virus. Amer. J. Trop. Med. Hyg. 18(5):762–767.
Kokernot, R.H., J. Hayes, R.L. Will, C.H. Tempelis, D.H.M. Chan and B. Radivojevic. 1969e. Arbovirus studies in the Ohio-Mississippi Basin, 1964–1967. II. St. Louis encephalitis virus. Amer. J. Trop. Med. Hyg. 18(5):750–761.
Lumsden, L.L. 1958. St. Louis encephalitis in 1933. Publ. Hlth Repts. 73(4):340–353.
Nero, R.W. 1951. Pattern and rate of cranial ossification in the house sparrow. Wilson Bull. 63:84–88.
Rivers, T.M. 1952. *Viral and rickettsial infections of man.* J. B. Lippincott Co., Phila. 2nd Ed. 719 pp.
Rubin, R.H., T.H. Glock and N.J. Rose. 1970. St. Louis encephalitis in Saline County, Illinois. 1968. J. Infect. Dis. 122(4):347–353.
Sever, J.L. 1962. Application of a microtechnique to viral serological investigations. J. Immunol. 88:320–329.
Sudia, W.D. and R.W. Chamberlain. 1967. Collection and processing of medically important arthropods for arbovirus isolation. CDC, PHS, USDHEW, Atlanta. 65 pp.
Sudia, W.D., R.O. Lord and R.O. Hayes. 1970. Collection and processing of vertebrate specimens for arbovirus studies. CDC, PHS, USDHEW, Atlanta. 29 pp.
Thompson, W.H., R.O. Anslow, R.P. Hanson and G.R. DeFoliart. 1972. La Crosse virus isolations from mosquitoes in Wisconsin. 1964–1968. Amer. J. Trop. Med. Hyg. 21 (1): 90–96.
Watts, D.M., S. Pantuwatana, G.R. De Foliart, T.M. Yuill and W.H. Thompson. 1973. Transovarial transmission of La Crosse virus (California encephalitis group) in the mosquito. *Aedes triseriatus.* Science 182: 1140–1141.

CONTROL OF *MANSONIA* SPECIES IN GABON USING ULV PYRETHROIDS

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ABSTRACT. A field trial was carried out on Lambaréné island, Gabon, against *Mansonia* spp. with ultra low volume applications of Reslin 15S, a synthetic pyrethroid formulation containing 2.0% w/v S-bioallethrin ((+)-*trans* chrysanthemic ester of (+)-allethrolone) and 13.0% w/v bioresmethrin ((+)-*trans* chrysanthemic ester of 5-benzyl-3-furyl-methanol) applied with a Leco® HD cold aerosol ULV generator. The level of control was determined by bait catches at fixed sites. The treatments gave very high immediate kill of adult mosquitoes and, although penetration into the main breeding sites of the ULV mist was hampered by physical conditions, the level of control obtained during the trial was better than expected from a *Mansonia* spp. population model incorporating a similar spraying regime.

INTRODUCTION

Lamberéné island situated on the River Ogooué in the Moyen Ogooué region of Gabon, some 200 km southeast of the capital Libreville is an area of endemic malaria. The main transmitters are *Anopheles gambiae* Giles and *An. funestus* Giles (WHO 1974). The original purpose of the trial was to determine the level of control of *An. gambiae* by ultra low volume applications of Reslin 15S, a synthetic pyrethroid formulation, containing S-bioallethrin ((+)-*trans* chrysanthemic ester of (+)-allethrolone) and bioresmethrin ((+)-*trans* chrysanthemic ester of 5-benzyl-3-furyl-methanol) using a ground-based ULV generator. For reasons which are not clear the *An. gambiae* density at the time the trial commenced was extremely low, (end of

January) although potential breeding sites were plentiful and progressively increased with the onset of the rainy season (February-May).

The synthetic pyrethroids have been used for some time in ULV formulations to control flying insects of public health importance. Mahdi et al. (1976) working in Cairo demonstrated that ground-based ULV applications of bioresmethrin at 10 g/ha gave 96–99% control of the house fly *Musca domestica* L. The once daily ULV application carried out for 15 consecutive days interrupted the life cycle of *M. domestica* allowing a maintenance control regime to be introduced.

In general, mosquito species are more susceptible than Muscids to synthetic pyrethroids. Brooke et al. (1974) obtained 88–92% control of *Aedes taeniorhynchus* Wied. on Grand Cayman island with 1.5 g of bioresmethrin in 50 ml of diesel oil per hectare dispersed from the ground as a ULV aerosol. ULV applications of bioresmethrin applied from the air at only 3 g/ha have also been found to give a high level of control of *Ae. taeniorhynchus* on Grand Cayman (Lee and Giglioli 1974).

MATERIALS AND METHODS

STUDY AREA. The town of Lambaréné with a population of approximately 10,000 is located on the eastern tip of the island, spreading to both banks of the mainland (Figure 1). The urban area on the island comprising 285 hectares was selected as the trial site. The greater part of urban Lambaréné is situated on two hills with the dominant vegetation being palm and ookumé trees. On either side of the western hill are swamps composed mainly of papyrus and mangrove. The roads were unmetalled with the exception of the main highway linking the two bridges over the river and the road along the southern shore.

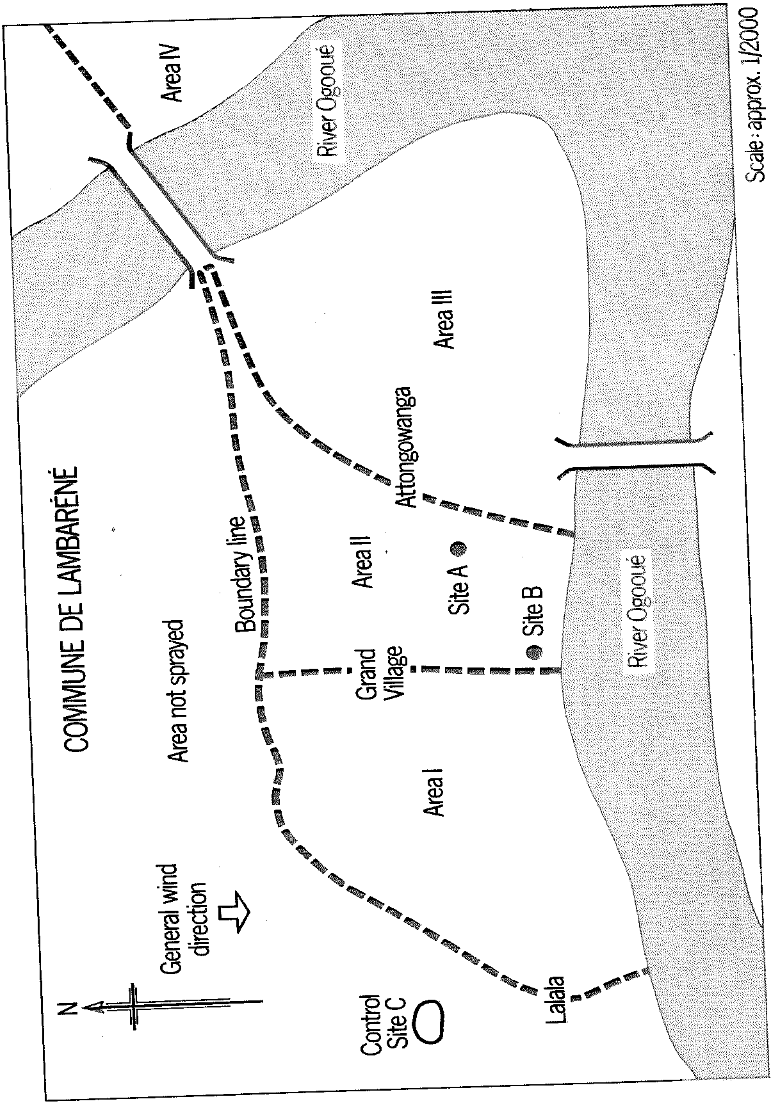
SPRAYING OPERATIONS. The spraying equipment used was a Leco® HD ULV generator mounted on a Landrover with the control panel installed in the driver's cab allowing the operation to be carried out by one man. A Leco Mini ULV generator was also used in an area of restricted access. The insecticide used was Reslin 15S composed of 2% w/v S-bioallethrin, 13% w/v bioresmethrin and 15% w/v piperonyl butoxide. This was diluted for use at the rate of 1 + 6.5 w/v with diesel oil. The small quantity of S-bioallethrin in the formulation is believed to cause rapid irritation to resting *Musca* sp. stimulating rapid flight and, therefore, greater pick-up of the major killing pyrethroid bioresmethrin (Mason et al. 1977).

The trial site was divided into three areas (see Figure 1) with a further area of boundary spraying on the northern bank of the mainland. The area (Area 11) containing the major breeding sites was treated at 10 g total pyrethroids per hectare, i.e. 500 ml of diluted insecticide, and the other areas at 5 g total pyrethroids per hectare. The spraying route in each area was planned with regard to the available road access and the prevailing wind direction. The Leco HD ULV generator was calibrated to deliver 550 ml/min. The spraying time to deliver the required dosage/hectare was calculated for each area.

Area 1	105 hectares, application rate 5 g/ha spraying time 47.7 min, 7 km spraying route.
Area 11	60 hectares, application rate 10 g/ha, spraying time 54.5 mins, 4 km spraying route.
Area 111	120 hectares, application rate 5g/ha, spraying time 54.4 min, 6 km spraying route.
Area IV	80 hectares, application rate 5g/ha, spraying time 36.4 min, 4 km spraying route.

The vehicle speed was then determined from the measured spray routes. This varied between 5–10 k.p.h. To improve coverage, stationary spraying was also carried out for several minutes at points where penetration of the ULV mist was

FIGURE 1. TRIAL LOCATION SHOWING SAMPLING SITES



better. Treatments started at dusk and the total spraying time for the four areas (365 ha) with stops for re-filling of the reservoir tank was slightly under 3.5 hrs. Temperatures during the sprayings ranged between 27–31°C and relative humidity between 70–91%.

In the original trial protocol, it had been intended to carry out a minimum of 10 ULV applications at 2-day intervals which, as proposed by Brooke et al. (1975) using an *An. gambiae* population model, would theoretically be sufficient to reduce the breeding potential of this species in the area to very low level.

Even though the *An. gambiae* population was low, it was decided to follow the protocol and assess the efficacy against the predominant species present. However, penetration of the ULV mist into Area 11 was particularly poor. Additional treatments with the Leco HD ULV machine were, therefore, carried out in Area 11 and also the Leco Mini ULV generator was situated at Site A, the lowest point in the area and on occasions 4.5 l of diluted insecticide (0.6 g a.i.) were applied to the surrounding area. The treatment schedule is shown in Table I.

ENTOMOLOGICAL EVALUATION. A preliminary survey to establish the species type and localised densities was carried out at various locations on the island and both banks of the mainland. Bait catches, CDC light traps (Sudia and Chamberlain 1962) and Monks Wood light traps (Service 1970) were all used during the survey. It was established that *Mansonia uniformis* and *Ma. africana* were the only species present in sufficient numbers for the collation of presentable data.

Insecticide susceptibility tests were carried out using the WHO field test kit for adult susceptibility, using papers impregnated with different concentrations of bioresmethrin, DDT and malathion. *Mansonia* spp. were found to be susceptible to all 3 insecticides. During the preliminary survey two sites, A and B both in Area 11, were selected for monitoring the efficacy of treatments and a third Site C approximately 1.5 km outside the trial site and upwind of the prevailing wind direction was chosen as the control site. (Fig. 1).

Bait catches gave the most accurate determination of *Mansonia* spp. densities. These were carried out at the designated sites between 21–22.30 hrs. at 1–2 day intervals throughout the trial. The number of operators involved varied from 1 to usually 2 and this number was sometimes accompanied by assistance from local residents. The number of *Mansonia* spp. captured per hr. per site was recorded. No attempt was made to differentiate between the numbers of *Ma. uniformis* or *Ma. africana*. The majority of *Mansonia* spp. captured were dissected to determine the parity rate using the tracheole technique (Beklemishev et al. 1959).

RESULTS AND DISCUSSIONS

The trial commenced with the onset of the rainy season (end of January), and the rain which came every 2–3 days continually plagued post-treatment assessment. From the numbers of *Mansonia* spp. caught at the control site (see Table I) it is evident that the onset of these conditions led to a marked increase in the mosquito population.

ULV ground applications of Reslin 15S undoubtedly gave a very high immediate kill of adult mosquitoes. No *Mansonia* spp. were caught at bait immediately after the first treatment. On the following night no bait catches were made due to wind and rain, but on the night after the 2nd spraying a large number of *Mansonia* spp. were captured, i.e. 60 per hr at Site A and 24 per hr at Site B. It was felt that these high counts were due to inadequate penetration of the insecticide into Area 11 and that undoubtedly the spray cloud was reaching only a small proportion of the adult population. This was confirmed when an hourly rate of 35 *Mansonia* spp. were present in a bait catch at Site A during the time of the 3rd spraying. The poor penetration was due to the fact that access into the area which was mainly swamp was very limited and the prevailing wind con-

Table 1. Numbers of *Mansonia* spp. captured by bait catches

Key: a = spray carried out in Area II only
r = catch affected by rain
R = catch cancelled because of rain.

* Additional spraying with Leco Mini.

Date	Spray No.	Nights on which rain fell	Numbers captured per hour per site		
			Site A	Site B	Site C Control
21.1.76			57	—	—
22.1.76			18	—	—
23.1.76			—	—	—
24.1.76			—	—	—
25.1.76			—	—	33
26.1.76			—	23	—
27.1.76			—	22	—
28.1.76			85	—	29
29.1.76			—	45	—
30.1.76			—	21	—
		Average Pretreatment	53	28	—
31.1.76	1		—	O	—
1.2.76		Rain	—	R	R
2.2.76	2		—	O	28
3.2.76			60	24	—
4.2.76	3		35	—	—
5.2.76		Rain	—	R	—
6.2.76	4*		—	—	92
7.2.76	4a*		—	—	—
8.2.76	5*		1	O	—
9.2.76	5a		—	O	83
10.2.76	6	Rain	8	17	—
11.2.76	6a*		—	1	75
12.2.76	7		1	9	—
13.2.76	7a	—	—	—	—
14.2.76	8*		2	—	—
15.2.76		Rain	R	R	—
16.2.76	9*		8	—	98
17.2.76			2	4	—
18.2.76	10*	Rain	1r	—	8r
19.2.76			—	O	28
20.2.76	11*		O	—	—
21.2.76		Rain	R	R	—
22.2.76			—	7	21
23.2.76	12*		O	—	—
24.2.76			—	7	—
25.2.76		Rain	33r	54r	—
26.2.76	13*		16	—	—
27.2.76		Rain	R	R	—
28.2.76			11	15	—
29.2.76	13a*		—	—	—
1.3.76			10	13	—
2.3.76			12	17	—

Table 2. Population model of female *Mansonia* spp.

Time in Days	Instar No.	Egg 1	Larvae 2	Pupa 3	Adult 4	* Adult 5	Adult 6	* Adult 7	Adult 8	* Adult 9	Adult 10	* Adult 11	Adult 12	* Adult 13	Adult 14	* Adult 15	Total Adult Instar
	Day No.	1–6	7–27	28–31	32–35	36	37–39	40	41–43	44	45–47	48	49–51	52	53–55	56	
	Daily Survival	0.891	0.864	0.864	0.795	0.841	0.841	0.841	0.841	0.841	0.841	0.841	0.841	0.841	0.841	0.841	
	Treatment No.																
0		360421	273651	5899	2958	403	866	200	428	100	214	50	107	25	54	12	5417
1	1	301950	273649	5899	1497	101	216	51	107	25	54	13	27	6	13	3	2113
5	3	82400	274439	5899	1402	25	14	3	7	2	3	1	2	0	1	0	1460
10	5a	6900	165791	5899	1258	22	0	0	0	0	0	0	0	0	0	0	1262
20	–	5825	30187	5899	1282	6	7	0	0	0	0	0	0	0	0	0	1295
30	13a	36803	10139	2042	2124	101	54	3	5	2	2	8	7	0	0	0	1854

* Adults laying 100 egg per day.

To achieve a balanced population it is necessary to allot daily survival rates such that egg production is sufficient to maintain the cycle.

ditions hindered the proper dispersion of the spray cloud.

To improve the control achieved, 4 additional sprayings were made in Area 11 on nights after the planned application i.e. spray numbers 4a, 5a, 6a, 7a. Thereafter spraying was resumed at 2-day intervals. No bait catches were possible on the night after the 8th spraying, but the assessments on the night after the 9th spraying were free of influence from weather conditions or the effect of additional treatment. At Site A, two *Mansonia* spp. per hr. were recorded and four at Site B. In relation to the average pre-treatment bait catches, not allowing for the fact the mosquito population was increasing, this represents a level of control of 96% and 86% respectively.

Using the bionomics supplied by Laurence (1961) a population model of the type used by Brooke et al (1975) and originally described by Chadwick and Toner (1972 unpublished) was developed for a generalized *Mansonia* spp. The parameters used to construct a constant breeding population are given in Table 2 which also shows the results of subjecting the population to the spraying regime used in the trial in which each application achieved 75% control of all adult instars. Table 3 summarizes the expected % control after each spraying in relation to the basic population. The model also accommodates the migration of adult instars into the trial area, and this level was arbitrarily taken as 5% of the adult population. It can be seen that after the 9th spraying, the expected level of control would be 61% without migration and 57% with migration. The ULV treatments were, therefore, undoubtedly giving a very high level of control.

During the period of pre-treatment assessment 287 *Mansonia* spp. were dissected to determine parity rate, and 50% were found to be parous (see Table 4). During the spraying period this percentage dropped as would be expected if the ULV applications were effecting control of adult mosquitoes. However, on a number of occasions the data were obtained from examination of the ovaries of less than 10 individuals which makes it difficult to assess their significance. However, this in itself is an indication of the high level of control being obtained.

The sharp drop in the number of *Mansonia* spp. at the control site after February 18 is thought to have been due to contami-

Table 3. Expected % control using a *Mansonia* spp. population model against which the trial sprayings were simulated

Date	Treatment no.	% expected control: 75% kill of adults each spraying no migration	% expected control: 75% kill of adults each spraying 5% migration
31.1.76		61	61
1.2.76		50	43
2.2.76	2	71	70
3.2.76		58	55
4.2.76	3	73	72
5.2.76		60	57
6.2.76	4	73	72
7.2.76	4a	76	76
8.2.76	5	77	77
9.2.76	5a	77	76
10.2.76	6	77	76
11.2.76	6a	77	76
12.2.76	7	77	76
13.2.76	7a	77	76
14.2.76	8	77	76
15.2.76		63	60
16.2.76	9	74	73
17.2.76		61	57
18.2.76	10	74	73
19.2.76		60	57
20.2.76	11	74	73
21.2.76		60	57
22.2.76		50	45
23.2.76	12	71	70
24.2.76		59	55
25.2.76		49	43
26.2.76	13	71	70
27.2.76		59	55
28.2.76		48	41
29.2.76	13a	71	67
1.3.76		58	50
2.3.76		62	50

nation from spraying on that occasion. An observed change of wind direction caused drift of insecticide towards the control site during spraying operations in Area 1. Unfortunately, the inhabitants of the hamlet then insisted on insecticide treatments to alleviate their mosquito problem beginning on February 23 and there was no opportunity to observe if the population returned to its previous high level.

Table 4. Summary of parity data in *Mansonia* spp.

Date	% Parity rate	
21.1.76–30.1.76	Pretreatment period 50	
	Post-treatment period	
	Treated Area	Control Area
31.1.76	—	—
1.2.76	—	—
2.2.76	—	58
3.2.76	27	—
4.2.76	34	—
5.2.76	—	—
6.2.76	—	37
7.2.76	—	—
8.2.76	—	—
9.2.76	—	46
10.2.76	59	—
11.2.76	100*	88
12.2.76	44*	—
13.2.76	—	—
13.2.76	—	—
14.2.76	—	—
15.2.76	—	—
16.2.76	0*	54
17.2.76	20	—
18.2.76	—	62
19.2.76	—	25
20.2.76	25*	—
21.2.76	43*	—
22.2.76	—	27
23.2.76	—	—
24.2.76	14*	—
25.2.76	33	—
26.2.76	12	—
27.2.76	—	—
28.2.76	40	—
29.2.76	—	—
1.3.76	59	—
2.3.76	—	—
	50% mean post treatment—Control Area	

* = Rate determined on less than 10 individuals.

The last 3 sprayings were carried out at intervals of 3 days to examine the level of control obtained 2 nights after treatment. On the 1st occasion February 25 rain shortened the capture time and the catch extrapolated to per site per hr. appeared high, i.e. 33 at Site A and 54 at Site B. However, only 33% were parous, the majority being newly emerged adults. The remaining assessments indicated a level of control which was at least as good as that expected from the population model data.

The inhabitants of Lambaréné were favorably impressed with the alleviation of their mosquito problems during the trial period, and this was visibly demonstrated when mosquito nets were no longer used at night.

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References

Beklemishev, W.N., T.S. Detinova, V.P. Polovodova. 1959. Determination of physiological age in anophelines and of age distribution in anopheline populations in the USSR. Bul. Wld. Hlth. Org. 21:223–232.

Brooke, J. P., M.E.C. Giglioli and J. Invest, 1974. Control of *Aedes taeniorhynchus* Wied. on Grand Cayman with ULV bioresmethrin. Mosquito News 34 (1):104–111.

Brooke, J. P., S.J.S. Martin and D.C. Stewart. 1975. Pyrethroids in malaria control. Paper read at the Scientific Conference on Malaria in Nigeria, 24th-27th November.

Laurence, B.R. 1961. The biology of two species of mosquito, *Mansonia africana* (Theobald) and *Mansonia uniformis* (Theobald) belonging to the subgenus *Mansonioides* (Diptera, Culicidae). Bull. Ent. Res. 51 491–517.

Lee, C.W. and M.E.C. Giglioli. 1974. Aerial application of malathion, pyrethrins and a pyrethroid on Grand Cayman for mosquito control. P.A.N.S. 20 (2):208–214.

Mahdi, A.H., A.M. Taha, J.P. Brooke, O.M. Kamel and M. Nawawy, 1976. Fly (*Musca*) control with ULV bioresmethrin in Cairo. P.A.N.S. 22 (4):443–448.

Mason B., J.E. Johnson, J.P. Brooke and D.C.Stewart. 1977. Fly control in Monrovia with synthetic pyrethroids. Int. Pest Control 9 (1):8.

Service, M.W. 1970. A battery operated light trap for sampling mosquito populations. Bull Wld. Hlth. Org. 43:635–641.

Sudia, W.D. and R.W. Chamberlain. 1962. A battery operated light trap, an improved model. Mosquito News 22 (2):126–129.

World Health Organization Report. 1974. Plan decimal de lutte antipaludique au Gabon. WHO. Monograph Series AFR/MAL/140.