# PAPERS AND PROCEEDINGS OF THE 33rd ANNUAL MEETING Of The AMERICAN MOSQUITO CONTROL ASSOCIATION

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# ENEMIES AND DISEASES OF MOSQUITOES THEIR NATURAL POPULATION REGULATORY SIGNIFICANCE IN RELATION TO PESTICIDE USE, AND THEIR FUTURE AS MARKETABLE COMPONENTS OF INTEGRATED CONTROL[1]

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Canadians are currently considering the formation of a national association along the lines of the AMCA. The convening of this session jointly with the LMCA is thus timely in drawing attention to our topic's regional diversity. So is my presence at this plenary session, over which I feel much honoured.

Our mutual adversaries, the Culicidae, like us pursue their activities across Federal, State and Provincial boundaries. Last summer, anybody concerned about the reassertion of mosquito-borne encephalitis was acutely aware both of this, and the impediments to fast and decisive remedial action for which we must thank ecohysteria. Those suffering from the latter complaint to my mind better deserve branding as our enemies than the source of our livelihood; which was why I used the more generous term, adversaries, for mosquitoes.

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I shall instance only one example of the kind of fuel being used a few years ago to overheat emotions at a time when specific examples of pesticidal contamination, and resultant laboratory experimentation, were being twisted to provide the basis for untenable generalizations. My example goes back to 1969. In October of that year, a NATO session at Brussels was solemnly warned by a U.S. Presidential Adviser that mankind may have a less than 50–50 chance of surviving until 1980.

Nearly a decade further along the road, mankind somewhat more numerously and healthily continues to cope. The inexorable increase in our numbers is certainly worrying. However, there's little to be done at this late stage about avoiding an end-of-the-century world population of up to seven billion. Recognizing that the amount of arable land all those people are to be fed from is round about what we're using today, we must therefore do all we can to ensure that our descendents (and not a few of ourselves now here in this room) are reasonably well supplied with food and fibre and in adequate health by the time the bells ring in the year 2000 A.D.

This is going to represent a considerable challenge to everyone involved in mosquito control. It is most certainly going to demand a high level of availability of insecticidal chemicals (including environmentally persistent ones) too. Above all, though, it is going to demand commonsense solutions to control problems, founded upon collective decisions which not only define those problems, but also embody consensuses offsetting benefits and risks against one another.

In 1977, we aren't really doing too badly as scientists and technologists. Mankind is within reach of the final eradication of the scourge of smallpox, for example. In the field of vector-borne disease, synthetic chemical larvicides have made possible the initiation of a complex inter-relationship of socio-economic and disease-control activity, the World Health Organization's Onchocerciasis (river blindness) Control Programme in West Africa's Volta River Basin. The immediate objective is to suppress populations of the vector blackfly, *Simulium damnosum,* so as to break the chain of this disease's transmission. Other benefits will accrue to the area and to developing countries elsewhere thanks to WHO's newly-funded Special Programme for Research and Training in Tropical Diseases. Under this, methodologies and management techniques will be developed to control the vectors of the trypanosomiases, leishmaniasis, the filariases and malaria, as well as the snail hosts of schistosomiasis.

A disruption of purely pesticidal control could result from a worsening of the resistance situation, in a period noteworthy for industry's reluctance to spend (in each instance) yet another 10 to 15 million dollars in developing new chemical pesticides. As an advocate of biocontrol of vectors for rather more than 30 years, I dislike having to concede that years after science and technology made it possible for men to lumber over and then drive about the moon, we public health entomologists are still totally dependent upon chemical pesticides in the major vector-borne disease-control situations, which demand percentage levels of control in the high 'nineties. Our fortunate colleagues in economic entomology can settle for substantially less than this—chewed, gnawed and bored agricultural products remain useable, if the damage isn't overwhelming. These colleagues have therefore been able to profit more than we from current advances in pest management, except insofar as the control of pest (as distinct from vector) mosquitoes is concerned. I shall return to this matter later.

Nevertheless, we clearly must move away, as soon as feasible, from present total dependence upon synthetic toxicants into integrated vector control methodologies. Carefully designed for minimal adverse health and environmental side-effects, such methodologies will have places for new components ranging from juvenile hormone mimics (like Zoecon's Altosid) and chitin inhibitors (like Thompson-Hayward's Dimilin) to mass-produced microbial control agents. These last aren't yet available for use in medical entomology in the quantities required for major vector suppression projects, although some already are, with respect to agricultural pest control. Juvenile hormone mimics and chitin inhibitors will soon be in wide use against economic pests. Both are well advanced as regards evaluation against vectors, and insofar as aquatic non-target organisms are concerned, show better promise of environmental acceptability than chemical toxicants generally. They seem highly likely to comprise our first non-conventional reinforcements available in large commercial quantities for deploying against mosquitoes and other vectors.

It would have been good to be able to say the same for diseases and enemies of mosquitoes, but at all events it is encouraging to know that WHO's recently-announced Special Programme for Research and Training in Tropical Diseases includes a strong biocontrol element. The philosophy of integrated approaches to mosquito suppression, of course, dates back many years. Ronald Ross spelt it out 75 years ago, in his little book, "MOSQUITO BRIGADES AND HOW TO ORGANISE THEM."

At a time when society sets so much store by our "rights" while de-emphasizing our "responsibilities," we might do well to remember that sound discipline was as fundamental to Ross' concept of effective mosquito control as it was to that of his New World contemporaries, Carlos Finlay and Walter Reed, who so successfully employed sanitational measures in dealing with Cuba's yellow fever crisis at the beginning of this century. Many years earlier than that, J. Davies had Englished the compilation of de Rochefort, "THE HISTORY OF BARBADOS. . ." Published in London in 1666, this book informs us that what we would now call repellents, environmental management and chemotherapy, were already in use against mosquitoes in the Caribbean. Taking "Tobacco in the room" or making "a fire that shall smoak much" were recommended to discourage these pests. So was removal of "the trees hindering the East-wind" and (once bitten) getting rid of the itch by wetting "the place stung with Vinegar, or the juyce of the lesser kind of Citron. . ."

By the early 1900's certain fish were being used against Culicidae, other biocontrol agents of which range from bladderworts through *Hydra* and ducks to bats. The more minute of these organisms inflict diseases upon mosquitoes. They range from viruses (*entomopathogenic* ones, far removed from entities causing disease in man and other mammals) through bacteria and rickettsiae to fungi and protozoa. Mosquito mortalities take place thanks to parasitic worms, too. Also, notable inroads into mosquito populations are made by predators. In this connection, many data remain to be fed into our storage and retrieval facilities. Among these, I personally like Paul Combes' (1896) assertion in a little paper on "Les Moustiques de L'Isle D'Anticosti," to the effect that on this large island of the eastern St. Lawrence River, freshly emerged mosquitoes are sometimes attacked and killed by "*Simulium*, which is a great plague in that region."

Doesn't that conjure up a wonderful vision—one of two major groups of biting pests and disease vectors turning upon the other! Putting aside such enchanting thoughts for the moment, though, let's look at an area that for reasons not only climatic was warmer than New Orleans in 1945. The time was not notable for universal international collaboration. The place was in the then Territory of New Guinea (today the independent nation of Papua New Guinea). The circumstance was that a newly-landed and heavily-laden Australian infantryman was overheard complaining to a friend about something that he held by one of its hind legs. That "something" was a gloriously metallic and clearly upset *Toxorhynchites*, the best part of a couple of centimetres in wingspan. What the soldier was exlaiming was, "Stone the crows, mate, look at the size of the effing mozzies on *this* island—a bloody inch across!"

Three needs besides watching one's language are evident from my last sentence. Firstly, it's time we were all using metric in the interests of universal comprehension. Secondly, we must know our adversary (and in this case a slandered friend was involved, the colorful members of the genus *Toxorhynchites* being mosquito predators as larvae, and vegetarians as adults). Therefore, we must have access to trustworthy identifications. The third need is for accurate definition of each of our pest problems.

Two months ago, an RUVP researcher enjoyed a temporary escape southwards. His assignment was to mass-produce the mosquito mermithid worm, *Romanomermis culicivorax*, for a West African joint project between RUVP and the Institute for Onchocerciasis Research in Ivory Coast, concerning the already-mentioned blackfly, *Simulium damnosum*. His work was done at the USDA's Gulf Coast Mosquito Research Laboratory, the generous cooperation of which in this and other respects it now gives me real pleasure to acknowledge publicly.

While at Lake Charles, Joe Mokry spent

spare time out searching for Simuliidae and their pathogens, in company with "Tiny" Willis of Dr. Chapman's staff. A locality where they collected had been the scene of complaints that pest mosquitoes just weren't getting controlled. It now seems likely that the special local problem is due less to mosquitoes than to this continent's most widespread and persistent man-biting blackfly, *Simulium venustum*; which proved only too abundant in running-water habitats not previously sampled for these insects in a mosquito-obsessed region.

So much for the need to define pest problems, within the integrated (or any other) control context. In designing the resultant control methodology to remedy the situation, we'll require one of the more useful (though sometimes bureaucratically overcomplicated) consequences of the late-'sixties hysteria already referred to—an environmental impact statement.

Supposing, though, that we're facing an emergency situation? This was sometimes the case back in the tropical Pacific of the mid-'forties, when Nissan Island (an isolated raised atoll east of New Ireland and New Britain) became familiar to many Americans and New Zealanders. Malarious when captured, Nissan was soon rendered healthy by the then-newly available compound which so greatly helped to hasten the end of World War II—DDT. Effective vector control broke the chain of malaria transmission in short order. Indeed, anophelines seemed to have disappeared altogether. The action duly moved northwards, and the atoll was abandoned.

Some two months after control had ended there, I had the chance of making a mosquito survey. My average count for *Anopheles farauti* larvae was about 800 per square metre of water-surface, regardless of the permanency of the habitats concerned. Semi-permanent pools would normally have exhibited a complex fauna of water beetles, water boatmen, dragonflies and so forth. Like the mosquitoes, though, these had fallen victim to the pesticide. But unlike them, having relatively lengthy life-cycles, these predators were necessarily slow about re-establishing their populations. Meanwhile, the highly dangerous malaria vector, *Anopheles farauti*, was enjoying population levels unattainable earlier, when there had been a degree of natural biocontrol. Almost a quarter of a century before environmentalism, it was providing proof for Harold Chapman's Presidential contention at last year's Boston AMCA meeting, namely that ". . . . . the responsible leaders of mosquito control agencies . . . . should know and appreciate the present benefits that they are receiving from biological control, particularly in semi-permanent and permanent water habitats."

Later personal efforts to obtain floral and faunal inventories of individual mosquito larval habitats, extended to some three weeks of sampling from a subarctic Canadian snow-melt pool, two metres in diameter, in the spring of 1959. After very considerable correspondence (the latter part progressing from coaxing through pleading to near-rudeness), with many systematists all over the world, I finally found myself in possession of as complete an inventory as I was ever going to have—precisely nine years after making the collections.

Incomplete as it still was, this inventory ran to well over 200 identified species of plants and animals from that one little pool. Several of those species, incidentally, were aedine mosquitoes. Their larvae so dominated the scene, that a casual observer could have been forgiven for not appreciating that a significant degree of natural biocontrol was being achieved at the time of this study by various elements in the mind-boggling association of other, though much less conspicuous, life-forms present.

Commonsense compromises thus seem called for in seeking meaningful, and rapidly-enough achievable, environmental impact statements on which to base necessary mosquito abatement measures as harmless as feasible to already-operating natural population regulatory factors due to enemies and diseases of mosquitoes. Vector control in tropical developing countries may face special difficulties in this connection, for not infrequently work cannot commence towards environmental impact statements until the expertise and equipment for pesticidal operations have been imported. Investigations of such things as the natural limitation of mosquito numbers through already-present disease agents and natural enemies, thus have to proceed alongside actual control measures. Even then, those concerned often find it impossible to obtain accurate and prompt identifications of aquatic flora and fauna.

Relevant communications are, however, improving. The World Health Organization has shown leadership in this regard—by the mid-'sixties, in fact, WHO had established its first International Reference Center concerning bio-control of vectors. Headed by Dr. John Briggs at Ohio State University, Columbus, this laboratory (aided by pocket-sized collecting kits developed and widely distributed by WHO) has built up effective services for the identification and furthur study of pathogens and parasites of arthropods of public health importance. Recently retitled WHO Collaborating Centres, Columbus' and some newer facilities are keeping pace with the needs of a rapidly expanding programme.

One of the newer Collaborating Centres (under Dr. John Shadduck's direction at the University of Texas, Dallas) investigates mammalian safety aspects of microbial control agents. Another is the one at Memorial University of Newfoundland, St. John's. Located at the Research Unit on Vector Pathology (RUVP), its responsibilities concern the identification, ecology and safety of non-target organisms.

A "non-target organism" (NTO) being anything alive in the control zone against which no harm is intended, RUVP would indeed be overextended were we to be deluged with requests for determinations of NTOs. To date we haven't been, although enough approaches have been made to us over the past two years or so to enable the establishment of a panel of collaborating specialists knowledgeable on 35 major aquatic taxa, and good enough to be ready to drop primary interests in order to provide early identifications (of, for example, mosquito predators) to vector control workers in urgent need of such information. In particular, during the two years since the discovery that cyclopoid copepods are alternate hosts for *Coelomomyces* fungal pathogens of mosquitoes, it has been possible to arrange prompt assistance for investigators needing determinations of these microcrustaceans in connection with life-history studies.

One of RUVP's odder achievements with respect to copepods was our establishing contact between a specialist in this group located in Tennessee, and an inquirer in Florida. While on the subject of our host region, I might also mention that North America's pioneer invertebrate pathologist, Dr. S. A. Forbes, who according to L. O. Howard was the first American entomologist "to adopt the word *ecology* and to insist upon the broad applications of studies of that character," was enabled to study Greek and Spanish while a prisoner of the Confederacy. He survived this experience (being a POW, I mean, not a language student) for long enough to gain the distinction of being arrested for speeding on his eightieth birthday. Now, the soundly-structured insect control programmes initiated by such men as Forbes led naturally towards the pest management approach that is currently giving such promising results against agricultural pests.

Unfortunately, only a part of the armament of pest management is available for mosquito control purposes, except in the special cases of problems associated with ricefields, fish culture and some rather localized (particularly tropical) crops with which certain Culicidae are intimately associated (examples are taro and water hyacinth). Rice cultivation and fish farming lead to the artificial promotion and concentration of anopheline and culicine populations. They provide control situations largely paralleling those of the monocultures for which economic entomologists are devising environmentally more acceptable, and sometimes cheaper, pest control strategies. In such situations good use can be and has been made of larvivorous fish.

There is room for enterprise here, in searching for ecologically preferable alternatives to *Gambusia.* Time has proved that mosquitofish eventually became harmful in some areas to which they were introduced half a century or so ago—the harm ranged from eating the eggs of economically desirable fish, to endangering rare indigenous species. Dr. Anatolii Dubitskii and his group at Alma-Ata, Kazakhstan, have lately secured good results with an indigenous larvivore, *Aplocheilus latipes,* against mosquitoes there and elsewhere in the U.S.S.R. They've also been having some success with field introductions of other enemies and pathogens of mosquitoes ranging from predatory aquatic insects to *Coelomomyces* fungi. The broad-front biocontrol element of their integrated approach, favoured by the concentration at Alma-Ata of 20 professionals and the same number of technical workers in this one team, perhaps comes closer to the equivalent phase of pest management as used against agricultural pests, than most western-world mosquito control at this time.

We must now turn to the future of enemies and diseases of mosquitoes as marketable components of integrated control. In contemplating this future, we might do well to keep in mind that not one chemical control agent has ever been developed through the various steps up to commercialization, with mosquito control markets primarily in mind.

To consider the predators first of all, I've already referred to the useful role that larvivorous fish can play in pest management approaches to, for example, ricefield mosquito abatement. This is all the more so, when their acquisition of a degree of resistance to the pesticidal compounds in use favours truly integrated control programmes, with selectively-applied synthetic chemicals involved as well as fish and perhaps additional biocontrols. Certain fish have a real future, too, in "wild" mosquito control situations. Examples are the "annual" or "instant" fish of the South American and African genera *Cynolebias* and *Nothobranchius.* These, being so nicely adapted to survival in intermittent pools, could be used against important vectors far from their present range (like *Anopheles punctulatus,* in Melanesia); as could the Asian *Aplocheilus latipes* and the Fijian eleotrid *Lairdina hopletupus,* both of which have the capacity to move from large pools across stretches of damp ground to invade relatively short-lived hoofprint pools that so often harbor pest culicines and aedines. Insects that eat substantial numbers of larval Culicidae include the predacious species of *Toxorhynchites,* that have already been the subjects of field-release experiments, and another tree-hole-frequenting genus that has not—*Sigmatomera* species, Amazonian craneflies. I greatly doubt, though, whether such predators offer real commercial incentives, except perhaps to small firms with prospects of subsidization. Predator establishments generally seem more an area of enterprise for the appropriate national and international bodies.

Useful though predators may be in helping reduce pest mosquito populations to tolerable levels, major industry is unlikely to work up real enthusiasm for anything less than the development of saleable products based upon the mass-cultivation of microbial control agents by methods similar to those already used for antibiotics. The future availability of such products specifically tailored for mosquito control, and in amounts comparable to those in which agricultural chemicals are currently obtainable, in my view represents the key to effective integrated control in medical entomology. Not until they are purchasable in adequate quantities, like chemical pesticides, will we be able to step off the treadmill of purely chemical control that we are still turning with respect to all major vector suppression programmes.

For, to break the chains of transmission of malaria, Bancroftian filariasis and other mosquito-borne diseases, we must attain levels of vector suppression far beyond those satisfactory in economic entomology, and maintain those levels for lengthy periods, moreover. We need lethal control agents; and we need them in great amounts. Accepting that for obvious health and environmental reasons these agents must not remain totally chemical for any longer than necessary, we must now examine the alternatives.

It is to be hoped that these will include entomopathogenic baculoviruses. However, although several viruses peculiar to mosquitoes have now been isolated, none has so far shown the kind of promise likely to lead towards commercialization of a mosquito-control equivalent of the *Heliothis* virus (last year registered for use against certain crop pests in the USA). The latter advance called for exhaustive, protracted and costly safety-testing, before this new microbial control agent could supplement the few already on the market. These include species of *Bacillus* (in the U.S.A., notably *B. popilliae* which thanks to Dr. Sam Dutky's early work has been developed so successfully against the Japanese beetle—and in various parts of the world, *B. thuringiensis*). This last spore-former is primarily active against a wide range of Lepidoptera, although strains of it (and still more so, of a relative, *Bacillus sphaericus*) are showing some promise against biting flies. *B. sphaericus*, and the imperfect fungus *Metarrhizium anisopliae* (which has upwards of 200 insect hosts, and is already mass-produced for field use in the U.S.S.R.), are highly rated by WHO among candidate mosquito biocontrol agents that have passed beyond the initial laboratory-evaluation phase of the safety-testing protocol.

This protocol involves five stages, the first two of which are confined to the laboratory, and include identification, assessment against selected vectors, preliminary work on mass rearing, and mammalian infectivity tests. Stage III comprises preliminary field trials, strictly regulated under WHO supervision, to determine efficacy against disease vectors under natural conditions. Further laboratory investigation of mammalian safety takes place at Stage IV, as do field studies concerning the safety of non-target organisms. After a review of the results achieved in Stages I to IV, large-scale field trials may then follow in the final part of the sequence, Stage V.

A single mosquito control agent has passed through the whole of such a screening process, with progression to a US-registered product. This is the warm-water mermithid worm, *Romanomermis culicivorax*. The product is Fairfax's Skeeter Doom. The organism, as already mentioned, is mass-produced at the USDA's Gulf Coast Mosquito Research Laboratory, Lake Charles. To my mind, the relevant work of Drs. Harold Chapman, Jim Petersen and their associates there represents the present pinnacle of biocontrol achievement in medical entomology. Their current field trial against El Salvador anophelines involves the elegantly programed use of as much as 700 kilogrammes of infective *Romanomermis* material of demonstrated viability, in damp sand—an immensely greater amount than previously field-tested for any microbial or parasitic mosquito control agent.

So far, the mass-production of *Romanomermis culicivorax* is a strictly *in vivo* affair, calling for the rearing of the worms in very large numbers of culicine mosquitoes. Nevertheless, Dr. Jean Finney of RUVP has lately succeeded in raising females of this mermithid, with well-developed sexual features, *in vitro*. To reach this stage, the worms admittedly required six weeks instead of the six days needed for the same degree of growth in the natural host. However, Dr. Finney and her colleagues are now working on the improvement of nutritional factors in the culture media to shorten development time. There is thus at least a measure of hope that an industrially feasible *in vitro* process for mermithids may be attainable. There are, incidentally, a variety of mermithids known from mosquitoes. These include a cold-water one from Wyoming, to which the name of *Romanomermis nielseni* is now restricted. This worm has neither been extensively studied, nor field-tested; nor have other species, known from subarctic Canada. There is surely room for well-guided commercial enterprise here, for products based on such cold-water worms have truly vast markets awaiting them as components in integrated methodologies directed against boreal aedines. These are a major component of northern biting-fly problems. They prejudice full economic development of forest and fuel resources not only across the high latitudes of Canada, but also in ecologically similar parts of the Old World from Scandinavia to Hokkaido, Japan.

It is submitted that any industrial enterprise finally displaying the initiative to venture upon biocontrol in medical entomology the kind of R. & D. investment required for the development of a new chemical pesticide, might also take a hard look at hybridization prospects (with their Patent possibilities), in the face of the available range of candidate mermithids. Such an enterprise might also do well to bring heavy resources to bear on the *in vitro* route to mass cultivation. Once achieved, this would not only obviate the need to maintain vast mosquito colonies, but would also allow the adaptation of existing technological pathways to commercial production.

*In vitro* routes are already available for *Bacillus* species and for *Metarrhizium anisopliae*, a fungus already at Stage III in WHO's testing protocol (it has shown efficacy against *Anopheles gambiae* under contrived larval habitat conditions in Nigeria). Encouraging results have also been obtained from Stage III field trials of fungi of the phycomycete genus *Coelomomyces*. *In vivo* production of these fungi has been achieved in the laboratory, notably by Emeritus Professor John Couch, at the University of North Carolina, Chapel Hill. Other fungi already field-tested to some extent against mosquitoes and their larval associates include species of *Lagenidium* (in the southern U.S.A.) and *Culicinomyces* (in Australia). Only *Metarrhizium anisopliae* (already, be it noted, in practical use in the U.S.S.R. without any reports of adverse health or environmental effects) has progressed through an orderly sequence of evaluation in the U.S.A. and elsewhere to the (still-proceeding) mammalian safety investigations of Stage IV. Moreover, a considerable range of strains of *Metarrhizium anisopliae* is available, from various parts of the world. A major company now considering a new biocontrol involvement, could thus do worse than to concentrate on this particular fungus.

This brings us to the Protozoa. Among these, the microsporidans stand out by virtue of their facility for transovarian dissemination. One of them, indeed, despite some unanswered questions concerning mammalian safety, has already been moved into the Stage III field trial stage against anophelines in Pakistan (I refer to *Nosema algerae*). So far, laboratory production of microsporidans is a strictly *in vivo* affair, which, however, in the case of *N. algerae* is greatly enhanced by the protozoan's capacity to develop in huge numbers in large lepidopterous larvae.

Time does not permit even a mention of any of the many more presently-known microbial candidates for trial against mosquitoes. One can well understand that like Bethlehem parents smarting from the Massacre of the Innocents and decidedly anti-Herod, some major manufacturers of insect control products (themselves sore from recent bereavement in terms of pilloried pesticides) are reluctant to get back to the business of procreation again. Yet, despite the daunting problems (like commercial production) still to be overcome, and related issues (like safety) still to be resolved, I would like as I've done before in this context to recall the immortal words of Charles Dickens' Mr. Jaggers: who, with respect to young Pip, declaimed "And the communication I have got to make is, that he has Great Expectations."

So has biocontrol in medical entomology. This is the more so, as through pesticide resistance, non-selectivity and bioaccumulation problems, and the fact that in common with all other petrochemical 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

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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 re-