Conclusions

A comparison with the catches of *S. damnosum* on human bait (Davies *et al.*, 1982) shows that with the deltamethrin application in Block N a similar pattern was observed for biting females, gravid and non-gravid females. The application was followed by zero catches on the day of treatment. Recovery was slow, but because of the low numbers it is not clear whether it was due to any residual effect of the insecticide.

After the application of endosulfan in Block C biting *S. damnosum* densities fell to nearly one third, stayed at this level for three days and then decreased further until the tenth day when a recovery began. In contrast, catches on the plaque traps did not fall until the second day after spraying. At no time were any of the collections reduced to zero.

The situation on the barrier is confused, probably because of the influx of *Simulium* from the untreated river upstream. Dieldrin had no immediate effect on *S. damnosum* but might have killed gravid *Simulium* of other species on the day of application only. The effect of endosulfan here was also limited, and deltamethrin did not show the dramatic reduction in flies demonstrated in Block N. It is possible that *Simulium* of all species were traversing the short length of the barrier as far as the traps without coming into contact with the insecticide.

Final conclusions on these experiments are given in the third paper of this series (Davies *et al.*, 1983).

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References

BELLEC, C. (1976) Captures d'adultes de *Simulium damnosum* Theobald, 1903 (Diptera, Simuliidae) a l'aide de plaques d'aluminium, en Afrique de l'Ouest. *Cahiers de l'Office de la Recherche Scientifique et Technique Outre-Mer* (Série Entomologie Médicale et Parasitologie) 14 (3): 209–217.

DAVIES, J. B., GBOHO, C., BALDRY, D. A. T., BELLEC, C., SAWADOGO, R. and TIAO, P. C. (1982). 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. *Tropical Pest Management* 28 (3): 284–290.

DAVIES, J. B., WALSH, J. F., BALDRY, D. A. T. and BELLEC, C. (1983). The effects of helicopter applied insecticides for riverine tsetse control on *Simulium* populations in a West African savanna habitat. III. Conclusions: the possible role of adulticiding in onchocerciasis control in West Africa. *Tropical Pest Management* 29 (1): 13–15.

QUILLÉVÉRÉ, D., SÉCHAN, Y. and PENDRIEZ, B. (1977). Étude de complexe *Simulium damnosum* en Afrique de l'Ouest. V. Identification morphologique des femelles en Côte d'Ivoire. *Tropenmedizin und Parasitologie* 28: 244–253.

Tropical Pest Management 29 (1): 13–15

The Effects of Helicopter Applied Adulticides for Riverine Tsetse Control on *Simulium* Populations in a West African Savanna Habitat. III. Conclusions: the Possible Role of Adulticiding in Onchocerciasis Control in West Africa

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Abstract. The partial success of applications of dieldrin, deltamethrin and endosulfan for tsetse control in also reducing populations of *Simulium* spp. in a riverine Guinea savanna habitat in Upper Volta has been established. However, there is insufficient information available concerning the resting sites of adult *Simulium* to determine the best location of spray swaths to achieve the maximum effect. Further trials based on knowledge of the biology of adult *Simulium* could improve the success of the technique for blackfly control. It is suggested that localised adulticiding in onchocerciasis control schemes could be effective, particularly where a high level of reinvasion causes unacceptable levels of disease transmission for short periods of the year.

Introduction

Applications of endosulfan and deltamethrin by helicopter to 30 km lengths of the Komoe river and dieldrin to a 5 km length of the river in Upper Volta during the dry season of 1978, as part of a series of trials to determine their effect on the tsetse fly *Glossina tachinoides* Westwood, have been described by Baldry *et al.* (1981). The effect of a single application of these insecticides on biting adults and aquatic stages of *Simulium damnosum* Theobald has been described by Davies *et al.* (1982), and the effect on other physiological stages of *S. damnosum* s.l. and other species of *Simulium* caught on aluminium plaque traps is given by Bellec *et al.* (1983).

In these studies it was not possible to assess the persistent effect of the insecticide on biting *S. damnosum* because in some cases the residues which fell into the river killed all the larvae, thereby interrupting the production of newly emerged adult flies. There was evidence to suggest that flies were traversing a 5 km insecticide barrier into the sprayed area. However, of the three insecticides applied, deltamethrin applied at 12.5 g a.i./ha had the greatest effect and considerably reduced the biting population of flies for four days.

Discussion

In considering the effects of the insecticide applications it is important to remember that the spraying was specifically designed to kill tsetse, using a refined technique against a pest whose life cycle and biology was well known. The target species, *G. tachinoides*, produces a single larva in each gonotrophic cycle, which develops *in utero* and is only briefly exposed to the environment before pupating below ground. The adult rests on vegetation at sites which are relatively restricted.

In contrast, *S. damnosum* s.l. is highly fecund, producing 400 to 900 eggs per cycle with aquatic larval and pupal stages. Little is known of the habits of the adult female between the times of blood feeding and oviposition.

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The trials took place in the dry season when foliage is reduced and *G. tachinoides* is confined to the riverine vegetation where it is most easily controlled by insecticides. Spraying was limited to the morning and evening, when temperatures were below 30°C and wind speeds less than 0.5 m/s, in order to reduce loss by drift and convection. As a result, the helicopter was restricted to treating about 30 km of river per day (Baldry *et al.*, 1981). The spray swath was estimated to have a width of 30 m and was applied 15 m from the river bank.

Data on the resting sites of *S. damnosum* s.l. are very sparse. However, recent studies (Bellec and Hebrard, 1980) indicate that resting flies may be found at all levels in the vegetation up to at least 100 m from breeding sites in rivers. At Vea Dam in northern Ghana, gravid *S. sirbanum* Vajime & Dunbar collected in large numbers on the riverine vegetation about one hour before oviposition, and some gravid females were taken on a sticky trap at a height of 9.2 m in a tree 106 m from the water's edge (Walsh, 1972). That the Vea Dam observations are not exceptional is supported by the trapping of flies on sticky traps placed in trees at heights above 6 m at three other sites by the White Volta river and one on the Red Volta river, both in Ghana. Davies (1962) working in northern Nigeria had earlier described how, about one hour before sunset, gravid flies were found resting on riverine vegetation in a manner very similar to that seen at Vea. Before that, Crisp (1956) collected large numbers of *S. damnosum* by sweep netting riverine vegetation at the confluence of the Kamba and Black Volta rivers in Ghana. These catches included males, which suggests that they did not just consist of potential biting flies attracted to the collectors. It is probable that migrant flies do rest in the vicinity of oviposition sites both before and after oviposition. The build-up of peaks of immigrant biting flies over two or three days suggests that these flies are in the area for some time before they begin to bite (Garms *et al.*, 1979), and Bellec (personal communication) caught large numbers of gravid flies on aluminium plaque traps before the peak in numbers occurred on human bait.

A recent but as yet unpublished study by G. Zerbo and S. A. Sowah (personal communication) has shown that the majority of immigrant, invading *S. damnosum* are found biting less than 100 m from the river bank, and at 1 km densities may still be of the order of 10% of those at the river. This estimate was based on catches of biting females.

Garms *et al.* (1979) and Walsh *et al.* (1981) have shown that in the rainy season part of the Onchocerciasis Control Programme (OCP) area is invaded by the 'savanna' cytospecies of *S. damnosum* s.l., already infected with *Onchocerca volvulus* (Leuckart) in sufficient numbers to ensure the transmission of onchocerciasis in spite of the elimination of local populations by larviciding. The areas particularly at risk are sections of the rivers of Mali and Ivory Coast adjacent to the frontier of Guinea. The same situation may exist along part of the eastern boundary of Benin, although there is some evidence that fly movements occur in a predominantly westerly direction. These authors have also shown that at such sites *Onchocerca* transmission by invading flies reaches unacceptable levels for about three months during each wet season. An adulticiding regime that ensured a high mortality of invading *S. damnosum* before they had a chance to feed, and thus preventing disease transmission, would therefore be a very attractive proposition and might be considered for areas of particularly close man-fly contact. It is envisaged that in such areas the larviciding regime would continue as normal and that adulticiding would be carried out whenever transmission was shown to be reaching dangerous levels.

Although older flies, and in the dry season all flies, seem reluctant to bite at long distances from river banks (Le Berre, 1966; Duke, 1975), their movements along rivers are likely to be substantial (Thompson, 1976; Davies *et al.*, 1981). Therefore, further trials should be made using not only wider swath widths, or several swaths on each bank, but also on experimental blocks of 30 km or more in length in order to minimise immigration from untreated areas. Blocks of this size would almost certainly preclude the possibility of spraying from the ground, if persistence is short.

The frequency of application would depend on the persistence of the insecticide used. In the wet season, suitable meteorological conditions for spraying would probably exceed one hour in the morning and evening but, even so, adulticiding would probably need to be limited to the beginning and end of the day. Evening spraying is likely to be more efficient, given the concentration of oviposition activity towards dusk. However, most daylight hours could be used for normal anti-*Simulium* larviciding, which is not affected by air temperature. In this way, a single helicopter could possibly fulfil a dual role.

The authors are aware that such a dual role depends on the selection of an insecticide that is persistent against adult *Simulium*, and is acceptable environmentally. It may also be necessary, as indicated above, to develop special techniques for spraying against *S. damnosum* s.l., remembering that if such techniques should also prove to be effective against tsetse a double objective would be achieved.

Baldry *et al.* (1981) reported that insecticide applications caused considerable mortality of the vertebrate and invertebrate river fauna. It may prove possible to reduce the adverse effects of the insecticides by moving the spray swath further away from the river bank. Otherwise, it will have to be decided whether such non-target mortality over comparatively short lengths of river, which could be rapidly repopulated from up- or down-stream, is acceptable.

Conclusion

It is concluded that the results of the anti-tsetse adulticide trials described in this series of papers were sufficiently encouraging to warrant further trials directed specifically against *S. damnosum* s.l.

To ensure that the results will not be confused by the mortality of aquatic stages, the trials should be conducted in an area in which larval control is effective but where the numbers of invading flies are sufficient to ensure a constant influx of adults to test the residual effect of the insecticide deposits. Such areas already exist in the OCP area.

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References

BALDRY, D. A. T., EVERTS, J., ROMAN, B., BOON VON OCHSEE, C. A. and LAVEISSIERE, C. (1981). The experimental application of insecticides from a helicopter for the control of riverine populations of the tsetse fly *Glossina tachinoides* in West Africa. VIII. The effects of two spray applications of OMS-570 (endosulfan) and of OMS-1998 (decamethrin) on *G. tachinoides* and non-target organisms in Upper Volta. *Tropical Pest Management* 27: 83–110.

BELLEC, C. and HEBRARD, G. (1980). Les lieux de répos des adultes du complexe *Simulium damnosum* (Diptera : Simuliidae). 2. Etude de la distribution spacio-temporelle. *Cahiers de l'Office de la Recherche Scientifique et Technique Outre-Mer* (Série Entomologie Médicale et Parasitologie) 18 (3): 277–289.

BELLEC, C., HEBRARD, G. and D'ALMEIDA, A. (1983). The effects of helicopter applied insecticides for riverine tsetse control on *Simulium* populations in a West African savanna habitat. II. Effects as estimated by non-biting stages of *Simulium damnosum* s.l. and other blackfly species caught on aluminium plaque traps. *Tropical Pest Management* 29 (1): 7–12.

CRISP, G. (1956). *Simulium and onchocerciasis in the Northern Territories of the Gold Coast.* Lewis, London. pp. 171.

DAVIES, J. B. (1962). Egg-laying habits of *Simulium damnosum* Theobald and *Simulium hargreavesi* Gibbins in northern Nigeria. *Nature* 196 (4850): 149–150.

DAVIES, J. B., GBOHO, C., BALDRY, D. A. T., BELLEC, C., SAWADOGO, R. and TIAO, P. C. (1982). 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. *Tropical Pest Management* 28 (3): 284–290.

DAVIES, J. B., SEKETELI, A., WALSH, J. F., BARRO, T. and SAWADOGO, R. (1981). Studies on biting *Simulium damnosum* s.l. at a breeding site in the Onchocerciasis Control Programme area during and after an interruption of insecticidal treatment. *Tropenmedizin und Parasitologie* 32: 17–24.

DUKE, B. O. L. (1975). The differential dispersal of nulliparous and parous *Simulium damnosum*. *Tropenmedizin und Parasitologie* 26: 88–97.

GARMS, R., WALSH, J. F. and DAVIES, J. B. (1979). Studies on the reinvasion of the Onchocerciasis Control Programme in the Volta River basin by *Simulium damnosum* s.l. with emphasis on the south-western areas. *Tropenmedizin und Parasitologie* 30: 345–362.

LE BERRE, R. (1966). Contribution a l'étude biologique et écologique de *Simulium damnosum* Theobald, 1903 (Diptera: Simuliidae). *Mémoires de l'Office de la Recherche Scientifique et Technique Outre-Mer* 17: pp. 204.

THOMPSON, B. H. (1976). Studies on the flight range and dispersal of *Simulium damnosum* (Diptera: Simuliidae) in the rain forest of Cameroon. *Annals of Tropical Medicine and Parasitology* 70: 343–354.

WALSH, J. F. (1972). *Observations on the resting of* Simulium damnosum *in trees near a breeding site in the West African savanna.* (WHO/ONCHO/72.99) World Health Organization, Geneva. pp. 4.

WALSH, J. F., DAVIES, J. B. and GARMS, R. (1981). Further studies on the reinvasion of the Onchocerciasis Control Programme by *Simulium damnosum* s.l.: the effects of an extension of control activities into southern Ivory Coast during 1979. *Tropenmedizin und Parasitologie* 32: 269–273.