasionally adult *Simulium damnosum*, thought to be immigrants, were caught at Folonzo ford. In order that a local population could become established to give a sufficient density of flies for adulticide evaluations, larviciding on a 120 km length of the river was stopped at the beginning of October 1977. By the end of December a moderate local population of *S. damnosum* s.l. and some other species had become established, giving biting rates of 30–50 *S. damnosum* s.l. per day at Folonzo ford (Fig. 1). A small sample of larvae collected on 30 December 1977 were all identified cytotaxonomically as *S. damnosum* s. str. Normal routine larviciding recommenced on 12 February 1978 on completion of the adulticide evaluations.

Insecticide applications

Details of the anti-tsetse helicopter spraying programme in the River Komoe valley during 1978 are given by Baldry *et al.* (1981).

The insecticides were applied during January and February 1978 by a Bell 47G-4A helicopter fitted with eight electrically driven rotary atomisers. For the spraying of experimental blocks N and C a unilateral placement

*Abate ®, Cyanamid.

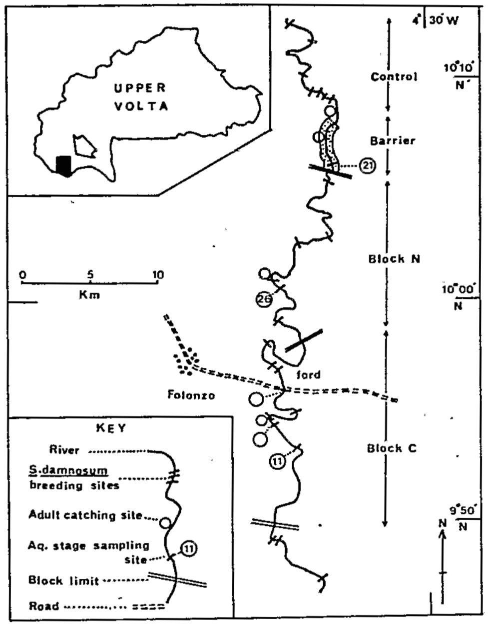

Fig. 1. Map of the experimental area on River Komoe, showing the location of sampling sites and spray blocks.

technique, involving four atomisers on the left boom, of the type described by Baldry *et al.* (1978) was used. The helicopter was flown at 30 km/h, parallel to and 15 m from the inner edge of the riverine fringing forest. The nominal swath was estimated to be *c.* 30 m and the droplet vmd 150 μm. A single spray swath was applied to all forest areas up to a width of 100 m. Larger forest areas received supplementary swaths. Details of the insecticides applied are as follows:

1. Block C
   Hoechst Thiodan, a 25% a.i. oil-based formulation of endosulfan (OMS 570). The insecticide was diluted 1 : 9.7 with diesel oil and applied at a swath dose of 100 g a.i./ha during the morning in the northernmost 8.5 km of the block, and in the evening in the remainder of the block on 28 January 1978.

2. Block N
   Roussel-UCLAF Decamethrin, a 1.5% a.i. oil-based formulation of deltamethrin (OMS 1998). The insecticide was diluted 1 : 2.19 with diesel oil and applied at a swath dose of 12.5 g a.i./ha during the evening of 29 and the morning of 30 January 1978.

3. Barrier
   The same basic unilateral spraying technique was used here except that only three atomisers were employed. The insecticide was Shell Dieldrex 20, a 20% a.i. e.c. of dieldrin (OMS 0018). It was diluted 1 : 1 with Shellsol-A and applied at a swath dose of 400 g a.i./ha during the morning of 27 January 1978.

The barrier was reinforced on 29 January and on 1 February 1978. A space rather than a placement technique was used on 29 January to apply endosulfan. The unilateral technique involved only two atomisers which were rotated at high speed (15,000 instead of 7000 rev/min) in order to produce a droplet vmd of *c.* 40 μm. The helicopter was flown along the inner edge of the forest at 40 km/h and produced a swath dose of 10 g a.i./ha. On 1 February the technique employed was identical to that used in experimental block N.

The insecticides were normally applied during periods of temperature inversion while there was sufficient light to fly the aircraft. Applications began at 0630 h or at 1730 h local time.

Estimation of densities of aquatic stages of Simulium damnosum *s.l.*

Larval and pupal densities of *S. damnosum* were recorded as often as feasible, when densities of young larvae (I), mature larvae (L) and pupae (P) were estimated qualitatively on a scale reading from 0 = absent to 3 = very abundant. At the time of the experiment water levels were very low and each breeding site consisted of only one or two small cascades. Between the breeding sites there were long stretches of deep, still or sluggish water.

The sites are indicated in Fig. 1. Since checks had to be made at breeding sites which were accessible and adjacent to catching stations they were unevenly distributed in the experimental blocks. Both the barrier and Block N were sampled at one site each, while Block C was sampled at three sites.

Estimation of densities of biting Simulium damnosum *s.l.*

The populations of biting female *S. damnosum* were estimated by making human bait catches (0700 h to 1800 h local time) at three points sited in blocks N and C and the barrier (Fig. 1). A fourth, control site was added 2 km upstream of the end of the barrier to sample an untreated area and to estimate the population density immediately adjacent to the sprayed stretch of river.

Catches were made by two vector collectors working one hour each alternatively. The flies were caught individually in plastic tubes, recorded by hour of capture, and dissected alive at the end of each day for age-grading by the technique described by Lewis (1958).

Results

Aquatic stages

The results of all searches for aquatic stages of *Simulium damnosum* s.l. are set out in Table 1.

TABLE 1. RESULTS OF SURVEYS FOR AQUATIC STAGES OF *SIMULIUM DAMNOSUM* S.L.

Date	Barrier			Block N			Block C								
	Site 21			Site 26			Ford			Centre			Site 11		
	I	L	P*	I	L	P	I	L	P	I	L	P	I	L	P
Jan 27	dieldrin														
	3	3	3	1	1	3									
28							endosulfan			endosulfan			endosulfan		
	3	3	0	2	2	0				0	1	0	3	3	0
29	endosulfan			deltamethrin											
													0	2	0
30				deltamethrin											
31	0	3	3	0	0	2	3	3	3	0	0	0			
Feb 1	deltamethrin														
	0	(3)	3	0	0	0	0	2	2	0	0	0			
2	0	(1)	2	0	0	1				0	0	0			
3	0	0	2	0	0	0	0	2	2						
4	0	0	1	0	0	0	0	2	2						
5	0	0	0	0	0	0				1	0	0	0	2	2
6	0	0	0	0	0	0	0	0	0				0	1	1
7	0	0	0	0	0	0							0	1	1
8	0	0	0	0	0	0				0	0	0	0	1	2
9	0	0	0	0	0	0							0	1	1
10	0	0	0	0	0	0							0	1	1
11	0	0	0	0	0	0							0	1	1

*I = young larvae; L = old larvae; P = pupae.
Rating: 0 = absent; 1 = scarce; 2 = moderate; 3 = abundant.
Figures in parentheses represent dead larvae.

1. Block C (endosulfan at 100 g a.i./ha)

Pre-treatment checks made at Site 11 indicated fair numbers of young and old larvae. The day following spraying, only old larvae could be found at Site 11 and at the catching station, while two days later all stages were present at the ford. The insecticide appears to have been lethal only to young larvae since old larvae and pupae were found at the ford and at Site 11 on nearly every day that post-treatment checks were made.

2. Block N (deltamethrin at 12.5 g a.i./ha)

Checks at Site 26 showed moderate to low numbers of both young and old larvae as well as pupae on the two days before spraying. After spraying no further larvae could be found. Pupae were present up to three days after the spraying and absent thereafter.

3. Barrier (dieldrin, endosulfan and deltamethrin)

Following the dieldrin application, pupae and young and old larvae were found at Site 21. After endosulfan, the young larvae disappeared and after the deltamethrin application only dead larvae were found. Pupae disappeared the third day after the deltamethrin spray.

Biting females

Daily total catches of *Simulium damnosum* s.l. and their parous rates at each of the four catching stations are given in Fig. 2. Observations began on 24 January and ended on 17 February 1978, except for 13 February when no catches were made.

1. Control site

The three days before the first insecticidal application on the adjacent barrier gave an average daily catch of 104.6 *S. damnosum* s.l. per man-day with a parous rate of 78%. On 27 January, when the barrier was treated with dieldrin, the parous rate rose to 93% and thereafter fluctuated between 83 and 100%. Adult densities remained constant at about 100 per man-day until 10 February when catches were depressed for two days. Observations at this point ended on 12 February. It is possible that the drop in density and increase in parous rate observed on 27 January were due to a reduction in nullipars migrating upstream from the barrier treated that day, but in spite of this, it is considered that those catches provided a satisfactory standard against which the results of the spraying could be judged.

2. Block C (endosulfan at 100 g a.i./ha)

The mean catch of 30 flies per man-day recorded for the three days before spraying was reduced to 8.7 per man-day for the first three post-spraying days, falling to 1 per man-day on 1 February, the fifth post-spray day. At the same time parous rates rose from about 80 to 100%. Mostly parous flies were then caught at densities of less than 10 per man-day until 9 February when an increase in biting to 13 per man-day, of which half were nullipars, suggested an onset of breeding in the vicinity of the catching point. It was tentatively concluded that the application of endosulfan reduced the initial population of hungry *S. damnosum* s.l. to about 30%. The continuing decline in catches suggested that flies were resting on vegetation which supported endosulfan deposits.

3. Block N (deltamethrin at 12.5 g a.i./ha)

Catches for the three days before spraying showed an average biting density of 23.7 flies per man-day, with parous rates of 93 and 96% on the two days that they were determined. Zero catches were obtained for four consecutive days after spraying, after which three parous flies were taken. They were probably immigrants. Two of five flies caught on 8 and 9 February were nullipars, coinciding with the nullipars taken in Block C and suggesting that breeding was taking place nearby and that the insecticide had no persistent effect.

4. Barrier (dieldrin, endosulfan and deltamethrin)

The residual application of dieldrin on 27 January had no apparent effect on the number of biting *S. damnosum* s.l. taken at the barrier catching station. The only apparent change was a small drop in the parous rate (87 to 76%) which was within the range of normal daily variation. Because of the apparent ineffectiveness of dieldrin, endosulfan was applied as a space spray at 10 g a.i./ha on the morning of 29 January. Again there was no immediate effect and following day biting densities almost doubled. Unfortunately, no control data were collected for these three days so it was not known how this situation compared which had been observed in Block N. Catches dropped from 280 to 1 February in an attempt to confirm the effect with had been observed in Block N. Catches dropped from 280 to 156 per man-day and then remained constant at about 180 per man-day. Parous rates remained high, varying between 90 and 100%.

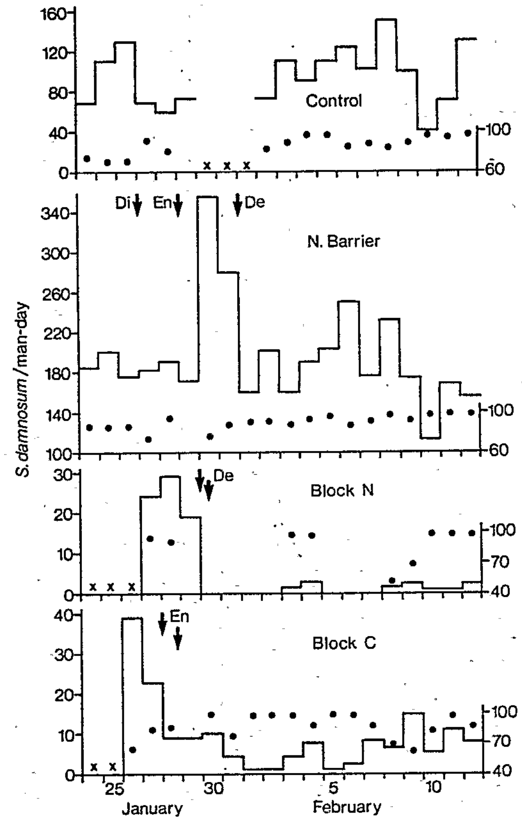

Fig. 2. Numbers of adult female *Simulium damnosum* s.l. caught on human bait per man-day at the four catching stations. Parous rates are shown by dots; insecticide applications are shown by arrows: Di = dieldrin, En = endosulfan, De = deltamethrin.

Conclusion

Subject to the limitations imposed by the low adult *Simulium damnosum* s.l. populations in Blocks N and C, and the sudden increase in fly densities on the barrier on 30 and 31 January, the following conclusions can be drawn:

Deltamethrin applied to 30 km of riverine vegetation at 12.5 g a.i./ha almost eliminated all adult *S. damnosum* s.l. for a period of about nine days. It also killed all *S. damnosum* larvae in the river.

Endosulfan applied to 30 km of riverine vegetation at 100 g a.i./ha appeared to cause over 60% reduction in biting *S. damnosum* s.l. for 11 days. The residues which fell into the water killed only young larvae.

Both dieldrin and endosulfan when applied to 5 km of riverine vegetation (the barrier) appeared to have no effect on biting densities of *S. damnosum* s.l., although in the case of endosulfan this may have been due to the lower rate of application when compared to Block C. Deltamethrin applied to the same vegetation was followed by about a 50% drop in biting flies. It seems probable that most *S. damnosum* caught on the barrier were traversing the 2.0 km between the untreated area and the catching point without being affected by the insecticides.

Further observations made on other *Simulium* species and on non-biting stages of *S. damnosum* s.l. will be given in Part II of this series (Bellec *et al.*, in press). Final conclusions will be made in Part III (Davies *et al.*, in press).

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