cal derivatives, synthetic pesticides are becoming prohibitively expensive for many of those most in need of them, these compounds have begun to fail vector control requirements at a time of ebbing production of new insecticides. Meanwhile mankind is steadily increasing in numbers; our food and petrochemical crises are augmenting accordingly.

If, by the end of this century, we don't have not just one or two but a wide range of biocontrols for mosquitoes on the market in sufficient quantities for rational choices to be made for integrated methodologies from among them and competing chemical agents, those responsible for the year 2000 A.D.'s vector control (including, don't forget, workers now in this room) will be facing unprecedented problems spearheaded by myriads of unhealthy and decidedly discontented people.

In order to have the necessary biocontrol supplements commercially available then, the time to begin working towards them is neither 10 years hence, nor next year. It's *NOW*.

SOME ENTOMOLOGICAL ASPECTS OF INTEGRATED CONTROL OF VECTOR BORNE DISEASE

J. P. BROOKE and J. B. KING

The Wellcome Foundation Ltd., Ravens Lane, Berkhamsted, Herts HP4 2DY, England

Integrated programmes for the control of insect borne disease utilize the planned application of complementary entomological and medical and sometimes veterinary measures. Although each programme may be designed to fit individual situations, the purpose of the entomological techniques employed will be to achieve a level of vector control at which individual adult insects are unlikely to survive to an age at which they can transmit the parasite. This applies to diseases where the insect vector is an essential part of the parasite life-cycle, as in malaria, and also to diseases where transmission by the vector is mechanical, as in communicable ophthalmia. At the same time, medical or veterinary measures can reduce the reservoir of infection in the human or animal host as in leishmaniasis. Thus complete integration will obstruct the disease cycle at 2 or more different points.

This principle is valid for several different vector-borne diseases.

MALARIA. Malaria control programmes using intradomiciliary residual insecticides require transmission to be interrupted during the attack phase. This phase may last perhaps 4 years. If interruption of transmission is rapid, then in the natural course of events a decline of malaria in man may occur. This decline may be largely in young children who are not exposed to infection as transmission pressure is reduced.

Traditional malaria control methods, relying in the entomological phase upon residual insecticides, are based upon the premise that most endophilic female *Anopheles* sp. will rest for some time upon an internal surface of a room following a blood meal. However, a prolonged attack phase, during which the *Anopheles* sp. concerned is often subjected to insecticide pressure at sub-lethal doses, may be a prime cause of the development of resistance, although some authors blame agricultural use of insecticides for this. It is our belief that by greatly shortening the attack phase by the additional use of techniques other than intradomiciliary residual spraying, the development of resistance may be delayed. Larviciding and control of adult mosquitoes outdoors by the planned use of ultra low volume aerosols may be suitable complementary techniques. Medical measures designed to act directly against the parasite in man can similarly shorten the attack phase. Therefore, integration of both entomological and medical measures into a single programme can provide marked benefit.

Nevertheless, one must recognize that methods of vector control requiring expensive equipment and needing a high degree of treatment repetition may not be suitable for use in and around small settlements, and because the area treated must be extensive enough to cover the flight range of the mosquito species concerned and prevent inward migration, a high per capita cost may be incurred. Cost effectiveness must be a guide to planning.

The species of *Anopheles* present will have a bearing on the success of the measures taken, especially the periodic flight activity, the degree of exophily exhibited and the migration habit. For example, *An. sergenti* Theobald should be a more amenable species to control by the use of outdoor ULV aerosols, because of its exophilic habit, than *An. gambiae* Giles although the potentially long flight range of *An. sergenti* (Shapiro et al. 1944) will make control very difficult.

Anopheles stephensi Liston and more particularly *An. gambiae* are house haunting species with fairly well defined breeding places and a short flight range. Nevertheless, *An. stephensi* with its rather specific and limited breeding sites may be relatively susceptible to larviciding while *An. gambiae* with its far more diverse and extensive habitats in temporary ground water during the wet season, is an extremely difficult species to control by larviciding.

Martin, Stewart and Invest (1977) described a field experiment conducted in Gabon using ULV pyrethroids for mosquito control. On that occasion, *Mansonia uniformis* Theobald and *Ma. africana* Theobald were the target. The techniques employed were used in conjunction with a population model. Although problems were encountered with the long flight range of these species, the control achieved approximated to the theoretical levels shown by the model.

The use of theoretical population models in vector control has been demonstrated by Brooke, Martin and Stewart (1975, Scientific Conference on Malaria in Nigeria) where a technique which gives 95% control of (adult female) *Anopheles* sp., at each repeated application, carried out at 2-day intervals, was shown to provide theoretical interruption of malaria transmission after 3 treatments (Tables 1 and 2). If an external ULV adulticide aerosol is combined with an intradomiciliary residual spray, then once transmission has ceased the ULV aerosol can be withdrawn and it may not be necessary to continue to the point at which the life cycle is interrupted. The presence of the residual insecticide on indoor surfaces ought to ensure that the density will not rise to a level at which transmission recurs. However, it is only possible to determine the validity of this supposition by field experiment. The ULV aerosol technique ought certainly to remove the exophilic, and a large proportion of the endophilic, individuals if the treatments are timed to coincide with peak outdoor activity.

TRACHOMA. The population model approach can be applied to any species and any vector borne disease situation. For example, in an integrated approach to control of communicable ophthalmia where the vector is probably *Musca sorbens* Wied. (Jones, Darougar, Mohsenine and Poitier 1976 WHO Inter-Regional Meeting) control patterns can be predicted by means of the model. This has been demonstrated by Mahdi et al. (1976) who showed in a field study conducted under very unfavourable conditions, that the theoretical point where interruption of the life-cycle of *Musca* sp. occurred appeared to be valid.

Communicable ophthalmia, which includes trachoma, is often a disease of dry, dusty climates. In village situations, where isolated populations are far enough apart

Table 1. Female instars representing adult *Anopheles* sp. population in balance.

		Egg	Larva	Pupa	Adult	Adult	Adult	Adult	Adult	Adult	Adult	Adult	Adult	Adult
Time	Instar No.	1	2	3	4	5*	6	7*	8	9*	10	11*	12	13*
	Day No.	1–2	3–10	11–12	13–15	16	17–18	19	20–21	22	23–24	25	26–27	28
Days	Daily Natural Survival	0.740	0.696	0.764	0.672	0.794	0.794	0.845	0.845	0.822	0.822	0.560	0.560	0.560
0		173998	170213	5176	3636	519	741	260	406	157	235	87	76	15
10		173509	167899	5319	3738	534	761	267	412	157	235	87	76	15
20		171695	169367	5304	3702	522	743	261	412	161	242	90	78	16
30		174476	169788	5249	3708	536	762	268	416	161	239	89	76	15
40		173603	169533	5333	3735	531	756	265	413	159	240	89	78	16
50		174139	170703	5307	3721	532	759	267	417	161	242	89	78	16
60		174837	170570	5323	3750	537	761	268	415	161	240	90	78	16
70		175053	171098	5344	3747	534	763	267	418	161	242	90	79	16
80		175307	171594	5351	3757	537	765	268	419	162	242	90	78	16
90		175971	171875	5359	3770	539	765	270	419	163	243	90	79	16
100		176367	172234	5379	3774	539	769	270	421	163	244	90	79	16

* Egg laying stage.

Table 2. Effect of 10 treatments at 2 day intervals providing 95% control of adult female *Anopheles* sp. on each occasion.

		Egg	Larva	Pupa	Adult	Adult	Adult	Adult	Adult	Adult	Adult	Adult	Adult	Adult
Time	Instar No.	1	2	3	4	5*	6	7*	8	9*	10	11*	12	13*
	Day No.	1–2	3–10	11–12	13–15	16	17–18	19	20–21	22	23–24	25	26–27	28
Days	Daily Natural Survival	0.740	0.696	0.764	0.672	0.794	0.794	0.845	0.845	0.822	0.822	0.560	0.560	0.560
0		173998	170213	5176	3636	519	741	260	406	157	235	87	76	15
10	Treatment begins day 10	78771	167899	5319	1859	27	38	13	21	8	12	4	4	1
12		3940	117068	5198	1859	1	2	1	1	0	1	0	0	0
14		2082	53752	5195	1817	1	1	0	0	0	0	0	0	0
16		1988	22079	5237	1816	1	1	0	0	0	0	0	0	0
18		1943	6658	5269	1839	1	1	0	0	0	0	0	0	0
20		1943	1987	2447	1841	1	1	0	0	0	0	0	0	0
30	Treatment end day 28	66	387	60	32	1	0	0	0	0	0	0	0	0
40		1012	1895	2	0	1	0	0	6	4	3	0	0	0

* Egg laying stage.

to restrict vector migration, the vector is represented in isolation. In these circumstances, the use of the ULV technique to interrupt the life-cycle of the fly and therefore transmission, can be integrated with medical treatment, chemoprophylaxis and environmental measures in order to control the disease. In trachoma management, the prevention of transmission is an essential component of the integrated programme.

LEISHMANIASIS. The sand fly is intimately connected with the transmission of cutaneous leishmaniasis, although knowledge of the bionomics of the Phlebotomine vectors is limited. A detailed understanding of the resting, flight and feeding habits of the adult sand fly is essential. Adequate preliminary studies of sand fly biology, biology of the rodent/canine hosts of *Leishmania tropica*, and the relationship of these hosts to sand fly vectors must be completed before an integrated programme can be designed to control cutaneous leishmaniasis. This is an area where perhaps more is known of the parasite than the vector, since effective medical treatment is available.

It is established that all sand fly species spend part of the adult stage of the life-cycle outdoors and, being active after dusk, are exposed to control by ULV aerosols at this time. The sand fly may spend many weeks in the immature state. This must also be taken into account when designing control programmes utilizing ULV and residual adulticides. Some sand fly species can be described as domestic in their habits, which implies 'continued presence within a man-made shelter throughout the whole or a definite part of the gonotrophic cycle' (Senior White 1954). Where residual insecticides have been used indoors during malaria control projects, a measure of control of some species of sand flies has been recorded. This implies that on these occasions the adult sand fly has become domestic in habit. Nevertheless, leishmaniasis can be endemic in animals in uninhabited country where itinerant travellers can become infected, so the term domestic may be meaningless; thus each situation may need a different approach.

CONCLUSION. These three examples, and there are others, serve to illustrate the part to be played by entomological measures within the structure of an integrated programme. The benefits of this approach are such that it may be worthwhile re-examining traditional methods which rely upon a single entomological or medical measure.

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