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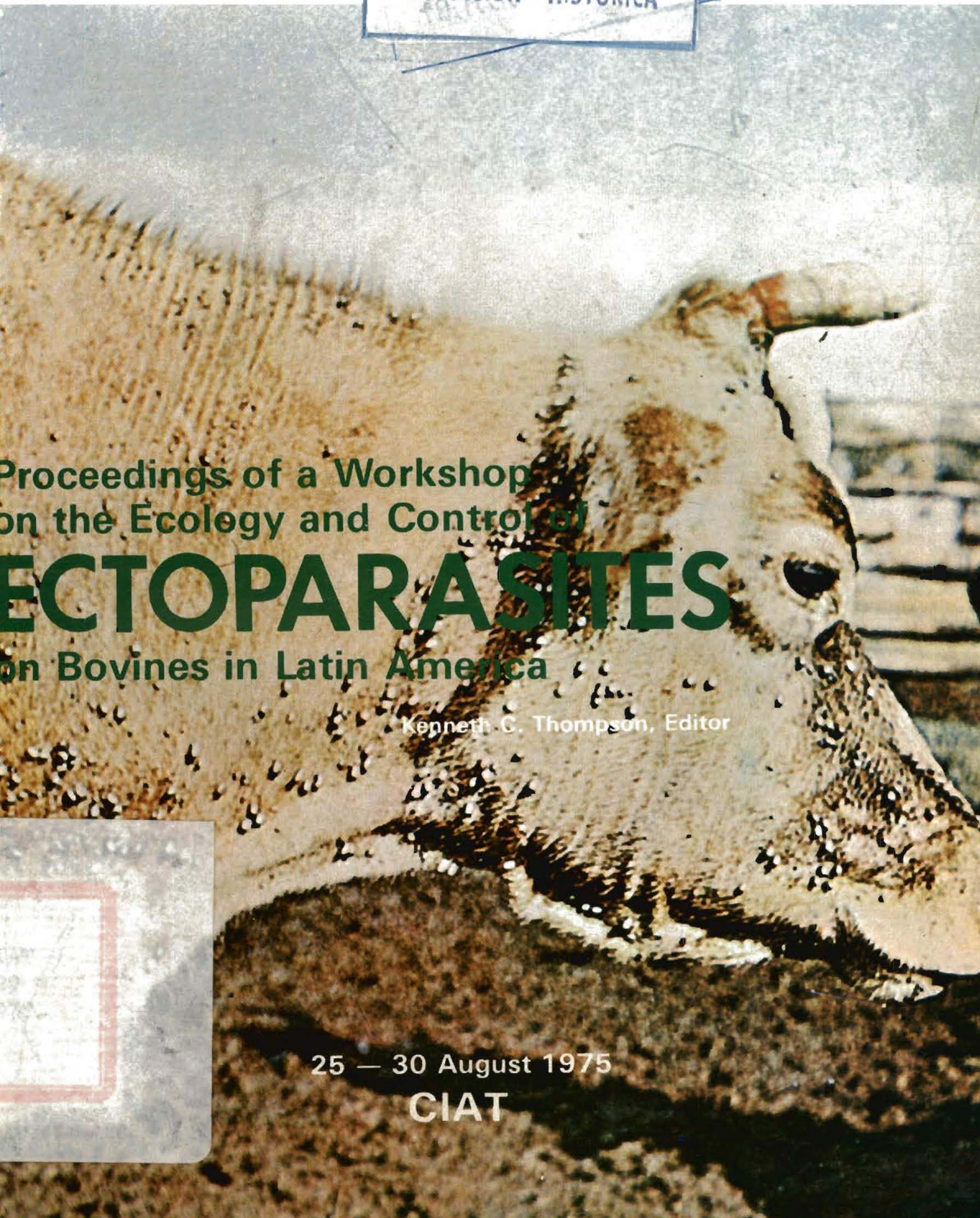

Proceedings of a Workshop on the Ecology and Control of ECTOPARASITES on Bovines in Latin America

Kenneth C. Thompson, Editor

25 — 30 August 1975
CIAT

~~Workshop~~
on the

ECOLOGY AND CONTROL OF EXTERNAL PARASITES OF ECONOMIC IMPORTANCE ON BOVINES IN LATIN AMERICA, Cali, 1975.

August 25 – 30, 1975

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Centro Internacional de Agricultura Tropical, CIAT

Apartado Aéreo 67-13 Cali, Colombia, S. A.

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Objectives of the Seminar

(1) Review the current situation relating to cattle ectoparasites of economic importance in Latin America.
(2) Determine the principal impediments to control.
(3) Suggest priorities for research needs.

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The Animal Health Program in CIAT

Eric A. Wells *

I want to comment first on why, in English, we have called this meeting a "workshop" and not a "seminar". By definition, a seminar is an exchange of ideas. A workshop, on the other hand, is a place where something is concluded, something is done. We have not yet been able to find a Spanish word giving the same impression. Perhaps you can suggest one.

Secondly: I want to briefly explain the animal health program at CIAT. We have given you a booklet in which the philosophy of our work and the current projects are outlined. All I want to do at the moment is to explain the relationship of the contents of the booklet to this workshop.

In our program we emphasize the economics of animal health, that is, the cost of the actual losses from disease and the cost of control. This emphasis is vital to our continued existence in this International Center for Tropical Agriculture. Donor agencies will only be interested in long-term support if we are are able to identify important causes of production losses in cattle which require research. Moreover, there have to be some advantages for this research to be carried out in an international center and not in national government laboratories.

Earlier this year we held a workshop on hemoparasitic diseases. Some of you attended. At the end of the workshop we formulated various resolutions. These are being acted on. For example, FAO is examining the possibility of having regional banks of antigenic and antibody material for research. Here in CIAT we are accepting

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more professionals for training in serological techniques so that they can return to their own countries and work on the distribution and importance of hemoparasitic diseases.

You will notice on the program that our last session is devoted to the needs for training and research in medical and veterinary entomology in Latin America. We hope that you will remember this. Your recommendations will influence the future of our programs in CIAT.

One more point on economics. We have not included a paper on economics because we are assuming that everything we are talking about is of economic importance. However, we hope that economics will be discussed in relation to control programs. Perhaps the need for economic evaluation of control programs may be one of the resolutions arising from the workshop.

On behalf of the animal health team in CIAT, may I give you all a very warm welcome.

Ethics of International Research

Carlos Sanmartín *

Almost three years ago, I had the honor of expressing before the American Society of Tropical Medicine and Hygiene some ideas about the orientation that scientific research and personnel training must follow in what I then called super developed sub-countries. These are characterized by introducing, accepting and adopting, in an indiscriminate manner, the more recent advances of technology and science, while their social and economical structures lag behind. At the same time, they still suffer from problems already vanished from the countries in which such progress originates.

I am most thankful to the International Center for Tropical Agriculture for the honor of inviting me to go back to the subject and to give some comments concerning men and animal health.

Before I go on I would like to make clear that what I say are my personal ideas and in no way do they represent those of the organization with which I am now connected.

I have asked myself what could be the reasons for my being the one who presents the matter before you. I believe that only years of experience authorize me to accept such an honorable task. Let this be the opportunity to say how much of my present education is related to the harmonious relationship I have always maintained with the veterinary profession, from which I have learned invaluable lessons.

The question of what course scientific research must follow in countries like ours has been the subject of endless concern, over which much has been said and written through the years. Everything seems

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to rotate over the everlasting matter of pure, basic, fundamental investigation that is usually contrasted with practical and applied research. This division, in many ways arbitrary, depends many times on the interests of those who are making definitions in each case. Technological complexity is generally taken as fundamental to qualify scientific research.

Pasteur, to whom Michael Hoskin referred, started his scientific career studying crystals, which in solution have certain optical properties, such as making the polarized light plane rotate. What might be more academic than this? However, these works led him toward microorganisms that play an essential role in industrial processes such as fermentation, and eventually to the germs menacing human and animal health. Along the same line, Jenner with nothing but his alert observant mind, developed a method never excelled for a smallpox vaccination which within a few years made it a forgotten disease.

One main characteristic research must have in developing countries is to be "proper", i.e. to give all projects and ideas a certain priority within the limited resources available, which will permit their effective improvement.

I believe that what is important in these countries is epidemiological research; the field exploration to find out simple but fundamental facts. In this way, it would be possible to quantify what is happening, to evaluate its impact and to take resolutions based on realities rather preconceived ideas.

It is not rare to observe, for example, that some infectious processes are usually blamed for the considerable losses in cattle, when lack of management, problems with fertility, or feed could be what is really affecting the animal production.

One sometimes may wonder if we are not attributing to some germs responsibilities they do not have. When there is positive serology or the isolation of a microorganism, without the existence of any clinical or epidemiological reason to say that such infection corresponds to a pathogenic process, it would appear that, in certain cases, a germ's capacity to cause disease (or its prestige) is linked to the investigator's who in a naive manner becomes its exploiting manager. It should be remembered that Koch's postulates are still in vogue.

In the scientific field and research, as in every other human activity there is the danger of insisting on one interest and easily making it the only important one, others being considered secondary. Such a narrow minded attitude is what possibly distinguishes insecure people and makes them exclusive owners of diseases, microorganisms, laboratories, methods, physical spaces, etc. so that one can even lose the ability of wondering about the permanent and infinite manifestations of nature and the mind.

There is a group of transmissible diseases on which knowledge about the causal agents, parasite cycles, transmission mechanisms, diagnostic methods, control systems, vaccinations, etc., are extensive. However, investigations are continually diversified, when the right thing to do would be to prove why they are not applicable and how could they be adapted and made effective.

Very often in our countries people aspire to adopt the more advanced methods for research and diagnosis without understanding that they depend on multiple factors not easily found in distant or isolated places. Maybe, it would be better to use systems which although not as reliable, may be used more broadly. Thus, we sacrifice some quality in exchange for greater coverage.

The magnitude and diversity of our present knowledge makes it necessary that studies such as zoonosis have a multidisciplinary focus, provided that they be integrated in a common plan of action in whose outline individuals from various activities participate; from the sociologist and economist, to the specialist studying viral molecules. All of whom, among other things, should listen, discuss and bear in mind the opinion of the people whose countries they expect to benefit. Among the diseases affecting man and animals, we have those caused by hematophagous arthropods, which when feeding on vertebrates transmit biologically or mechanically, causal agents such as: metazoan-like filarias, protozoan-like hemosporidias and hemoflagellates; bacteria such as bubonic, tularemia and recurrent fevers; rickettsias; the epidemic typhus, the murine type or spotted fever transmitted by ticks; and, finally, viruses like yellow fever, equine encephalitis, etc.

To understand the ecology of these agents it is necessary to accumulate evidence about their vectors, assuming that their isolation from arthropods, not filled with blood, is a reason to believe they are involved in the biological cycle of the organism. Ample and detailed entomological information can show not only the habitat of a particular etiological agent but also, in a general way, the group of vertebrates that should be considered in their natural history.

To define the role an arthropod can play in the perpetuation of an agent we must remember that a low density of a vector can be compensated by: (1) a short extrinsic incubation in the vector; (2)

long life of the arthropod; (3) arthropod resistance to unfavorable conditions such as dry seasons, cold winters, etc.; and, (4) an ample spectrum of vertebrate hosts susceptible to bites and good multipliers for the agent. On the other hand the low effectiveness of some of these factors named above, or the combinations of one with another, can be compensated by a high density in the vector populations.

Two facts of great importance for the perpetuation of some germs, are: the hibernation of infested hematophagous arthropods; and the transovarial transmission of etiological agents which is observed, especially in ticks and which recently had been found in mosquitos with some arboviruses.

The vertebrate type in which a particular arthropod specie feeds can be defined by several methods including simple fact observations, the use of traps with different lures, and the identification by precipitin test of the blood ingested vectors captured in natural conditions.

Remembering that the isolation of a virus, for example, from a particular mosquito, if it is backed up by epidemiological evidence, can then incriminate a particular species as the main vector. Nevertheless, the final proof of such a condition, will be given by the positive results of transmission tests made with mosquitos taken in the field. Another similar alternative is to experiment with mosquitos reared in the laboratory, bearing in mind that by colonizing a specie at the insectary, a selection has been made, hence, eliminating those predominant in nature.

In the field of hematophagous arthropods exciting research themes are posed, whose results may have practical implications of immediate applications for the control of diseases carried by hematophagous arthropods. The work done must have a multiple focus, considering not only the arthropod but also its biology, environment, the vertebrates on which it feeds, etc.

Students from our countries pursue careers, in the universities of the most advanced countries, in programs of irrefutable quality with the purpose of getting an academic degree. One necessary requisite, is that the thesis be done under the supervision of prestigious scientific supervisors. It is not much to ask that the thesis deal with subjects directly applicable to the countries to which they belong, and, also, that the thesis relate to activities the student will develop when coming back.

We, also, see the inconsistency of training the student for a most difficult procedure in microbiology, when the fundamentals have still been ignored. It is dangerous for a person without the basic knowledge to interpret all the alternatives, to go on with methods he does not fully understand. On some occasions, these different training programs are only creating a generation of magician apprentices.

I can give two examples which say a lot about the risks of seeing too much or not seeing at all, when there is not the competence to interpret what is being done. The first case occurred some years ago, when as an official of the Institute 'Carlos Finlay' of Bogotá, I went to investigate a serious epidemic affecting a Colombian city; mine was short-term work, simple and effective, since all I did was to verify that everything was the figment of someone's excited imagination when faced with the fascinating spectacle of a dark microscope field which he could not decipher. On the other hand, during the 1930's the department of Nariño was struck by an epidemic causing thousands of deaths. It was a feverish and anemic disease with a high mortality. Among all the etiological possibilities malaria was considered but discarded because of the negative results from the patients' blood slides. Without a doubt those who made the exams did not see, or overlooked, **Bartonella bacilliformis** which would certainly be abundant in such preparations.

It is surprising the number of trained people in a laboratory who are capable and competent under normal conditions, but when something goes wrong they lose their effectiveness. We might explain this as due to their ignorance of the fundamental facts, such as: the composition of a dehydrated culture which they have bought; the method of preparing a compound for immunoflorescence that they buy "ready to use", etc.; also, a person working in microbiology should prepare, at least once, an ordinary broth culture starting with the meat and becoming familiar with the stages from washing to the sterilization of the material. He should know how to bleed a lamb and fix the red blood cells for the complement fixation test; learn how to change the centrifugal brushes without having to put the machine in the shop, etc.

If cultural shock makes adaptation difficult in a foreign country, it is also hard for the students to readapt when they return home. It is not uncommon for them to blame local conditions, which always existed, for the failures arising from their own mistakes.

I would like to say, before concluding, that I am pleased to see, once more, friends of so many years and of having the opportunity to visit this center in which, no doubt, many of the aspects that I outlined for you have been considered for its organization and function.

Survey Techniques for Tick Species Affecting Domestic Animals

Jane Walker *

Ticks are certainly the most important external parasites of domestic animals in Africa and, although I am not equally familiar with the situation in your countries, I am sure that they are as important here because of the damage that they cause and the diseases they spread. In many parts of Africa they constitute a limiting factor to successful stock farming unless measures are taken to control them.

No two species of ticks are exactly alike in their habits, life cycles, distribution and ability to transmit pathogens. Consequently, it is essential when difficulties do arise to know with which ticks one is dealing. When one has adequate information beforehand, it is often possible to prevent difficulties from developing. For example, when animals are moved from one part of the country to another a knowledge of the tick species and tick-borne diseases that they may bring with them, or to which they may be exposed in their new environment, can prevent losses for the farmer. So one can say that a knowledge of the precise distribution of the different species with which one is dealing is an essential prerequisite to the control of both ticks and the diseases they carry.

Before going on to discuss the various techniques involved in carrying out tick surveys, I should like to say just a few words about tick identification. Obviously, it is no use going to all the trouble of

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collecting vast numbers of these parasites unless the personnel and facilities for accurate identification of adult ticks are available. Ideally, of course, one should be able to identify all stages of all the species occurring in the area one is studying but there are few, if any, parts of the world where this situation prevails. In South America a great deal of the essential taxonomic spadework apparently still remains to be done. In their 1972 report on the ticks of Venezuela, the workers at the Rocky Mountain Laboratory comment: "The number of immature **Amblyomma** that are unidentifiable emphasizes a basic problem in the study of South American ticks. Life histories of most species are unknown and few have been reared in the laboratory. Confusion has been compounded by the fact that the larvae and nymphs are often taken on different hosts. A great contribution to the knowledge concerning ticks of this area could be accomplished by basic laboratory and field studies of their life history". I gather from the CIAT Animal Health section of the Annual Report for 1974 that this problem is well recognized here and a start has been made on some of these basic studies by establishing colonies of **Boophilus microplus** and **Anocentor nitens**. I imagine that when live specimens of any of your other tick species become available attempts will also be made to breed them in the laboratory. Even if you do not keep every strain going subsequently —and this involves a great deal of work if you have a lot of species— a good F_1 series of each for use as reference material would be invaluable. In fact, I would go as far as to say that it is essential, especially when one starts on tick identifications, to have good, reliably identified collections (preferably laboratory reared) of at least the common species with which to compare one's field collections. Of course, sometimes one has to rely on descriptions alone and, provided these are well illustrated, one should be able to make an accurate diagnosis from them, but it is always preferable to make a direct comparison between actual specimens whenever possible. Some people, of course, like working with keys, though I myself do not, and it can be extremely frustrating if the key one is using does not include all the species in the area one is working in. Also, although keys can be used as a starting point they are not always reliable for a final answer.

In Africa, South of the Sahara, i.e. the Ethiopian region, surveys have been made to a greater or lesser depth in many countries. We now know quite a lot about the host range and geographical distribution of many of our more important tick vectors of disease and, on the basis of this information, can sometimes predict with a reasonable degree of certainty which species are likely to occur in areas which have not yet been surveyed. I shall begin by describing techniques used in two of these tick surveys, covering South Africa and Tanzania, with a few comments on the Kenya survey.

The South African survey was started in 1937 as part of the general Zoological Survey, its object being simply to obtain more detailed information about the occurrence and distribution, both geographical and seasonal, of the local ticks. The State Veterinary Officers in the field were made responsible for the collections and each officer was instructed to divide up his area into several blocks, according to the altitude, vegetation, rainfall, and burning practices, and to select three or four farms in each block. On each farm the ticks were to be collected from cattle at definite times representing the four seasons of the year. These collections were then forwarded to Onderstepoort for identification. This task was carried out by Dr. Gertrud Theiler, with whose name the survey is now associated.

Now this probably all sounds very nice and neat but, as Dr. Theiler herself pointed out in her introduction to the first paper she wrote on this survey, dealing with **Amblyomma hebraeum,** the South African vector of heartwater of ruminants, there were snags. Since her comments are as true today as they were in 1948, when they were written, I propose to quote them to you in full. She says:

> "Faunal surveys, planned essentially for the mere plotting of the distribution of a particular group of animals, are always at best but ecologically incomplete. The very nature of the present survey, in which the collecting was carried out by numerous individuals, not one of them a trained ecologist, stationed in different parts of a large tract of country showing a great range and variety of climatological, physiographical, biotic and other conditions, leaves much to be desired from the strictly ecological point of view. The setbacks to a properly controlled sub-continental survey are numerous; thus an officer already stationed for some considerable time in an area of control would experience no difficulty in dividing up his district into representative blocks, whereas one but recently appointed to an area would not be familiar with its vegetative zones and his division of his territory into collecting blocks would be faulty. Apart from the above unevenness in the parceling out of collecting blocks, the human element of the collector is an added inequality (some individuals just do not make good collectors). Nor are all officers always in a position to make systematic collections at the quarterly intervals, due to the greater importance of routine or of extra-routinary matters. Thus, to obviate and eliminate some of the grosser unevennesses from the final plotting and to check up on the

suitability or on the completeness of the collections which were being sent in, trial plottings of three of the more prevalent species of ticks were carried out early in the survey. According to the findings of this preliminary survey further collections were called for from some areas to fill apparent gaps in the vegetational zones or to check up on the human element as a factor, as well as to counteract the attitude "ticks are scarce now, so no collections have been made this winter. The collections will be resumed again after the first rains when tick life will be more abundant".

"The very inequality of the collections makes it difficult to interpret the results consistently. The ideal collection theoretically was four collections from each block spread over four consecutive seasons; but this could not always be done and the collections varied from the ideal four down to one, or worse still, none at all. In one district the officer concerned was able to send in a monthly collection spread over fifteen months. The four-time collection in conjunction with the fifteen-time collections, gave, as it were, some standard of reliability of the three-, two- or one-time collections. In those instances where any one given species appears four times in the quarterly collections it can safely be assumed that the collection as a whole was adequate and that not only was a given tick present, but that it was also safely established in the area; if it occurs three out of four times then the same conclusions can be drawn as to the adequacy of the collection and as to the establishment of the tick; here the tick may be absent due to the fact that it shows periods during which it does not feed. But if the tick is present less frequently, then the interpretation is not so straightforward, and several explanations are possible: either that the tick is present and established on the farm but the collecting was not too good (for some collectors are bad); or that the collection was adequate and the tick was but recently introduced and was not established, or that the tick had a long nonfeeding period; further if the tick is absent in the neighbouring collecting areas then it is concluded that the record is one of a recent introduction. Cases where only one batch of specimens is sent in present the most difficulties, and hence the conclusions drawn from these records are the least reliable, for the absence of e.g. **A. hebraeum** may not be truly absent for the reasons enumerated above; however, though one-time collections are most unreliable for recording the absence of a species, they are yet valuable for their positive records of the presence of the tick, and hence serve the main purpose of the survey, namely the plotting of the areas in which the tick has been proved to occur.

"In spite of the shortcomings inherent in such a generalized survey, it has nevertheless been possible in many instances to draw definite conclusions as to the factors encouraging or discouraging the increase of various tick species, and hence as to their distribution in South Africa."

The value of the cattle tick survey was enhanced by the Zoological Survey of the Union covering wild animals, running concurrently, from which Onderstepoort received all the external parasites collected. At the same time, engorged female ticks were called for from various regions and their progeny reared in the laboratory. These rearings not only revealed the possible range of variation in the F_1 adult generation of a given species but also linked up the adults with the right immature stages. By identifying the larvae and nymphae occurring on the animals collected in the Zoological Survey, it became possible to work out the different ticks' life histories and thus indicate which wild host might have to be considered as possible reservoirs of pathogens affecting domestic animals.

One very important point Dr. Theiler notes is that the survey was based entirely on ticks that were examined and identified in the laboratory; no notice was taken of any verbal statements. This is an absolutely essential point. Most farmers in South Africa, not to mention a good many veterinarians and stock inspectors, will say that they know, for example, what a blue tick is but when they are asked for specimens the variety that one gets is sometimes quite remarkable.

Broadly speaking, Dr. Theiler related the distribution of the various species with which she dealt to the altitude, rainfall and vegetation, and in some instances, to frost. Obviously, the effects of these factors are interrelated and a particular species may be able to exist at, say, a higher altitude than one might otherwise expect if it is protected by a denser vegetative cover. **Amblyomma hebraeum**, for example, can survive at higher altitudes in bush or scrub-covered areas than it can in tall grassland. It is completely absent from the short grass areas. This is perhaps an appropriate moment to point out that vegetative cover is liable to change and when this happens changes can also be expected in the local tick fauna. In some parts of South Africa **A. hebraeum** is extending its range in the wake of bush encroachment and in others, **Ixodes rubicundus**, the Karoo paralysis tick, is following the spread of Karoo-type vegetation into the short-grass veld of the Orange Free State.

In a few cases Dr. Theiler found, when she had drawn up her tick distribution maps that they did not make sense when she tried to relate them to the various environmental factors i.e., some ticks seemed to occur under widely differing ecological conditions. At the time, she said such findings suggested that two or more tick species which looked very much alike, but had differing ecological requirements had been lumped under one name. Current research is now confirming this.

I will now turn to the ixodid tick survey that was carried out in Tanzania during a 10-year period from 1955 onward.

Here the **modus operandi** was very different from that in South Africa. At the start a single Veterinary Research Officer, Guy Yeoman, was assigned to the project and worked on it full time for six years. During this period he and his small, carefully-trained team of assistants made tick collections in all nine mainland provinces and in all but two of the 55 districts in the country, which altogether cover an area of over 885,000 sq. km (342,000 square miles). This meant that there was a high degree of uniformity in the methods used and there is no doubt that the results achieved were due primarily to his energy, enthusiasm and dedication. Quite early, I became involved in the project as taxonomic referee, with the job of trying to identify the more unusual and difficult specimens as well as identifying some of the field collections. Somewhat later, we were also joined by two other veterinarians who worked part-time on the survey.

The Tanzania survey was based primarily on the ticks of cattle and the areas in which these animals are kept were all covered by carefully planned collections. These cattle collections were supplemented in places by collections from other domestic animals, and sometimes from wild animals. It was impossible, though, to cover the whole country equally thoroughly. For one thing there are enormous areas in Tanzania that are still infested by tsetse flies and these are, by and large, sparsely inhabited, so few —if any— collections were made there. (There is no doubt that in the future more attention will have to be paid to these parts of the country as the expanding human population pushes its way into them, taking its domestic animals—and, no doubt, their parasites—with them.)

To give you some idea of the work involved in the Tanzania Survey, over 180,000 adult ticks were collected from cattle alone. If you add to this the considerable numbers of ticks obtained from other animals included in the survey, plus the larvae and nymphae, and then remember that every specimen was examined at least once under the microscope, you will begin to realize why it took us about 10 years in all to complete this survey!

The basic collecting team consisted of a group of five people, always led by a trained and experienced collector and including someone with local knowledge, traveling in a Land Rover. This team worked systematically through each district, taking care to include all the different physiographical, climatic and vegetational zones assuming of course that animals, preferably cattle, were available. I have sometimes been asked what the distance between collecting points should be but for a general survey like this, covering a very large area, it is really impossible to lay down hard and fast rules. It may depend on the availability of animals and it also depends very much on the nature of the area itself: obviously, in an ecologically diverse region it will be necessary to make more closely-spaced collections to get a true picture of the tick species present than in an ecologically uniform one. For example, if one took a transect running 20-25 km southwards from the top of Mt. Meru, just outside Arusha in northern Tanzania, out into the Masai plains one would pick up representatives of at least three different groups of tick species with quite different and distinct ecological preferences. In other parts of the country, however, one could easily cover far greater distances and still remain in ecologically the same type of terrain. It follows, therefore, that one cannot necessarily expect to make exactly the same number of collections every day: Mr. Yeoman found that under ideal conditions he could sometimes make up to eight collections, each from three beasts, per day but this was very hard going—usually he only made about five or six. In sparsely inhabited areas, though, he sometimes found it took him a couple of days or so to get even one collection.

In every case, as soon as a collection was completed, full details were entered in a field record book, including the collection serial number, the number and description of the animals used, the place, date and the senior collector's name. Additional notes were made on such features as the altitude and vegetation and local opinions on the tick and disease position, including calf survival rates. The degree of infestation with **Boophilus** was also noted since, purely for practical reasons complete collections of blue ticks were not made as a rule. Any special points about other ticks present, such as their attachment sites, were also recorded.

Before going on to talk about the collecting techniques themselves I should just like to say a little about host and place names. As I said earlier, our interests, like yours, were mainly in the ticks of domestic animals. When the opportunity occurs, however, I feel that, in surveys like this, collections should also be included from wild animals. This does not mean, though, that I would advocate going out and catching every wild creature in sight simply to find out what tick it is carrying. Tick collections can often be made during the course of other studies. In many parts of Africa there is at present great interest in the biology of all sorts of wild animals, ranging from rats to elephants, and we have sometimes obtained excellent tick material from zoologists and other scientists engaged in these studies. In all instances, the full scientific name of the host animal should be put down if it is at all possible. Even if this name is changed subsequently by some enthusiastic taxonomist a scientific name is much easier to track down than a popular one, whose use may be restricted to one particular area and of course a scientific name has the additional merit of being the same in any language in the world!

So much for host names—now we'll turn to place names. In the past, place names, or what I thought were place names, have been the source of endless trouble —particularly when I was working on the Kenya survey. Some, of course, were easy enough to trace but others have upon investigation turned out to be anything from old farm names to the names of deceased native chiefs. I have now come to the conclusion that the one and only way to pinpoint a locality permanently is by recording its geographical coordinate —even the politicians haven't got round to changing these yet! When tick collections are being made, therefore, I feel it is extremely helpful for the senior collector in a team to have available detailed maps of the area, if possible at a scale of 1: 250,000 or 1: 500,000. The exact site of each collection can then be marked on the map itself or alternatively, other nearby places, the distances from known points or some such references can be entered in the Field Record Book. The precise coordinates can then be worked out later and entered in the permanent records. This means that, when the distribution maps are finally drawn up, it is easy to plot all the records accurately. It also means that if for any reason another survey is done later, the same collecting points can be revisited. This can be very important in all sorts of studies ranging from taxonomy to investigations on the spread, or retreat, of either the ticks themselves or the diseases they carry.

In the Tanzania Survey, our basic "collection unit" for cattle was three adult animals. A statistician might well quibble about using such a small number but Mr. Yeoman found that this is about the maximum that can be dealt with at one time in the field over a long period under trying conditions. It is also about the maximum that local cattle owners and helpers will tolerate. Each beast was caught in turn, cast and firmly restrained by one man at its head, one kneeling behind the hump holding its upper foreleg in a fully flexed position and a third pulling a rope tied to its hind legs. Care was taken to keep its head up-slope and to safeguard its lower eye, also, to see that it could breathe properly. If the tick collection took a long time the beast was allowed to rise to its feet periodically to avoid the danger of bloat. A fourth man was put in charge of the collecting bottles, leaving the collector free to search for ticks.

The examination of each animal was carried out according to a strict routine, starting with its ears and head, then working back along the undersurface of its body to the perianal area and down the tail to its tip. Its feet and legs were inspected, followed by the back, rump and flanks, then the beast was turned over and the remaining parts of its body searched. During this examination each tick was grasped quickly, with the flat of the forceps across it so as not to puncture it and as near to the anterior end as possible so as not to decapitate it, and then turned over, pulled off the skin gently and immediately put into 70 percent ethyl or methyl alcohol. When large collections were made, especially if there were a lot of engorged females present, the alcohol was subsequently changed several times to ensure that all the specimens were properly preserved. Finally, a label with the district serial number was placed **inside** each collection bottle. These labels were written beforehand in black waterproof ink on good paper. Labels stuck on the outside of bottles are not satisfactory as they tend to get dirty and semilegible or come off altogether.

As was pointed out earlier, the South African tick survey was based on quarterly collections because it was well known that the activities of the different stages of these parasites are definitely seasonal there. In an equatorial country like Tanzania, however, one can usually find at least a few adults of the commoner cattle ticks throughout the year. Even so we should have liked to make several collections at each point in our survey but we decided against it because, under the prevailing conditions, it would have meant relying on relatively unskilled local staff to do much of the field work for us and we knew from practical experience that this would be unsatisfactory. Instead, two areas —Sukumaland, representing the central plateau and one of the most important cattle areas in the country, and Iringa, representing the highlands— were chosen for special study. Careful seasonal collections were made in these areas over a period of several years under our own supervision and these gave us an idea of the seasonal activities of our commoner cattle ticks.

All our specimens were identified in the laboratory under a microscope. After examination each collection was replaced in a carefully labeled bottle and at the end of the survey these bottles were assembled under their district serial numbers and stored. If it is possible I feel it is important to retain such collections because one inevitably finds later that one wishes to go back and re-examine some of them.

This is perhaps an appropriate point at which to say something about suitable containers and preservatives for ticks. I hope you will forgive me for mentioning what you may think is an elementary subject but it has in the past given me a great deal of trouble! For collecting in the field we used wide-mouthed glass bottles of about 60 ml (2 oz) capacity with metal screw caps. These hold plenty of preserving fluid and one can briskly shake one's forceps in them to dislodge ticks clinging to tips. These days, similar shaped polyethylene bottles may be available. Thin glass specimen tubes are useless because they break too easily, and containers made of the clear, rigid type of plastic become brittle in time and then break. Wide-mouthed McCartney bottles (universal containers) are very practical for the long term storage of specimens. The black rubber liners inside the screw caps deteriorate in time when in constant contact with alcohol or formalin plus chloroform and should be replaced either with cork liners faced with tinfoil or, I'm told, with liners that are now being made from a chemically inert butyl rubber. For inornate ticks, 70 percent ethyl alcohol is a good preservative. For ornate species such as **Amblyomma**, however, a solution of one part of concentrated formalin (containing 40 percent formaldehyde) with seven parts of distilled water, saturated with chloroform (a little is simply poured into the diluted formalin), gives much better and more long-lasting preservation of the color patterns. In fact the color pattern of an **Amblyomma** that has faded after long immersion in alcohol is sometimes partially restored if it is soaked in this formalin/chloroform mixture.

To get back to the Tanzania Survey, when the identifications were completed all the information in the field and laboratory records for each collection were transferred to the appropriate District Record Book. Finally, a complete list of the material utilized in the survey was compiled and used as the basis for our text.

You will find, when you come to do a tick survey, that the field work and subsequent identification of your specimens only represent about half the work involved! Getting the results together, sorted out, written up and through the press is a long, tedious, but ultimately extremely worthwhile process.

In the Tanzania Survey we begin with a fairly detailed description of the country itself and its physiography, vegetation and climate, plus an account of the livestock industry, as the background to our information about the ticks.

Each tick species is then dealt with in turn, in alphabetical order for easy reference. References to one or more good descriptions are given for each, plus information on any particular points that should be noted when identifying it. (We were subsequently criticized for not including either keys or description but we felt at the time this was unnecessary, and furthermore, it would have greatly delayed the completion of the work).

A section on the host relationships of the tick follows. In this we list, among other things, the number of stations and/or individual animals of each species that have been examined during the survey and the number from which the tick in question has been obtained; this gives some idea of the frequency with which a particular host is infested by a particular tick, and is important.

The next section deals with zoogeography and includes a map plus descriptions of the tick's distribution in terms of the political divisions of the country and its physiography, vegetation and rainfall.

Several features regarding the maps deserve special mention. It is a good idea to draw the tick distribution map on transparent drafting film. This map should be on the same cartographic projection and at the same scale as the reference maps of the area so that, when complete, it can be laid over each of the reference maps in turn. It is then easy to determine, in general terms, the tick's ecological preferences in the area.

Besides the positive symbols indicating the presence of a particular species, we originally intended to plot negative symbols also, showing where it was absent from collections as Dr. Theiler did in her survey. For practical reasons we abandoned this idea. Instead we produced a master map, showing all our collecting stations, and a comparison between this and a tick distribution map, particularly for one of the common cattle ticks, immediately shows whether the blank spaces on the latter represent the absence of the tick or are merely areas where no collections have been made. (It is of course less useful for the rarer species).

A transparent copy of the political divisions map is included in a pocket at the back of the book and this can be laid over any of the other maps; this is very helpful and I wish we could have included overlays of the other background information maps too, but it would probably have increased our costs too much.

The final section under each individual tick species deals with its disease relationships, if known, and the work concludes with a host/parasite list, a short discussion of several conclusions that we drew from the survey as a whole and a list of references. Our final conclusion is that "field workers should base the delimitation of disease zones squarely on the proved distribution of the tick vector, as revealed by systematic survey work".

I wish to say very little about my more recent study on the Ixodid ticks of Kenya. A proper survey covering the whole country has never been carried out but a great many records had accumulated, often very haphazardly, over the past 30-40 years and it seemed to be worthwhile to analyse and review them. It is really quite surprising how much information there is, now that it is all put together, using much the same format as we did for the Tanzania survey. I thought it was worth mentioning this in case a similar situation applies in any of your own countries.

The surveys described so far were designed to determine tick distribution, and their host preferences, over large areas, I should now like to discuss, more briefly, the techniques employed in one other highly specialized survey designed to determine the predilection sites of some of the common cattle ticks and their seasonal activities in Natal, the eastern seaboard province of South Africa.

This survey was carried out by Drs. Maureen Baker and Du Casse of the Allerton Veterinary Investigation and Diagnostic Centre, near Pietermaritzburg, in a 15-month period from 1965-1966. Their aim was to determine the predilection sites of the common cattle ticks in Natal, and the seasonal variations in their activity, in the hope that existing control measures could then be modified and improved.

Weekly collections were made from two undipped calves on each of two representative farms, one well-managed and with good vegetative cover and the other with sparse vegetative cover, at four successive altitude levels, i.e., in the coastal zone (up to 1,000 ft), the thornveld zone (3,000 - 5,000 ft), the mistbelt zone (3,000 - 5,000 ft) and the highveld (over 5,000 ft). The calf's body was divided into 18 areas, each of which was dealt with separately, listed by the authors as follows:

(1) **Muzzle.**
(2) **Periorbital zones.**
(3) **Head** (delimited by a vertical line drawn from the base of

the ears ventralward over the throat latch but excluding one and two).

(4) **Pinnas** (both surfaces).

(5) **Ear passages.**

(6) **Poll** (including mane and upper neck border to withers).

(7) **Neck** (lateral surfaces).

(8) **Dewlap.**

(9) **Axilla** (delimited by a line joining the points of the two shoulders cranially and by one running from one olecranon to the other caudally).

(10) **Sternun** (caudal, sternal and xiphoid regions up to the umbilicus).

(11) **Belly and groin** (postumbilical and inguinal regions including udder/scrotum).

(12) **Lower perineum** (ventral to vulva in the female or anus in the male to base of udder/scrotum).

(13) **Upper perineum** (from base of tail around anus, including vulva in the female).

(14) **Tail.**

(15) **Tail brush.**

(16) **Feet** (below fetlocks).

(17) **Legs** (from fetlocks to elbows/stifles).

(18) **Rest of body** (lateral thoracic, abdominal, gluteal and femoral regions).

The ear passages were carefully deticked with a fine spoon curette. On the other sites the larger ticks were first removed with forceps and the site then thoroughly combed with a fine nit-comb to remove the remaining ticks, especially the larvae and nymphae. These combings were collected in a stoppered plastic funnel which had one side flattened simply by pressing it against a warm electric plate. From this funnel they were transferred into separate, permanently labeled plastic bottles for transport back to the laboratory.

In the laboratory it was found by experience that the best way to deal with the collections, which contained a lot of debris as well as ticks, was to put each in turn, into a special 100 mesh stainless steel sieve and then immerse the contents in a boiling 10% NaOH solution to dissolve the extraneous hair and wax. Great care has to be taken not to boil the ticks too long or they burst and are then almost impossible to identify. After boiling, the contents of the sieve were washed into shallow 15 cm (6 in) petri dishes and a random sample was taken for examination —a necessary procedure because of the enormous numbers of ticks sometimes obtained. This example was taken by dropping into the petri dish a specially made divider, consisting of eight fine metal pins radiating from a central pin, which separated the contents of the dish into eight equal compartments. Two compartments were then chosen, according to a biometric random numbers chart, and all the ticks in them were sorted, and identified microscopically.

As a result of this survey the authors were able to work out very precisely both the predilection sites of their commonest tick species and their seasonal activities.

In conclusion, I have described to you several different methods of carrying out tick surveys. The method chosen for any particular area should be governed, firstly, by what one wants to find out and, secondly, by the available personnel and facilities. Dr. Theiler has often told me that, when she did her survey, she was very much hampered by the lack of adequate maps. Today, we in Africa are fortunate in that most parts are well mapped and, in addition, we have in almost every country the excellent gazetteers issued by the United States Board on Geographic Names. This Board has also issued similar gazetteers for nearly, if not all, South American countries and, if you can lay your hands on them, you will find them invaluable.

I am now looking forward to hearing how far you have got in South America in determining the distribution of your tick species.

Current Knowledge of Tick Species Distribution in Latin America

Gonzalo Luque *

The livestock industry is one of the major economic potentials on this continent if we consider the extent of pastures, the old cattle raising tradition, and the worldwide rapid demographic growth and meat shortage.

Among many of the negative factors preventing proper development of this industry are ectoparasites. Of these, ticks are the most costly for animal production in Latin America.

Ticks are external parasites belonging to the Kingdom Animal; Sub-Kingdom-Metazoan; Phylum-Arthropoda; Sub-Phylum-Tracheata; Class-Arachnida; Order-Acarina; Family-Ixodidae; Sub-family-Rhipicephalinea, Amblyomminae, and Ixodinae; Generas-**Boophilus**, **Amblyomma**, **Dermacentor**, **Rhipicephalus** and **Ixodes**[1].

Accurate tick identification is an essential requisite for their control, and to justify rigorous quarantines and the high cost of eradication programs. Much work has been done on morphology, taxonomy, prevention or control of tick infestion in cattle. However, there is not enough information about distribution of certain species in some areas of this continent.

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[1] *Editor's Note* — The classification of ticks is generally indicated as Family-Ixodidae (hard ticks) and Argasidae (soft ticks); Genera-*Ixodes, Haemaphysalis, Boophilus, Rhipicephalus, Amblyomma, Dermacentor, Argas, Otobious, Ornithodoros, etc.*

One host ticks

Boophilus microplus (Canestrini 1887), 'Tropical Cattle Tick'

Morphological characteristics: It is a tick with very short and compact palps. The hypostome dentition is 3/3 and the basis capitulum dorsally is hexagonal. The scutum is not ornate. Eyes are present and spiracular plates are round or oval. The male has a posterior caudal lobe; in the female, coxae I have internal and external spurs, wide, round and wider than long. Coxae II and III have external spurs similar to those of coxae I. Coxae IV have external, very small spurs or are without them.

Distribution: It is found in Mexico, Central and South America, West Indies, the Caribbean, Australia, Asia, Africa and the Orient. In Colombia, it has been found in the middle and hot zones of the country. **B. microplus** is the tick of major economic importance in Latin America; it affects mainly bovines, but also, equines, caprines, dogs and deer.

Boophilus annulatus (Say 1821), 'Cattle fever tick'

Morphological characteristics: It is similar to **B. microplus**. The male lacks posterior caudal process. In the female, coxae I do not have internal spurs and external spurs are broadly rounded, wider than long. Coxae, II, III, and IV are without external spurs.

Distribution: it is found in Mexico, Central America, Asia, Sudan, West and Central Africa, Mediterranean basin, Near East. In Colombia, it has been found in the municipalities of Bogotá, Suba, Usaquén, Usme, Cajicá, Guachetá, and Pasto (Departamento of Nariño). This tick is close to extinction in the cold zones of the country. **B. annulatus** affects bovines, domestic and wild ungulates.

Dermacentor (Anocentor) nitens, (Neumann 1897), 'Common Horse tick'

Morphological characteristics: Palps are short and scutum is not ornate. It has eyes, an oval spiracular plate with 4 to 10 goblets, 7 festoons and coxae I have widely divergent spurs.

Distribution: D. nitens is found in Mexico, Central America, the Caribbean, southern tip of Texas and Florida, and Argentina. In Colombia, Reyes reported for the first time the presence of **D. nitens** on bovines in Palmira. Later Huber Luna found this tick on 11 farms from seven municipalities of the Cauca Valley.

In 1969, Todorovic, Luque and Adams in a study about Ixodid distribution in Colombia, collected ticks over period of one year from bovines of different breeds (Holstein, Zebu, Blanco Orejinegro, Costeño con cuernos) and found them to be infested with **Babesia bigemina** and **B. argentina**.

The infection of these animals was determined by blood smears and complement fixation tests. As a result of this study, **D. nitens** was found parasitizing bovines in Montería, Palmira, Buga, Bugalagrande and Sumapaz regions.

It has also been found on deer and **Hydrochoerus hydrochaeris**. A more complete investigation is needed to determine the role of this tick in hematozoarial transmission to the bovine.

Three host ticks

Amblyomma cajennense (Fabricius 1872), 'Cayenne tick'

Morphological characteristics: It possesses long palps. The hypostome dentition is 3/3. The scutum is ornate with abundant pale white marks distributed more or less in a form radiating from the center. The female has festoons with chitinous tubercles at a posterointernal angle.

Distribution: southern Texas, Mexico, Caribbean zone, Central and South America. This tick is a parasite of bovines, domestic and wild mammals and birds. It seems to be the second tick of economic importance in Latin America.

Amblyomma maculatum. Koch, 1844, 'Gulf Coast Ticks'

Morphological characteristics: Coxae I have internal spurs which are short and insignificant. Metatarsals II, III, IV, have two stout spurs on the distal extremity in the male and female.

Distribution: Regions of high temperature, rainfall and humidity bordering on the Atlantic Ocean, Gulf of Mexico, Jamaica and South America. In Colombia, it has been found on equines and canines in the middle and hot zones. Adults attack cattle, ungulates and man.

Rhipicephalus sanguineous Latreille 1829, 'Brown Dog Tick'

Morphological characteristics: Legs, integument and scutum are not ornate (brown) and have small punctations of moderate size. It has eyes, spiracular plates in a comma shape, and festoons are present. Males have adanal shields.

Distribution: This tick usually affects dogs all over the world. In Latin América, we find it distributed in Mexico, Central and South America, but there is not much information on its incidence and pathogenic action in bovines. **R. sanguineus** on bovines has been reported in Colombia in the municipality of Ambalema (Tolima).

Ixodes ricinus (Linnaeus, 1746), 'European Gastor Bean Tick'

Morphological characteristics: The palps are long. Eyes and festoons are absent. The spiracular plate is oval in the male, circular in the female. There are seven ventral shields in the male.

Distribution: There is not sufficient information about the distribution of this tick in Latin America. In Colombia, it has been found on bovines in Bogotá and Chocontá.

Summary

Ticks are one of the most serious pests of cattle and, of all the bovines' ectoparasites, they are the most costly for animal production in Latin America.

Proper identification and distribution of ticks is an essential requisite for their control and eradication. However, there are not enough trained personnel to carry on such a high priority task. Enough information about the distribution of some bovine tick species is not available, for certain areas of Latin America.

B. microplus is the most widely disseminated tick and one of major economic importance in Latin America. Nevertheless, there are other species affecting bovines, such as **Amblyomma cajennense** and **Ixodes ricinus** which should be thoroughly studied.

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Points Arising from Present Data on Tick Distribution in Latin America

David Evans *

A recent review (Evans, in prep.) of literature available to me at this time (which I am sure is as yet by no means exhaustive) on the tick species of Latin America revealed the situation summarized in Table 1. What becomes perhaps surprisingly apparent is the large number of species (170) already reported, i.e. nearly a quarter of the world number (Hoogstraal, 1973); also the breadth of genera (11-12) to which they belong; of the major world genera only **Aponomma** and **Hyalomma** have not been reported. As recently as Spring 1975 (FAO expert consultation on ticks and tick-borne diseases) Latin America was still considered a highly under-studied tick region and it is therefore probable that the real tick fauna in nature will prove to be much broader in species.

Thus, when planning tick studies in Latin America we have the definite problem of deciding on priorities. I would like, if I may, to offer for discussion points that have arisen during my own studies, and place them in two sections — those pertaining to: (a) known tick pest species; and, (b) potential tick pest species.

(a) It has been generally established that **B. microplus** represents the major tick species of economic importance to the cattle industry in Latin America. However, there is still a need for us all to exchange **recent** species lists to establish the present international limits of this, and other possibly widespread ticks. Much of the literature on which we currently depend is based on old and scattered reports; these

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TABLE 1 Summary of the Latin American and Caribbean tick fauna.

Family	Genus	Number of species: Colombia	Latin America	World *
Ixodidae	*Ixodes*	12	48	250
	Amblyomma	30	52	100
	Dermacentor	1	11	31
	(D. Anocentor)	1	1	1
	Haemaphysalis	4	6	150
	Rhipicephalus	1	2	63
	Boophilus	1	2	5
Argasidae	*Nothoaspis*	0	1	—
	Argas	4	7	50
	Ornithodoros	13	34	94
	Otobius	0	2	2
	Antricola	1	4	4
Total	11 (12)	68	170	750
		9%	23%	100%

* Hoogstraal, 1973.

need updating in terms of possible increase or decrease in the species actual or known range, or corrections due to advances in our knowledge of their taxonomic status.

A second requirement in extending our knowledge of the major tick pests is to define their distribution limits within our various countries and equate these with topographic and if possible climatic variation. We have heard from Dr. Jane Walker (1975) both of the effort but also high rewards of such studies. Once we have a reasonable idea of those regions that provide ideal and marginal conditions for the survival of such ticks we would be in a good position to conduct rational, intensive ecological studies on each important specie with stations at strategic locations with respect to its ecological requirements.

(b) Let us now look at potential pest species of ticks. I think such a consideration is necessary because a rich tick fauna creates a more complex situation with respect to their control. We do not have the same, more simple situation as one of the other **Boophilus** - plagued continents, Australia, that appears to have relatively few tick species other than **Boophilus microplus.** Thus, although we may learn much from their experience, there may be important modifications to incorporate. The question arises, which of these other numerous tick species should we worry about?

The first problem concerning potential pests I would like to consider is the comparative impact of closely related ticks as vectors. Recent taxonomic reappraisal of certain species has given separate species status to several ticks that were once recorded as one. Examples of those that may be pertinent to the cattle industry are **Amblyomma cajennense** which is now known (at least in Mexico) to have included a smaller form, **Amblyomma imitator** (Kohls, 1958). Also, early reports of **Amblyomma maculatum** showed the tick to be widespread throughout the countries of Latin America. It is now known to have consisted also of **A. tigrinum and A. triste** (Kohls, 1956a). The geographic distribution of these species (which are fairly simple to distinguish taxonomically) now needs reappraisal. As Dr. Jane Walker (1975) has indicated, no two species are precisely alike in their requirements for survival. It remains to be studied by the epidemiologist and ecologist whether they are significantly different to warrant special attention from the man for whom we are really concerned-- the stockowner.

Lastly, could I raise the question of how much attention should be paid at this stage to the problems associated with the increased host-range of ticks in Latin America due to man's activities in the cattle industry. These new tick-host relationships may be summarized as an equation:

$$\text{WILDLIFE} \underset{\text{EXOTIC TICKS}}{\overset{\text{INDIGENOUS TICKS}}{\rightleftharpoons}} \text{DOMESTIC STOCK}$$

This is the situation when domestic stock and their ticks are exposed to the indigenous fauna of a new country. The exotic ticks that survive continue to cause problems to the host specie on which they were introduced. They may also form reservoirs on the indigenous vertebrates. In addition, the introduced domestic stock may suffer ill effects by acting as exotic susceptible hosts to the indigenous tick species.

I would like to offer you a resumé of Latin American tick species which judging from the literature (Evans, in prep.) appear to have become involved to a greater or lesser extent in a cattle/horses/wildlife host spectrum. May I call on the delegates to offer their experiences on the economic significance of these species? It should be noted that generalist, non-specific host ticks usually pose the most problems in formulating control (or certainly eradication) regimes.

Summary of ticks with cattle/horses/a wildlife host spectrum

Ixodes boliviensis

This tick is considered a synonym of **I. bicornis** by Kohls (1956b) and is distributed throughout Central America and the Northwest of South America. It is reported as reaching high numbers, e.g. on dogs in British Honduras (Varma, 1973); there are other scattered reports including its presence on cattle and horses.

Amblyomma cajennense

It is usually quoted as the second most numerous of the widespread ticks in Latin America, after **B. microplus.** It is becoming a greater pest in localized regions. Now it may be necessary to study it separately from **A. imitator** as mentioned earlier.

Amblyomma coelebs, oblonguttatum and ovale

They are widespread throughout Latin America. However, judging from the literature the tick is present on wildlife and horses but not on cattle. **A. oblonguttatum** was the second most numerous tick specie in the British Honduras Survey by Varma (1973) (the first being A. cajennense).

Amblyomma maculatum, tigrinum, triste

It is apparently widespread but, as mentioned before, there is a need for recent accurate information. There is also a great need for more host information of **tigrinum** and **triste** to establish their origins; **triste** is at present so little known in terms of its host repertoire that it appears from the literature as an "indigenous tick of cattle". Ecological knowledge of these two "new" species is non-existent.

Amblyomma tapirellum

It is reported as a generalist species in Central and northern-South America.

A. tuberculatum

It has been reported on cattle but appears to be restricted to Mexico and Cuba.

A. variegatum

It is an introduced species on cattle from Africa; its present status in North-East South America and the Caribbean is unknown.

Dermacentor albipictus, dissimilis, occidentalis and **variabilis**

They are chiefly Mexican problem ticks as far as Latin America is concerned, unless inadvertantly introduced to the southern temperate regions of the continent where the seasonal climate may allow its unfortunate establishment.

Dermacentor (Anocentor) nitens

It is the well established Tropical Horse Tick of most of Latin America; the real economic damage of its infestations on horses (a vital component of our cattle industry) and on cattle is not established.

Haemaphysalis juxtakochi

There are scattered reports on cattle, horses and wildlife throughout Latin America but very little data on its significance as a pest, even on a localized basis.

Boophilus annulatus and **microplus**

They have clearly established pest status but does **B. microplus** form reservoirs on the indigenous Latin American fauna? It does not appear to have occurred when introduced to Australia. Is it still sufficiently unchanged physiologically to be able to transfer the concepts of its vector potential and ecology learned elsewhere?

Otobius megnini

It is a pest in localized dry regions all over Latin America. Is it at the final limit of its spread?

As a final word, may I apologize for the lack of real factual information in this brief communication but as Dr. Barnett said in his introduction of me, I have not been here in Latin America very long yet. I would like, however, to thank you all very much for the opportunity to have raised some questions, opinions of which I hope we will now hear.

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Summary of Discussions of Papers by:

Jane Walker
Gonzalo Luque
David Evans

Dr. Jose M. Payno from Bolivia, referred to a study which has been carried out over the last four years on the distribution of ticks in the Andes and Valley regions of Bolivia. The species identified at present are:

Boophilus microplus which is the most numerous species and the one causing the greatest problems. It has been found on bovines, equines, and ovines in Santa Cruz at 430 meters; in the departments of Beni and Chuquisaca at 145 and 420 meters, and most recently in the Cochabamba area at an altitude of 2,700 meters where previously, only **Otobius megnini** was detected. In Cochabamba there are also problems with anaplasmosis and babesiosis. However, it is not known if this problem originates from cattle in transit or if the tick vectors are being acclimated to the area.

Boophilus annulatus ticks have been infrequently encountered. The females are difficult to differentiate from **B. microplus** but since the males do not have tails, they are easier to distinguish between species.

Amblyomma cajennense has been found in sub-tropical zones on bovines, humans, deer, equine and ovine from 420 to 850 meters.

Amblyomma maculatum is less abundant; it has been found in the Santa Cruz area at 650 meters and in the Llanos at 430 meters,

Amblyomma americanum has been found on bovine, deer and humans between 145 and 623 meters.

Otobius megnini was found on bovines in Cochabamba, between 2,500 and 2,700 meters.

Dermacentor nitens was found on equines, bovines, and deer in the area of Santa Cruz.

Haemaphysalis sp. is believed to be present in Bolivia but has not been identified yet.

Rhipicephalus sanguineus was found in the Llanos in a subtropical area at 430 meters.

Ixodes scapularis was found in Santa Cruz on bovines between 1,980 and 2,000 meters.

Ornithodoros rostratum was found on pigs and humans, in Santa Cruz at 430 meters.

Dr. Marcelo Rojas from IVITA, the University of San Marcos, Peru, states that the incidence of ectoparasites is seasonal in the cattle zones of Pucallpa where the rainy season runs from October to March and the dry season from March to September. He indicated that in parasitism studies done with exotic cattle (which are more susceptible to tick infestations) the following tick species were found: **Boophilus microplus, B. annulatus, B. decoloratus,** and **Otobius megnini**. Of all ticks collected only one was found to be **B. decoloratus.**

Dr. Jane Walker from South Africa suggested that the presence of the one **B. decoloratus** specimen probably represented an aberrant species or was taken from an animal recently imported.

Dr. Luis G. Beltran from Mexico presented a summary of tick distribution in Mexico in a qualitative form and by State. The study took six years to complete with the participation of 3,000 collectors throughout the country. Ticks were collected from wild animals and bovines. At present 250,000 Ixodidae specimens have been examined and 25 species classified.

Dr. Walker added that inclusion of wild animals in a tick survey was very important in order to find the genera **Amblyomma.**

Dr. Gonzalo Luque (Colombia) asked Dr. Walker if the collections in Tanzania were made qualitatively or quantitatively. She replied that all the ticks presented were collected with the exception of **Boophilus.**

It was suggested by a number of participants that a tick reference center was needed for Latin America. Dr. Ronald Smith from the

University of Illinois, suggested that the Acarology Society of the United States could classify ticks and spread information throughout Latin America. Dr. Stephen Barnett (England) indicated that perhaps Latins would prefer a Latin consultative group.

Dr. Beltran stated that 90 million (Mex.) pesos would be invested to establish the Tick Research Institute in Mexico which could serve as the tick reference center for Latin America. While Dr. Gonzalez from Brazil added that there was a very good collection of ticks known as the "Cross Collection" in Brazil.

At Dr. Barnett's suggestion a list of tick taxonomists in Latin America was compiled by countries.

Argentina: Drs. J.C. Ivancovich and Oscar Lombardero.
Bolivia: Drs. J.M. Payno and Raul Grock.
Brazil: Drs. J. Gonzalez, H. Espinola and Flieshman.
Colombia: Drs. G. Luque, G. Mateus and H. Duran.
Mexico: Drs. L.G. Beltran, Alfonso de la Torre, Anita Hoffman, Irene Edith Carnales, Jorge Aguirre Esponda, Manuel Taracena and Manuel Chavarria Ch.
Surinam: Dr. Deryck W. Heineman.
Uruguay: Dr. Sumino.
There were no taxonomists for Chile, Costa Rica, Ecuador, Guatemala, Paraguay or Peru.

Dr. João Gonzalez (Brazil) inquired about the possibility of crossing **Boophilus microplus** with **B. annulatus.** To which Dr. O.H. Graham from U.S.A. replied that he had participated in experiments with crosses of **Boophilus microplus** with **B. annulatus.** The F_1 males were always sterile while the F_1 females were always fertile. He suggested that if, in Mexico, both species come into contact, due to the sterility factor one of the species will eventually become dominant.

Planning Research Support for Tick Control Programs

O. H. Graham *

It is obvious that no two tick control programs will be exactly alike and it follows that, if the supporting research is to be efficient, it must be designed specifically for a particular control program during the early planning stages of that program. But, it is certain that a national tick control program of any magnitude cannot succeed without the support of a well organized, objective-oriented research group. Research should be initiated at least two years before the start of any large scale control program and funds for research should be included in the budget for the control program. Experience indicates that expenditures for research should amount to 10 to 20 percent of the total spent on tick control or eradication.

When they are working on these programs, researchers are obligated by circumstances to devote their attention and energy to short term studies of those problems that are vital to the success of the control program. Usually, this will mean that they cannot undertake highly sophisticated research of a basic nature and that they will have to attack new problems as they arise before they have had time to fully answer all questions to which they previously addressed themselves.

At this point it is interesting to consider whether or not the ultimate objective of the control program will be the eradication of

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one or more species of ticks from a well defined land mass or merely to reduce the population sufficiently to eliminate all or most of the economic losses produced by that tick. Certainly, eradication is a laudable goal if it can be justified economically and if it can be maintained after it is achieved, but it should not be undertaken without giving careful consideration to the myriad of problems that are a part of every eradication program. Usually, eradication will be infinitely more difficult to achieve and vastly more expensive than the 99 percent or whatever percent control that is required for alleviation of the economic losses and should not even be attempted unless there is reasonable assurance of success and an even greater certainty that freedom from the pest can be maintained if it is achieved. In the case of ticks and the present state of the art and science of tick control, it is difficult to visualize a sound national eradication program for any well established three-host tick or even for a one host species that parasitizes a wide variety of hosts.

Ticks are the vectors of at least 30 distinct human diseases, some of them very important. But since man is only an incidental host for these ticks, with the possible exception of **Ornithodoros porcinus domesticus** in East Africa, there does not seem to be much hope that these diseases can be eliminated by eradicating the vector. This view may change if highly practical biological or area control measures should ever become available. In the meantime, if domestic animals are the sole, or virtually the sole, hosts of a particular tick, we are then justified in at least studying the feasibility of eradication and we can justify the expenditure of public funds for research on the control and eradication of such a tick. Eradication could also be justified if we are dealing with an economically important tick that has recently appeared in a new area of limited size or exists in an area which is not ecologically very suitable for its survival.

Research programs must be scaled to the size of the contemplated control program and may be very simple investigations carried out by a single scientist or may, at least in theory, be complex programs that utilize dozens of researchers from a variety of scientific disciplines. For the purpose of our discussion, I would like to consider all of the research approaches that are most likely to be used in a large, national eradication program that might continue for 10 to 20 years or longer. But please remember that not all of the research findings would have to be generated within one bureaucratic entity—much of it could originate from outside groups, universities, for example, or international organizations, and the information would be equally useful. It would only be necessary to integrate the data into the overall picture much as we fit the pieces of a jig-saw puzzle together.

In the process of planning and organizing our theoretical research program, we can utilize the training and talent of scientists working in at least 12 disciplines. The categories are artificial and the nomenclature sometimes varies, but let's look at the following approaches:

(1) Taxonomy
(2) Morphology
(3) Physiology
(4) Behavior
(5) Ecology
(6) Genetics
(7) Arthropod Toxicology
(8) Host-Parasite Relationships
(9) Disease Transmission
(10) Epidemiology
(11) Mammalian Toxicology
(12) Biometrics

The contribution that each of the above specialties might make to the planning and conduct of a national tick control program can now be briefly examined.

Taxonomy

As Jane Walker has already explained very clearly, a sure knowledge of the species with which we are dealing, their distribution and their recognition are fundamental. We must know our enemy if we are to eliminate it. Accurate descriptions of species, keys to identification, reference collections and expert taxonomists are all needed for the correct identification of ticks just as they are for any group of plants or animals, but tick surveys will not be any more valid than the collection records on which they are based. It would be difficult to overemphasize the importance of obtaining adequate numbers of samples and of maintaining detailed, accurate records. This usually means that professional people who already appreciate the importance of these fundamentals will have to make the collections or that field collectors will have to be carefully trained. It is essential that collectors appreciate the importance of obtaining samples of both sexes, all stages of development and all species that are present. Field records should accurately indicate seasonal incidence, hosts, abundance, geographic distribution, and such essential facts as whether or not the hosts were native to the collection place or in transit.

Morphology

In their studies of arthropods, morphologists must correlate form and function and, therefore, they often link taxonomy and physiology together. An adequate understanding of growth, nutrition, reproduction, longevity and other vital functions of the organism, depends on information about the structure and activity of both the internal and external organs and structures.

The electron microscope has made it possible for morphologists to extend our knowledge of the fine structure of cells and tissues. The scanning electron microscope has proven to be especially useful for studying ticks and other arthropods. Its great range of magnification and remarkable depth of focus have given us an improved understanding of both the appearance and function of a structure or organ.

Physiology

If an adequate knowledge of the physiology of the tick is not already available from the scientific literature, it will be desirable to undertake a limited amount of research on the normal physiology of the target species as an adjunct of the control program. These studies will provide necessary background data for studies in arthropod toxicology (which are usually studies in abnormal physiology), nutrition, growth, and reproduction.

It will almost always be necessary to colonize the tick in the research laboratory as a necessary first step to studies of chemical control, genetics, disease transmission, and biological control. Physiological studies provide the fundamental information upon which even small scale colonizations are usually based. The **in vitro** rearing of ticks has met with only limited success, but it is easy to visualize programs in which it might become urgently necessary to devise such techniques. Some progress has been made in membrane-feeding of ticks and other hematophagous arthropods but large scale **in vitro** rearing has not been attempted. If parasites, predators, or pathogens are to be used in a field, the normal growth patterns of the tick must be understood. The possibility of using pheromones in control programs is exciting because of the promise of improved efficacy with a minimum of environmental hazards. Obviously, physiological studies which would provide information on pheromone production on tick responses are needed.

Behavior

The life cycle of ticks is divided into two distinct parts, the parasitic and non-parasitic phases. Tick behavior, which has received only limited attention by a very small number of researchers, must therefore be studied on and off the host. Since behavior in arthropods is believed to be an autonomic response to stimuli, it should be worthwhile to know more about specific stimuli and the responses induced by them.

The aspects of parasitic behavior most likely to have economic connotations are feeding and mating behavior and the selection of host predilection sites. In the non-parasitic life cycle, the selection, if any, of oviposition sites and the questing behavior of unfed larvae strongly influence reproductive success and larval longevity. Information about the influence of environmental factors on behavior in most tick species is woefully inadequate and research is usually needed that will provide the specific data for one or more species in a definite geographical region. Since the unfed larvae utilize food carried over from the egg stage as their sole source of energy, it is obvious that their longevity is greatly shortened if they are highly active. The maintenance of water balance, also critical to larval survival, is also influenced by behavior. If the influence of climate and weather on behavior were better understood, it might be possible to improve the efficiency of control measures, especially pasture management approaches to control. Unfortunately, we do not presently have enough information about behavior to be able to recommend management practices that would shorten the life of unfed larvae and reduce the time that a pasture must be vacated in order to control **Boophilus** species.

Mate seeking and other aspects of reproductive behavior are critical points in the life cycle of most ticks. If normal behavior could, in some way, be disrupted, an advantageous new approach to control could be developed. The behavior of one—, two—, and three-host ticks is obviously very different and it is generally accepted that three-host ticks experience more hazards to survival than one-host ticks. In any case, if some drastic alteration in behavior could be induced by man, the tick life cycle would be disrupted and tick control would result. For instance, if engorged larvae of a one-host tick could be induced to drop from the host prior to, or at the time of, molting they would, very likely, never find another host or if any of the unfed stages of a three-host tick would lose interest in host seeking, these individuals would be eliminated.

Ecology

If, at some future date, non-chemical control measures for ticks are to be implemented, their successful use will almost certainly be based on at least a partial knowledge of the ecology of the species. Biological approaches to the control or elimination of any arthropod must take into consideration the role of the target species in a plant and animal community.

In national programs of control or eradication, the availability of maps that indicate the various ecological zones in an eradication area are essential to sound technical management of the program just as political maps are essential to administrative management. With adequate ecological data, it would be possible to prepare maps that indicate the zones in which: (1) the tick would probably reproduce rapidly in the absence of control measures; (2) the zones in which population fluctuates drastically according to weather conditions and other controlling factors; (3) the sub-optimum zones in which survival is apt to be tenuous; and, (4) the zones in which survival is not normally possible. In most countries, the number of ecologists studying ticks in the field is grossly inadequate and, although such studies tend to be long term, many large scale control programs should be supported by some basic studies in ecology. The successful use of pasture spelling for tick control is an illustration of applied ecology and in most regions a more thorough study of tick ecology in a particular region will permit the preparation of improved recommendations for pasture spelling as well as other livestock and pasture management procedures.

Genetics

Insects such as **Drosophila melanogaster** have been used by geneticists for many years as tools for laboratory studies, but the use of genetic approaches to insect control is a recent development. The prospects for using genetic modifications as tools in control programs appear to be excellent, but most of the techniques are still unproven. The most successful use has been the induction of sterility in male screwworm flies and the release of large numbers of these males to mate with native females. In this instance, the males are not truly sterile, but irradiation is used to induce a large number of dominant lethal mutations in the sperm. As a result, the eggs do not hatch even though they have been fertilized. Other genetic approaches have been proposed for other insects, especially mosquitoes, but have not yet been proven by large scale usage.

R.H. Wharton has expressed the opinion that genetic manipulation does not appear very promising for tick control and certainly a great deal more research would be required to implement any approach presently conceivable. However, the F_1 hybrid males produced by cross mating **Boophilus annulatus** and **B. microplus** are sterile and in small scale tests these males successfully competed with normal males of either species for mates. Before such males could be released in the field in large numbers, large scale rearing procedures would have to be developed and techniques for separating males from females would probably be mandatory. Continued research is justified, however, because of the potential usefulness of such an approach in areas where ticks are resistant to chemicals and also because the technique might be used to eliminate low populations of **Boophilus** near the end of an eradication program.

Genetic studies have contributed to a better understanding of the resistance pheromones in both insects and ticks and are a high priority research item in regions where control agencies are faced with a resistance problem. While the studies undertaken, such as those in Australia, have given us good explanations of the genetic bases of resistance, they have not so far provided a means for avoiding it nor an adequate explanation for the failure of resistance to appear in regions where conditions seemingly favor its appearance.

Arthropod toxicology

For at least the next 10-20 years, and probably longer, any national tick control or eradication program will have to be based on the use of conventional chemicals —the acaricides that are presently available or very similar ones. In such programs we usually are most concerned with the selection of the efficient acaricide and the proper dosage, —safety, cost, stability, availability, etc.— are secondary considerations that are evaluated only after we know that the chemical is an efficient tick killer. As a result, arthropod toxicology is usually studied in three phases. With **Boophilus** species, for example, candidate acaricides are first tested **in vitro** against a non-parasitic stage of the tick, either the engorged female or the unfed larva. In the second phase, the most promising candidates are applied to a small number of infested cattle to determine their toxicity to metanymphs, young adults, and engorged or partially engorged females. The third phase of testing is conducted in the field in a variety of practical situations that, among other things, provide information on the protection of cattle from reinfestation by the residual action of the chemical.

In regions in which insecticide resistance is a major consideration, studies in arthropod toxicology should be intensified so as to minimize the impact of resistance on the control program. In every program, the means of monitoring resistance should be provided for in the early stages as prompt recognition might make it possible to alter program strategy and avoid failure. While experience in Australia and Brazil indicates that resistance to other chemicals usually rapidly follows the first appearance of resistance, there is a possibility of developing treatment regimes that will delay the appearance of resistance or soften its impact on the program. The greatest need seems to be for the discovery and development of entirely new chemicals unrelated to those presently in use, which kill ticks by an entirely new mode of action; Wharton (1974) has discussed this in considerable detail.

Host-parasite relationships

It is generally accepted that some breeds of cattle, for example the criollo cattle of Latin America and the Zebu, are more resistant to tick infestation than the European breeds and it also appears that in individual animals of any breed, inherited immunity can be stimulated or intensified by exposure to tick infestation. This suggests that it might be possible to prepare an inoculation for cattle that would increase the level of immunity to ticks. Also, considerable thought has been given, especially in Australia, to the selection of blood lines that would be highly resistant.

Unfortunately, not enough is known about the immunity factors themselves and the exact manner in which they prevent tick attachment or feeding. Cattle breeding is a very complex procedure and it is not usually practical to select for only one trait such as tick resistance and ignore dozens of other traits which may be of even greater economic importance. Also, an animal geneticist cannot usually expect to work with more than 10 or 15 generations of cattle in the course of his career while **Boophilus** will probably produce as many as 100 generations in the same period of time. Just as ticks develop resistance to acaricidal chemicals by selection, they could also, at least in theory, acquire resistance to the biochemical or physical traits of cattle which produce immunity to ticks. While host resistance is obviously a useful adjunct to tick control and might, under some conditions, be the most important part of an "integrated" control program, it appears that, at least until more is known about resistance mechanisms, the tick problem will not be eliminated by this approach to control.

Disease transmission

The species of ticks which are most likely to be objects of national control or eradication programs are those which are also vectors of serious animal diseases. In the course of a tick fever eradication program, cattle in tick-free zones lose their immunity to babesiosis and are highly susceptible to infection if carrier ticks are accidentally introduced into a "clean" area. In most countries, **Boophilus** spp. are also important vectors of anaplasmosis but are not the sole vectors. If **Boophilus** spp. are not present to infect young cattle during the first few months of their life, the animals may suffer more severe effects if they contract anaplasmosis as adult cattle by exposure to other ticks, biting flies, or infected instruments. Some knowledge of the tick-transmitted diseases in a country, region by region, is therefore needed for the proper planning of tick control or eradication. Research on premunition and drug prophylaxis and therapy are important adjuncts to the overall program.

Vector capability studies should be coordinated with studies of tick ecology and genetics as there are indications that some strains of **B. microplus** are more efficient transmitters of **Babesia** than others. Vector efficiency may also be affected by environmental conditions and the fate of the bovine species of **Babesia** in non-bovine tick hosts such as horses, deer and sheep is very poorly understood. The vector capability of the male **Boophilus** is not known, but could be important since mature males can transfer from one host to another. These and other aspects of disease transmission could influence the course of an eradication program and deserve research attention.

Epidemiology

In a sense, the epidemiology of ticks and tick-borne diseases is merely one aspect of applied ecology. However, it is a science that consolidates all of the information pertinent to vector and disease incidence and dissemination. If sufficient epidemiological information is available, spread of the tick from its endemic zones can be minimized and technically sound quarantines can be established. The study of epidemiology is undertaken to understand the fluctuations in abundance and spread that have been observed and to anticipate those that will occur in both the near and distant future.

Epidemiological studies and predictions have to be based on data and their usefulness is directly proportional to the quantity and validity of the available data. Climatological data, tick surveys, livestock census reports, and ecological studies provide timely facts that can be combined with background information on the life cycle and behavior of the tick.

Mammalian toxicology

These studies, as a phase of a tick control program, would probably include pathology and the determination of pesticide residues in animal products intended for human consumption, but would concentrate on the undesirable effects of tick control materials on livestock, other beneficial species, and the environment. All pesticides are to some degree poisonous to higher animals so the mammalian toxicologist must estimate the margin of safety for each product; that is, the ratio between the lowest toxic dose to each class of livestock and the minimum effective dose that will control the arthropod. The margin of safety can vary greatly according to species and age of the animal, nutritional level and the impact of other stress factors. In a national program, it is almost inevitable that some poisoning will occur, but if the cause of each is determined, the number of such cases can be minimized and the use hazards for each pesticide can be estimated.

Residues of pesticides in animal products are important public health considerations whenever any product is used extensively. The magnitude and impact of residues are carefully studied before a new pesticide is approved for large scale use, but those studies should be continued during the course of an eradication campaign because use conditions affect the storage and degradation of these products in the animal's body. The techniques for determining residues are highly meticulous procedures in analytical chemistry and considerable advance planning and preparation will be needed if these determinations are to be carried out correctly.

Environmental contamination is usually a minor hazard in animal parasite control programs, but program personnel should be alert to possible dangers and avoid the contamination of water sources, soil, stored food, or human habitations with pesticides. Inspectors and other persons whose duties might cause them to be frequently exposed to pesticides should be carefully trained in personal safety procedures and provided with safety clothing and equipment. If these persons are exposed to cholinesterase-inhibiting chemicals, arrangements should be made for periodic determination of their cholinesterase levels and removal from exposure if significant decreases in cholinesterase are observed.

Biometrics

The exact function of a statistical group in a program will depend on the size and scope of the program and its ultimate goals. The accumulation and interpretation of statistical data might be a minor function in a control program that could be accomplished in the epidemiology or some other section or it might be a distinct activity in a large, national eradication program. As a general rule, the biometricians will not be able to collect data but will interpret data obtained from field reports and other sources. In this regard, it is important that field personnel not be overburdened with reports, statistical or otherwise, as report preparation should not interfere with primary duties. Good judgment should be exercised and proposed reports should be reviewed from several different viewpoints to insure that the data and the conclusions drawn from the data are essential to the proper management of the program and will contribute to program success.

Conclusions

The technical aspects of an organized tick control program that is national in scope can be properly planned and controlled only if if current, reliable technical information is readily available. As a general rule, research carried out in other countries, even though some of it may be pertinent, will not be adequate or fully applicable to the country with the program and some research will be needed that is local and is designed to solve local problems. The magnitude of this research will depend on size and probably duration of the program but even a limited research effort can substantially improve the efficiency of a tick control program and contribute to the ultimate success of an eradication program.

Current Research on Tick Control in Latin America *

Joao C. Gonzalez **

Dr. Gonzalez underlined the study of tick populations as a main factor in tick control programs stating that if their populations were controlled, their resistance and other factors would also be controlled. He noted that this technique is currently being used in Brazil.

Dr. Gonzalez then explained in detail each one of the most important factors for the decrease or increase of tick populations. Among them, geographic distribution, climate and vegetation, are very important but similar factors for all of Latin America. Vegetation is mainly a direct product of soil and climate quality. High grass, bushes and weeds serve as a protection against extreme temperatures and also as a spreading medium, as ticks are easily transferred from them to animals.

Tick predators are another problem. In Brazil, an ostrich-like bird (nandu) and some arachnids are tick predators. In bovines, some breeds are more susceptible and others more resistant to ticks. Management of cattle on the farm, management of dipping vats, the interval of treatment and the use of acaricides, all, influence the increase or decrease of tick populations. Referring to acaricides, Dr. Gonzalez said that tick resistance is a direct product of tick survival.

* Summary of lecture as no formal paper was submitted.

** Universidade Federal R. G. do Sul.

Principles Governing National Tick Control Programs

Ralph A. Bram *

The consequences of heavy tick infestations on cattle are well known to livestock producers throughout the world. Not only is there a loss of 1-3 millimeters of blood for every cattle tick completing its life cycle on an animal, but tick infestations cause irritation, damaged hides, and predispose animals to bacterial and fungal infections, as well as screwworm attacks, in the wounds left by tick bites. Of greater importance is the fact that ticks are the vectors of two major cattle diseases in Latin America: bovine babesiosis and bovine anaplasmosis. Either or both of these diseases may be limiting factors to efficient cattle production in many areas where they are epizootic. Recent studies by Barnett (1974 a and b) discuss in detail the economic aspects of tick and tick-borne disease control.

The Food and Agriculture Organization is encouraging improved control of ticks and tick-borne diseases throughout the world (Bram, 1975), since better control will improve the efficiency of meat and milk production, and will substantially reduce tangible losses due to tick-borne disease epizootics. Although each country must tailor its tick-borne disease control program to fit its own unique circumstances and national objectives, there are a number of basic principles which are generally applicable to any well defined, coordinated effort.

Naturally, the emphasis of a program will vary from country to country and even between areas within a single country, but

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consideration must be given to each of the factors which influence the control of ticks and tick-borne diseases before renewing or initiating intensive activities.

Preliminary preparations

Obviously the first step in preparing a national tick control program is to determine the incidence and distribution of tick species of veterinary importance following an entomological survey. In many countries, qualitative studies defining the species that are present have already been undertaken. However, a qualitative and quantitative survey of the incidence and distribution of the significant tick species in relation to the livestock population will undoubtedly reveal deficiencies in the knowledge of tick biology and population dynamics in different ecological zones. In addition, the tick survey should answer basic questions concerning the role of wildlife in maintaining different tick populations; the status of acaricide susceptibility of the different species in different areas and where obvious deficiencies in information exist, research projects should be designed to provide answers necessary for an operational control program.

While conducting the tick survey, an assessment of the tick control practices and facilities which exist throughout the country should also be made. A record of the number of dip tanks, spray races and hand-operated sprayers in use, and their state of repair and location should be recorded. This information is a prerequisite to increasing tick control capabilities within a country or area.

Equal in importance to the tick survey is an epizootiological survey, which must not only delimit the distribution of babesiosis and anaplasmosis within a country but must also clearly define the areas where the two diseases are epizootic, endemic, and non-existent. Such data as those compiled by Mahoney and Ross (1972) will have a major influence on the nature of the tick control programs in different areas. As with the tick survey, the epizootiological survey will highlight informational deficiencies and stimulate applied research necessary for the program.

Utilizing the data obtained from the tick survey and the epizootiological survey, a comprehensive plan for a coordinated, country-wide tick and tick-borne disease control scheme can be formulated. This does not necessarily imply a rigid, uniform, country-wide plan. On the contrary, there should be a flexible plan including variations for each of the ecological zones found within the country. Based on epizootiology, one ecotype may require intensive tick control; another, possibly tick eradication; and a third no control at all. In formulating a comprehensive tick and tick-borne disease control scheme, decisions will be tempered by the availability of financial and manpower resources and technical expertise, as well as by the economic benefits expected from the control program. It is, therefore, necessary that an economic analysis be conducted by trained economists in consultation with knowledgeable specialists in the control of ticks and tick-borne diseases.

Program execution

As a general principle, control should be organized as a responsibility of government animal health authorities; decisions affecting control initiatives would thus be made within the perspective of a country's total animal health commitment. Usually, the administrative structure, field organization, and field staff already exist within the appropriate government animal health agency and it is, therefore, more efficient and economical to utilize this establishment as the foundation for a control program, which should include: extension, research, surveillance, quarantine and actual control techniques.

For any animal disease control program to maintain its momentum effectively it is necessary to have the total support and cooperation of the agricultural community. Education and extension, therefore, play a primary and continuing role in a national tick control program. Bringing information to the large rancher or the owner of a single cow is a formidable task, but it could easily determine the long-term success or failure of a well planned and supported program. Information on the objectives and procedures of the program must be prepared in a convincing, understandable format and widely distributed to the various agricultural sectors. Practical demonstration ranches, emphasizing the economic benefits to be realized from effective tick and tick-borne disease control, are invaluable in stimulating local cooperation. Handbooks outlining the entire program are necessary to establish consistency among the professionals responsible for program execution (see Gonzalez, 1957) and it may be desirable to employ the news media to bring information to the producer level.

Applied research, designed to provide solutions to basic control problems, is a continuing component of any control activity. It has been estimated that at least ten percent of the tick control budget should be devoted to research (Graham, 1975). The research team should consist of entomologists and veterinarians and should have the flexibility to investigate problems in any of the various ecological areas.

We have seen that surveillance, both for ticks and for tick-borne disease, is indispensable to the preliminary preparations for a control program, and when it is in operation the need for tick and tick-borne disease surveillance does not diminish; indeed it is important in order to provide data on the success of the program and to indicate when adjustments in operational plans are required.

In some programs, particularly those which include areas of tick eradication in the overall scheme, it may be necessary to enact quarantine regulations which restrict animal movements into tick and disease free areas. Although never a popular component of any program, the realization must be faced that strictly enforced quarantines are essential to prevent reintroduction of ticks and disease.

At the outset, most control programs are based on the use of chemical acaricides to kill ticks. The selection of acaricides to be used in the program will depend on several factors including: (a) availability of compounds; (b) price considerations; (c) susceptibility of the various tick populations to the different chemicals; and (d) methods of application. The methods of acaricide application will depend on livestock management practices and availability of equipment. Cattle dips are by far the most efficient, effective and fool-proof means of applying acaricides. This technique is followed in importance by spray races, hand-operated sprayers, and finally hand dressing. It may be necessary for a program to encompass all of the available techniques of acaricide application. A national program, however, cannot afford to depend exclusively on the indefinite use of acaricides. From the very start, an effort should be made to develop alternative methods of tick control which can be incorporated into an integrated program including strategic dipping, pasture spelling and resistant cattle. These techniques have been emphasized by Warton (1974) who has stressed that we must either eradicate the tick where this is economical and feasible or reduce our dependence on acaricides.

Tick control versus tick eradication

Usually, programs which aim to achieve eradication eventually falter, with the result that large populations of susceptible livestock are left unprotected and subsequently succumb to one or more of the tick-borne diseases. Therefore, nation-wide tick eradication is not to be encouraged as a program objective in developing countries. The final conclusion to such a program could be an epizootic of major proportions. From a practical viewpoint nation-wide tick eradication demands an enormous commitment of financial and manpower resources, far exceeding that required for an effective control program. A national tick or tick-borne disease eradication effort should only be attempted when a long-term commitment of adequate finances, manpower, facilities and dedication are assured.

There are, however, special cases where a national policy of tick eradication is indicated. When an exotic tick species of veterinary importance is introduced into a country, every effort should be made to achieve its eradication before it becomes fully established or extends its range beyond the point of initial introduction. Eradication under these circumstances can reasonably be accomplished by massive control activities in a limited area supported by the regulatory authority to prevent its spread.

Eradication should also be considered when a particular tick species is present in a marginal ecological zone. In such cases, both the hostile environment and relentless control efforts make successful eradication probable. Thus, within the framework of a nationwide tick control program there may be valid opportunities to include areas where tick eradication is a reasonable objective. The question, then, is not tick control **versus** tick eradication, but rather tick control **and** eradication.

Summary

Due to the economic consequences of heavy tick infections, the Food and Agriculture Organization is encouraging countries throughout the world to intensify their efforts to improve the control of ticks and tick-borne diseases. Preliminary preparations for a national tick control program include: an entomological survey; an epizootiological survey; an assessment of existing tick control practices, facilities and an analysis of the economic benefits to be expected from improved tick control, and the formulation of a comprehensive, coordinated tick and tick-borne disease control scheme.

As a general principle, tick and tick-borne disease control should be organized as a responsibility of government animal health authorities. Although tick control programs must be tailored to the specific objectives, resources and requirements of an individual country, every operational program should at least consider including: extension, research, surveillance, quarantine and actual control techniques as basic program components.

Usually, programs which aim to achieve eradication eventually falter, with the result that large populations of susceptible livestock are left unprotected and subsequently succumb to one or more of the tick-borne diseases so that nation-wide tick eradication is not to be encouraged as a program objective in developing countries. Special cases where a national policy of tick eradication is indicated include situations where an exotic tick species of veterinary importance is introduced into a country and when a particular tick species is present in a marginal ecological zone. Thus, within the framework of a nation-wide tick control program there may be valid opportunities to include areas where tick eradication is a reasonable objective.

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National Campaign Against Ticks

Luis Beltrán *

Diagnosis

In Mexico, cattle occupy, without a doubt, a prominent place in the animal production sector of our country, not only for their total production value and their products for the internal and external market but also, for the large areas of land in which they are developed and the jobs they provide for people.

In the last decade 1960-1970, the national bovine population showed an annual growth rate of 3.9 percent, a coefficient slightly higher than the national human population growth rate (3.5%). Such a percentage expresses a low proportion of cattle per inhabitant due to a slow increase in cattle, i.e. 0.506 bovine head per inhabitant in 1960; 0.540 in 1970. It should also be noted that we included the cattle producer of meat, milk and the dual purpose breeds.

If the bovine production does not increase at the same rate as the human population as was shown in the last decade, the future shortage of bovine products (milk, meat, hides, etc.) will be aggravated.

The unusual demographic growth of our country demands a proper livestock development to solve the requirements of cattle by-products. But our stock industry suffers great economic losses from ticks; they interfere with cattle improvement programs and impede the development of an important productive agricultural sector.

Ticks cause up to a 48 percent loss in dairy production and it is easy to understand what this implies. Mexico stopped producing 202,500,000 liters of milk, which cost approximately $ 303,750,000 (Mex.) pesos.

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It is also calculated that in infested areas 150,000 head of cattle die annually from diseases transmitted by the **Boophilus** tick with a loss of $ 225,000,000 pesos.

In the country, there are areas with great grazing capacity which have stopped development because of the ectoparasite presence which does not allow highly specialized breeds to be exploited in such areas. In an infested zone, a calf loses between 40 to 50 kilograms or more of weight due to ticks during its productive lifetime. This figure could be particularly dramatic if we consider that without the parasite this animal could develop into a bovine of a highly specialized breed in meat production. Livestock losses in Mexico represent 550,086,500 kilograms of meat per year. If we calculate a price of $6 pesos per kilogram, the losses amount to $ 3,000,519,000 per year.

Hides of cattle suffer serious depreciation; scars, sometimes very deep from tick bites, and enlarged many times by screwworm attack which maim their industrialization and reduce their value up to 40 percent. The losses may reach $ 58,500,000 pesos.

The Food and Agriculture Organization (FAO) indicates that in those countries which have an adequate veterinary service and a high degree of rural culture, the losses caused by diseases reach 10 and 20 percent of the maximum total value of the annual cattle production. (France, Ireland, Italy, United Kingdom and the United States are in this group.) Where these two factors are deficient the percentage of losses oscillates between 30 and 40 percent. (Mexico is among this last group of countries and suffers a loss of approximately 37.3 percent of the total value of its commercial livestock production (FAO, 1962).

In many parts of the world the incidence of tick borne diseases in domestic animals is inter-related with the national and regional economy. This is the case of Mexico.

Ticks, therefore, cause national livestock losses of $ 3,587 million pesos per year or more than 8 million pesos daily, which are distributed as follows:

Milk	$ 303,750,000
Deaths	$ 225,000.000
Hides	$ 50,500,000
Meat	$ 3,000,519,000

In summary, the losses in kilos of meat and liters of milk, and the low quality products from the million head of cattle living in the tick infested areas of Mexico plus the deaths caused by bovine piroplasmosis lessen considerably the animal protein resources left for human consumption. Such losses add to the high percentage of malnutrition of the population in general.

Prognosis

This could be avoided by the use of better systems of bovine exploitation, eradication of ticks and elimination of the major bovine ailments such as parasitism and diseases affecting cattle, many carried by the tick (which is considered to be the primary constraint against the development of Mexican cattle).

Disease and parasitosis combined with poor nutrition constitute one of the major problems affecting Mexican cattle. Their effects are the cause of low animal production and the poor quality of cattle products, high infertility, temporary sterility, low birth rate and high mortality rate.

Therefore, there is a need for cattle development, fighting the causes of their stagnation in order to face the increasing demand for nutritional food and industrial raw materials required by a growing population.

Background

We have known ticks since long before the colonial period; the Mayas used the term "pech" to describe this parasite.

Piroplasmosis or "Ranilla" was the scourge of Mexican cattle. At the beginning of this century two pioneers of veterinary medicine, Dr. Eutimio Lopez Vallejo and Emilio Fernandez made some studies on ticks and their role in the transmission of diseases long before Smith and Kilborne discovered in 1889 the etiological agent and the role of ticks as vectors. When the Smith and Kilborne works appeared, Dr. Emilio Fernandez translated them into Spanish to confirm his suspicion that Texas Fever and Ranilla were the same disease.

The lawyer, Garrido Cabal, initiated the campaign against ticks in Mexico. In 1926, he began in the state of Tabasco and imposed by law, the building of dipping vats to fight ticks. Later, Dr. Manuel Chavarria Ch., professor of Parasitology of the National School of Veterinary Medicine did some work related to tick classification, its identification and distribution. But it was not until 1960 that the state of Sonora under the direction of MVZ Roberto Castillo Lavie, pioneered the tick campaign in a technical and intensive manner, incorporating 2,750,000 hectares into the free zone.

However, a national campaign against ticks was needed and legislation was initiated on the Federal and state level.

At the Federal level, there is the Plant and Animal Health Law of the United Mexican States, which has a special chapter concerning the obligations and responsibilities of cattle owners with the campaign against ticks for all of the country.

In each state of the campaign, a State Committee is established composed of all sectors involved in livestock production. Its functions are mainly to promote the campaign against the **Boophilus** tick, the transmitter of bovine piroplasmosis; to fix the quota for farmers; to designate the budget for administrative expenses; to establish quarantine stations; to survey and prevent movements of infested cattle; and also, to avoid the slaughter of such cattle in public or private places; to negotiate through the State Executive and the local parliament the promulgation of a law recognizing the Tick Campaign as a public necessity and giving it permanent status.

The legislation on which the campaign is based is variable; there are states with very complex legislations concerning animal health in which regulations about the overall campaign are specific and others in which the laws specify a tick eradication campaign. In some, legislation pertaining to tick eradication is formulated in a special chapter or in some articles of the State Livestock Law.

General Objectives of the Campaign

The primary objective of the National Tick Campaign is to eradicate the **Boophilus** genera which transmits bovine piroplasmosis and to control other tick generas. Subsequently, there will be a substantial production improvement with cattle mainly in the humid tropics where the introduction of highly specialized breeds can become possible in tick-free areas.

Therefore, the Tick Campaign will be one of the basic pillars of animal health such as the screwworm, brucellosis, dengue, equine encephalitis and exotic disease campaigns and others which may be introduced in the future. Based on these premises one can say that the campaign against ticks will help to lay the foundation of the livestock infrastructure in Mexico.

Program Aims

(a) Short-term: establishment of the technical-administrative part of the fideicommissium base on which the campaign work will rely. The programmed budget for the first phase 1976-1980 will be used for this purpose.

(b) Mid-term: field work pertaining to the **Boophilus** tick eradication and the control of other generas. The aim is to eradicate the tick within the first four years from 130,958,727 hectares in the states of: Aguascalientes, Baja California Norte, Baja California Sur, Coahuila, Colima, Chihuahua, Durango, Guanajuato, Jalisco, Nayarit, Nuevo Leon, Queretaro, San Luis Potosi (A), San Luis Potosi (H), Sinaloa, Sonora, Tamulipas, Veracruz, Yucatan and Zacatecas. In this phase dipping tanks will be constructed giving financial aid to the poor cattleman. This will cost US $ 16 million.

(c) Long-term (between five and eight years): the eradication of ticks in the total extension of the national territory. Starting the fifth year with intensive work in the federal entities in which the promotion campaign will have been made during the first four years to sensitize the different sectors.

Technical basis of the campaign

The objective is to break the biological cycle of the ticks by dipping. Cattle will be concentrated in a protected area or ranch and a 14-16 day bathing interval will be imposed for all cattle in the control or eradication areas to kill the emerging females on the host and also to stop maturity on days 19 or 21 thereby preventing the adults from dropping to the ground and depositing eggs. (This "round-up" operation would also force cattle owners to build more pastures or to divide those already existing thus, effecting better herd management which should produce a higher birthrate and an improvement in the use of the forage resources.)

The personnel assigned to this program supervise: (1) dipping of all cattle in the area; (2) the correct use of acaricides and the proper handling of the acaricide immersion bath to prevent the occurrence of a probable resistance to ixodicide products.

The acaricides used in the tick campaign are also effective against other ectoparasites such as mites, lice, horn flies, etc., while other enzootic diseases affecting the national livestock can also be controlled through periodic concentration of cattle which is also useful for vaccinations, horseshoeing, castration, phenotype selection, etc.

The basis for determining a correct bathing interval, which is the foundation of the campaign, is the identification of generas and species of ticks parasitizing cattle in the area. Therefore, periodical collections are made and the specimens are sent to the National Laboratory for tick classification in Mexico City where 240,690 specimens have already been identified. Of these, 54 percent are **Boophilus** and 28 percent **Amblyomma,** and 18 percent corresponded to **Rhipicephalus, Dermacentor, Otobius** and **Ixodes.**

The collections have been extended to wild animals in which only generas and species highly specific to the host have been found, and which only accidentally parasitize domestic animals.

Strategies

The following is the demarcation of the working areas:

Promotion

The first step to begin the campaign in a state is the elaboration of a working plan which is the basic structural information on which the campaign relies. Its foundation will be preliminary information given by field personnel consisting of: geographical data, cattle census, cattle routes, incidence and distribution of ticks, etc.

An intense information program will also be carried out based on conferences, films, slide projections, pamphlets distribution, practical demonstrations; all with the purpose of motivating the cattle owner showing him the necessity of fighting the tick for the benefit of his family patrimony. Then, he is given professional advice on the location and construction of the dipping tanks; the correct use of acaricides; the proper handling of cattle and periodicity of treatment.

Control

Dipping vats are installed in an area, and strict control of the dipping interval of cattle movements (even from field to field) is implemented; official documentation is required to enter or leave the area. Periodical surveys are also made to verify the decrease of the tick incidence.

Field experience has shown that it is also important to restrict cattle movement toward the zones in the campaign; quarantine stations will be provided and also mobile units for surveillance to block the cattle paths. The quarantine pens will be made of steel and portable so that they can be used several times.

Eradication

Certain geographical zones are submitted to special measures to eliminate the tick. This area will be incorporated into a free zone after two years of seasonal inspections.

Free zone

In this geographical area the tick does not exist in its natural form or which has been eradicated through a tick elimination campaign. For a zone to be declared officially free, the Agricultural and Livestock Secretary receives documentation with data of hectare surfaces, cattle census by species, number of properties and places under surveillance, owners and quarantine stations. From our experience, we stress that there are four basic factors which must be present for the success of not only a tick campaign but any health campaign one undertakes:

(1) Proper legislation
(2) Sufficient financing
(3) Correct technical planning
(4) Complete cooperation from the livestock sector.

Success is certain if all of these are present and in harmony. If any of them is absent, there is the risk of failure.

To obtain greater administrative flexibility which the National campaign required, the Fideicomissium National Tick Campaign was established to handle funding. It is administrated by a Technical Board which designates the line of action and a special fiduciary representative who is the executor of the program; the purpose being to avoid the problems of official procedures.

Two managements, the administrative and technical, depend upon the fiduciary representatives.

The administrative management contributes the elements and sources technically necessary for the campaign through state administrators.

The technical management is carried out through a state chief who is in charge of all aspects of the technical planning in all the states.

Within the technical management, there are three departments: Department of Technical Coordination; the Planning and Evaluation Department: the Information Department.

The Department of Technical Coordination will be in charge of interrelating the state campaigns, to correct any technical mistakes, to supervise the technical planning of the campaign, to make sure such plans are accomplished and to compile all the information at a national level. This department will have six professional instructors charged with giving periodical and permanent courses to inspectors and supervisors in each state. This department will be in close relationship with the Planning and Evaluation Department which will supervise and follow the development of the program, and do cost/benefit analyses.

The considerable increase of activities expected from the tick campaign emphasized the need for electronic data processing to handle the information for the control and decisions of the campaign. The information should come from the different activities of the campaign personnel as an orientation requisite for efficient work or as a product of direct research useful in planning and evaluation.

The areas which will need electronic assistance are mainly those in which manual processing is not adequate for the great amount of daily information and because there is a need for continual current reports.

Preliminarily, it is thought that the electronic aids can be used in the following areas:

(A) Handling of personnel and payrolls will comprise nearly 3,500 records of people working with the program; each record will have between 20 and 30 personnel and location data.

(B) Controller will program and control payments at a state level for each sector.

(C) Evaluation and economic planning will provide a system for collecting data of the programs' activities at a municipal level, which implies that more than 2,500 questionaires of about 50 to 60 questions each will need to be completed. Also, periodical processing of such data will be the statistical base on which a comparison of the program's activities and control can be evaluated.

(D) The National Center of Animal Parasitology to be established will need data collection from the program to complement or modify the technical strategies or data of useful material for making laboratory models which will later be used in the field or as evidence of experimental results.

Another use for this electronic data processing and probably the most important one from a medical-scientific point of view and, also, from the point of view of planning and program control, is the control and simulation of experiments in the different areas for the National Center of Animal Parasitology. The simulation and control of experiments are complementary to the campaign strategies of the program and point to different alternatives in the technical and economical strategies. All this with the purpose of not only solving the problems that may arise but also to prevent them before they occur and thus gain time and efficiency.

To accomplish the proposed aims, the Information Department will have 32 employee-professionals specialized in Social Information. There will be 16 trucks equipped with living quarters, and carrying slide projectors, films, pamphlets, etc. These communication specialists will be the pioneers in the new zones to motivate the cattle owners and farmers.

The tick infested areas of the country have been divided into 165 zones which will be served by the zone headquarters of the area, staffed by a chief veterinarian and a sufficient number of supervisors and inspectors required to cover the zone (Table I).

Table I. Present scope of the current tick campaign in hectares

I	Total surface area of Mexico	197,254,700
II	Total surface area of tick free zone	72,201,701
III	Total surface area of tick campaign	32,751,468
	a) Tick eradication zone	7,321,828
	b) Tick control zone	7,912,297
	c) Promotion zone	17,517,343
IV	Total surface area of tick infested zone	92,301,527

The campaign will have a radio-communication service for the entire country with 201 radio stations and 538 radio-mobile units.

At present, there are 12,504 dipping tanks in the campaign area, of which 811 are official and 11,693 are private. In the control areas, cattle, horses, and goats are subject to dipping. In 1974, 12,688,488 animals were dipped in the campaign zones and 2,449,839 hectares were incorporated into the tick free zone. This area corresponded to the states of Baja California, Coahuila and Zacatecas.

The free zones are protected by a quarantine line where quarantine stations are strategically located. These stations block the cattle paths and prevent reinfestation. The actual quarantine line is approximately 7,000 kilometers long, and has 75 quarantine stations, ranging from small to large according to the movement of cattle passing through them. In these stations, the cattle going to the free zone will be inspected, dipped and on some occasions quarantined.

A Manual of Basic Information, Inspector's Manual, Supervisor's Manual, Manual for Veterinarians, Manual for Applying Ixodicides and one edited in simple language for the cattleman entitled, **Death to ticks**, have been published. Also, there is a book in press called **The Importance of Ticks in Animal Health** which contains some highly technical chapters.

The National Headquarters is aware that better training of its technical personnel will rebound in a better and more efficient use of its resources. Therefore, 16 courses have been given to inspectors in Jalisco, Zacatecas, Durango, Sonora, Aguascalientes, Chiapas, Nuevo Leon, Sinaloa, Coahuila, Yucatan and Veracruz.

A course for veterinarians gives them current information about the advances obtained in the tick campaign; at present, courses have been given in Monterrey, Culiacan, San Luis de Potosi, Saltillo, Guanajuato, and Nayarit. When problems affecting several states arise, interstate meetings are programmed to search for solutions.

National Center of Animal Parasitology

It is necessary to have a proper technical-scientific support for the work to be done by the National Tick Campaign to eradicate the **Boophilus** genera and to control the other genera. This will be possible with the establishment of a National Center for Entomological Research and Pesticide Control. The objectives of the center will be:

(1) To prevent the use of acaricides in the campaign which do not meet the basic requirements of no toxicity, ample residual power, easy handling, etc., thus preventing a future obstacle in the implantation or modification of the campaign in any part of the country.

(2) To prevent useless waste of monetary investment on poor acaricides by cattlemen and farmers, since they are the ones who give the greatest contribution, (it is necessary to gain their confidence).

(3) To be certain that the acaricides in the campaign won't affect people's health.

The National Center for Entomological Research and Pesticide Control will have the following sections:

Taxonomy Section

The classification of ticks is indispensable to determine the geographical distribution of these parasites throughout the entire climatological spectrum. It is possible to condense the experience from prior classifications to continue the work of identification of ticks in order to determine the parasitic species and their incidence in the zone, which will be related to the ecological zone.

An understanding of the type of tick is basic for the elaboration of research programs and eradication. The functions of the dissemination of the entomological sampling results and the application of the taxonomic research results, will be the basis for epidemiology, and toxicology research.

Incubation Section

This section will supply the biological material for all tests in the center.

All the genera and species which are found in the country will be incubated, especially **Boophilus** which accounts for 57 percent of the ticks classified at present; if resistant lines are found this section will work with them in coordination with the genetics section.

Calves and rodents will be used for the reproduction of the parasitic phases, the eggs and the non-parasitic larval phase will be raised in temperature and humidity controlled incubators.

This section will have a laboratory, an incubation room, and completely isolated living quarters so that personnel will not come into contact with ixodide substances or with the animals used in the reproduction, thus avoiding probable contamination.

Biological tests

This section will be essential to the center's activities. Here, the effectiveness of the acaricides will be tested **in vitro** or **in vivo**. Toxicity to the different tick stages will be quantified and also activity of the various genera and their phases in relation to the acaricides will be tested.

All chemicals on the market or to be introduced will undergo all the required tests and their action on the different tick stages will be observed. The number of deaths at different dilutions, will be counted mainly in those recommended by producers establishing the margins of lethal action. Once these tests have been done, the chemicals will be tried on tick infested animals exposing all tick stages. This operation will be carried out in the bath part of the biological experimentation of each product. The groups of animals will be treated first by aspersion quantifying chemical activity, then by dipping. The animal will remain under observation for a reasonable period of time. The percentage of dead ticks will be obtained and if there were some live ticks remaining they will be transferred to the incubation tanks to verify if there is any inhibitory action against oviposition. If this is negative, then it will be necessary to verify if the eggs are fertile or not.

When all these tests have been done in the center, each product will be taken to the field to be used in the dipping tanks controlled by the technical personnel of the section. Such dip tanks would be located in all parts of the country, under different climatic conditions, soils, cattle breeds (dairy, meat, short hair or long hair) for the observation of the field chemical activity. Based on the results obtained, the chemical registration would be approved or denied. The dip tanks will be equipped with small meteorological stations to control the environmental factors and type of water to determine their influence on the effectiveness of every product.

Toxicology

The extensive use of pesticides, especially insecticides, has introduced new hazards for men, cattle and the ecology. Some of them, like the phosphates, are dangerous if used in a careless manner. Although, the cases of intoxication have generally been caused by human mistakes.

The battle against ticks demands the use of such pesticides which contain varied formulas depending upon the time, country, etc. Some of the chemical families are more important than others. All chemicals, due to their molecular configuration, can be toxic in every stage of life—reason enough to study their **modus operandi**, their qualitative and quantitative importance on the ecological cycle to prevent a disastrous imbalance in nature.

This section will study the toxic levels of these products, metabolism and elimination levels in animals. The emphasis is on animal by-products which could be contaminated with insecticides thus becoming hazardous for men.

A laboratory will be established where work would be done on pesticide residual studies, the effects of various conditions on the acaricide such as: pH; type of water; salinity; type of soil; climatic conditions; effects of the microfauna and microflora of the dipping tank; dynamics and process of chemical biodegradation.

Physical-chemical

The acaricide, as a chemical, must be studied starting with its structure, physical properties and chemical interactions with dissolving agents of the dipping tanks. It is important to define: (1) the behavior of the ixodide acaricide types according to their physical-chemical properties in the different waters of the country; (2) to study the biodegration dynamics and other factors from a qualitative and quantitative point of view to know how the acaricide activity can be modified by polluting agents in the tank; (3) to evaluate the interactions of dipping materials; (4) effects of climate on stored ixodicides in order to determine the caducity, behavioral modifications and to cross check standard methods; (5) to examine the acaricide **per se**, its nature, structure, etc., under different handling regimes.

Tick genetics

This speciality will be developed largely because of the problem of resistant tick lines which will need a major dosis and longer exposure time to the insecticide to cause mortality.

The genetic material of resistant ticks becomes modified with coded proteins for the diverse mechanisms which inhibit the acaricide action (these being genetically irreversible) and are transmitted to the progeny.

It is believed that resistance is produced by selection pressure. The genes exist independently of the ixodicide or are mutant genes. Resistance may be said to be due to genetic synergism. There is the possibility that such genes occur in ticks in Mexico. Therefore, we are thinking of tick survey patterns matching those ecological areas similar to those of the countries already facing tick resistance.

Parallel to the survey is an emergency plan to control the possible development of a resistant line. The plan would utilize such data as: infrastructure, ecology, population dynamics, cattle structure, and a program of eradication specific to the type of resistance and ixodicide in question.

Ecology

To be able to mark the activity areas of the tick, its behavior cycles, etc., it is necessary to study the relationship of ticks with other animals (parasitism), ticks with ticks (population dynamics) and the influence of the environment on the tick.

The country has been divided into ecological zones and integrated studies on flora and fauna, considering the limitations of the areas, will be undertaken. Studies about the substrate and climate together with those already mentioned will establish the bases for studying tick population dynamics.

Some work will also be developed on parasite distributions, times of appearance, identification of limiting factors, determination of structures by species, diversity ratios by species, general diversity ratios, etc.

At present only the theoretical program, methodology, and the design of the survey model have been developed.

A study of ecology of parasitism is planned containing such subjects as: effects of ticks on their hosts; general tick ecology; behavior studies; zoogeographic distribution; host-parasite specificity, and evolution and regressive tendencies of the parasite in the country.

From such studies a program will be designed according to the ecological situations to obtain better results since it will be possible to use natural forces which limit the spread and incidence of ticks in cattle production.

Experimental pathology

Ticks play an important role as biological and mechanical vectors of some diseases. Our knowledge about pathogenesis will be broadened with the development of tests and simple and more accurate diagnoses. Therefore, current programs of control will be based on disease patterns. This will tend to solve actual problems in the field while adjusting the parameters in the experimental design as indicated by the disease effects on cattle production. This vision of pathology associated with ecology to solve the problems based on research calls for the following specific subsections:

(a) General pathology
(b) Immunoflorescence
(c) Histopathology is required since of all the diseases transmitted by ticks the most important is piroplasmosis which affects the red cells and causes anemia from loss of blood. Therefore, special projects are needed to supervise the therapeutic and prophylactic systems in use.

Epidemiology

To apply the epidemiological principles of tick control for the diseases they transmit, demands a careful examination of the parasite incidence, its geographical distribution and its particular epidemiological characteristics. A systematic field analysis must include: parasite ratio and availability, efficiency and utilization of insecticide control measures. A study of tick morbidity and mortality effects of vaccines and therapeutic drugs must also be conducted. Observations of the tick situation and the regular distribution of the data from the field to the epidemiology departments would serve to dictate or modify the pattern of action of the tick campaign.

Statistics

A main cause for the actual ignorance of various problems of epizootiological, sociological and administrative order in the research field and parasitic control programs is the deficiency of basic information which is delayed, incomplete and inaccurate. Therefore, a research center must include a statistics section containing activities such as: design formulation, data collection and instructions for elaboration of analysis and presentation of such information. The ideal would be a biometrics department to coordinate the results of the research done for the different departments and to elaborate experimental designs of the tests to be done. These specialized personnel would also train new people for collecting original information that is valid from a statistical point of view.

Presently, the distribution, percentages, medias, etc., and studies of inferential statistics on the tick have been developed in Mexico, and integrated into epidemiological disease statistics like piroplasmosis and anaplasmosis to establish relations concerning disease progress, the development of programs for the solution of tick problems entirely, and their correct evaluation and presentation.

The center will include a module where the director, subdirector and administrative section will be located; it will also have a library and museum section.

The pedagogical work will take place in an auditorium specifically built for the purpose which will be equipped with film and slide projectors, and simultaneous translation.

The national campaign against ticks will have approximately 240 veterinarian/animal scientists, who will take care of the field work but all the personnel should receive continual training with courses on the different topics and studies to be offered at the center. The courses to be offered are:

(a) Taxonomy: according to the eradication plans, knowledge of the different kinds of ticks, their exact distribution and identification of each type of tick is essential.

(b) Incubation and biological tests: every stage in tick infestation of cattle will be verified through examination of all tests done in the center, since all the predominant species will be raised. One could also demonstrate the effectiveness of different acaricides, their toxic activity on the various genera and studies carried out on the different tick stages, both in dipping vats and spraying.

(c) Toxicology: the courses will deal with pesticide effects on animals, lethal dosage (50%), and possible intoxications and animal reaction to ixodicides.

(d) Physical-chemical: courses will be presented to determine insecticide concentration and factors influencing the conduct of the ixodicides in the vats (even if these drugs have been used before) and the measures needed to solve these problems.

(e) Ecology: the courses will deal with the following subjects—parasite and general ecology, tick ecology, and courses on population dynamics.

(f) Experimental pathology: practical and laboratory courses will be given about aspects of diagnosis, treatment, prophylaxis, control and eradication of the diseases being studied at the center.

(g) Statistics and Epidemiology: a large amount of data will be presented on the statistics and epidemiological requirements needed to correctly evaluate field problems in the campaign and for accurate interpretation.

These training courses will be accomplished with the coordination of all the field personnel since their work and experience in the field would lead the planning of research work in the laboratory.

It has been an honor to address this distinguished body and to express to you aspects of our number one problem for livestock in Mexico—the tick. The objective of this talk has been to let you know how the National Tick Campaign has been planned, its technical development and achievements.

We know about our deficiencies, the product of a young campaign recently established.

We are aware of the problems and of the urgent need to solve them for the benefit of the national livestock and Mexico.

We are engaged in solving our deficiencies to reach better goals based on self-improvement, dedication and determination.

The battle against ticks in Mexico has been characterized by its creation from zero, without the necessary economic and materialistic elements which were supplied because we believed it was the challenge to take. I have expressed these concepts here because I believe they are basic pillars when introducing any sanitary campaign, not only against ticks, but any in all Latin American countries.

Summary of Discussions of Papers by:

O.H. Graham
Joao C. González
Ralph A. Bram
Luis Beltrán

Dr. Stephen Barnett (England) suggested that the discussion be limited to **Boophilus microplus** and that importance be given to the ecobiological aspect without delving into tick resistance to acarcides which would be treated later on.

Dr. Alfonso Escobar (COOPER, Colombia) inquired when cattle dippings should be given and at what intervals. Dr. J. González (Brazil) replied that ticks are more susceptible when initiating the nymphal metamorphosis, the period when the sexual forms start to appear. He recommended an interval of 14 days.

It was suggested by Dr. Escobar that baths at 14 day intervals perhaps wouldn't attack nymphs. However, Dr. J. Gonzalez replied that metanymphs are susceptible.

Dr. Ricardo Ochoa (Colombia) indicated that in order to maintain immunity against the hemoparasites some ticks must be left on the animal. He asked, if bathing intervals of 14 days are recommended and how could this be done. Dr. J. Gonzalez recommended 14 day intervals as the longest period but added that the frequency of the bath depends on the tick population; if this is diminished, the bath should not be given. Three baths at 14 day intervals are recommended. Then the cattle are examined and the tick population is estimated. If it is numerous, two to three more baths are indicated. Once some balance has been accomplished, the baths are suspended. Surveillance is a very important factor.

Dr. Guillermo Mateus (Colombia) asked, if the days of residual effect of the product used are included in the 14 day interval, would it not be better to bathe every 18 or 20 days. Dr. J. Gonzalez maintained that despite the indications of residual power, what must really be considered is the residual left in the animal's hair. Phosphorate residual has been found 30 days after the animal was dipped, but it is not known if this would prevent tick reinfestation. He added that it would be risky to rely on a factor whose efficiency is dubious.

Dr. Hernan Zaraza (Colombia) stated that the relationship of the host-parasite should not be interrupted. Frequency of the baths depends on tick populations. Surveillance must be done by trained personnel. Dr. Barnett replied that he thought the 14 day interval for baths was the more adequate, nevertheless strict regulations cannot be followed. He stated that more experimentation is needed in Latin America.

Dr. Kenneth Thompson (CIAT, Colombia) asked Dr. J. Gonzalez to elaborate on the life cycle of the **B. microplus** in Brazil. Dr. J. Gonzalez offered the following data:

Larval stage (larvae and metalarvae): 1 to 7 days.
Nymphal stage (nymph and metanymph): 5 to 16 days.
Adult stage (males): 12 to 39 days.
Adult stage (females): 1st. neogina: day 3.
last neogina: day 35.
Most frequent moltings:
Larvae: day 4.
Nymph: day 8.
Metanymph: days 9-14-15.
Hatching: 2-3 days in December, January and February.
Oviposition: Minimal periods: 6-7 days in warm months in December and January.
Eclosion (to differentiate this from oviposition).

The life of the larvae: the larvae can live 240 days in warm and humid seasons. Heat will kill the larvae; cold will preserve them. The larvae deposited in cold seasons (June-July) die more easily.

Dr. Thompson inquired how long it takes for the development and subsequent hatching of the eggs, taking into account the cycle of **B. microplus** on the ground. Dr. J. Gonzalez stated that temperature greatly influences the period of pre-egg laying when the adult tick drops from the animal and starts to lay eggs. With favorable temperatures (warm months) minimal eclosion period is 17 days.

Dr. Barnett asked Dr. Gonzalez if the information obtained from his experiments in Brazil have been published. To which Dr. J.

Gonzalez replied that everything concerning the biological cycles has been published.

Dr. Gavin Braithwaite (ODM, Argentina) inquired if the figures concerning the biological cycle of the **Boophilus microplus** tick were obtained while working with temperatures at the field or laboratory level. Dr. Gonzalez replied that the work was done at the environmental level.

Dr. Marcelo Rojas (Peru) inquired about methods for studying larvae in the field. Dr. Braithwaite stated that larvae have been studied measuring them in three different environments. The engorged females were placed in the three areas and dates were recorded. They were observed three times a week in summer and two times in winter until the larvae emerged. The most important stage was the pre-hatching period (dropping of the engorged female) through observation of the first larvae) and larvae survival.

Under natural conditions the pre-hatch period lasted 80 days in winter and 27 in summer. The maximum duration of the parasitic stage was 140 days in winter and 63 in summer. The meteorological conditions were measured. This was done in nine different environments and there was always one control in the laboratory.

Dr. Rachel Galun (Israel) asked if the Zebu/Brahman breed is being crossed in Brazil in order to increase resistance to ticks. She asked if this resistance had been investigated against **B. microplus.**

Dr. J. Gonzalez stated that in Brazil, Zebu has been crossed with Aberdeen Angus and it has been observed that as Zebu blood increases, tick susceptibility decreases. It appears that thickness of the skin is not important since there is information that Zebu skin is even more delicate than that of European breeds. Some people believe it is due to the presence of sudoriferous glands. However, he believes that resistance in Zebu cattle is humoral in nature.

Dr. Rojas stated that there is information that resistance response occurs through serous histamine, depending on genetic factors. Zebu have 83 percent serous histamine, while European cattle have less. He, therefore, believes that resistance must have a genetic basis.

Dr. Antonio Gonzalez (Mexico) commented that the hypersensitivity phenomenon observed in Zebu cattle is what gives them their resistance. There are certain anatomical-physiological characteristics which give them this capability. The inoculation of certain shark liver oils leads to conditions in which the ticks drop from the animal. This oil was mixed with extracts of fat glands from Zebu skin. When ticks feed there is an exudation of material around their hypostome. Ticks then adhere and die.

Dr. Barnett inquired if there were in Brazil any national program to promote the crossing of Zebu cattle with **Bos taurus** to confront the tick problem. Dr J. Gonzalez indicated that there were programs mainly in the traditional areas of exploitation of European breeds.

Dr. Galun asked if there had been any research on cattle breeds resistant to ticks. Dr. J. Gonzalez stated that he did not know of any such programs.

Dr. Barnett noted that no one has worked on the economical aspects of babesia and anaplasmosis. In Argentina, there is no data about the cost of the eradication campaign.

Dr. Antonio Ibañez (Paraguay) suggested that since cost-benefit analysis in planning a tick campaign is requisite for politicians the economics of control programs versus eradication should be discussed.

Dr. R.J. Bawden (FAO, Uruguay) stated that the program must clarify its objectives and define its methodology. In Uruguay, there is a plan to study the importance of tick-borne diseases. Such a plan could be used to study other diseases as well. There are three stages:

(1) Identification of losses.
(2) Diagnosis of the parasites present.
(3) Advice from the control program (using data from other sources.

The phases:

(a) Diagnosis - Measurement - Assistance for the losses.

Prevalence in Uruguay: throughout the country.
Identification of the losses: direct and indirect. Closing of the external market, etc.
Quantification of the losses.
Function of the number of hosts with the number of parasites or with an equation from the Economic Bureau of Australia; it can be isolated and measured as a percentage of the depression in production (Johnson, Australian economist). (Includes the probability of animals which get sick).

(b) Classification of the losses.

Handling study.

(c) Controlled field experiments.

Analysis of cost/benefits of control; there are three phases which are important to measure and evaluate.

Dispersion.
Reproduction.
Infestation.
Description of the eradication parameters, analysis of the responses to the control measures. Development of the control program must be studied at the individual producer level and then generalized.

Macroeconomic analysis—The market repercussions are measured by macroeconomic analysis. The government must analyse the control situation according to the national investments, etc, and with the data obtained by the scientists.

Dr Mateus asked Dr. Beltran to clarify some aspects of the tick campaign in Mexico. He asked what were the studies on factibility; the basic data before initiating the campagn and the most difficult problems the campaign must face. Dr. Beltran replied that they must be one step ahead of the tick and the strategy was to convince the farmers of this. The decision to use dipping vats was due to the idiosyncrasies of the workers since aspersion baths were unsatisfactory. Dipping was more economical in Mexico. The most important problems faced were socio-economical in that there was little knowledge about tick damages and control techniques. The farmers regarded the tick as a natural thing to be tolerated.

Dr. Barnett inquired if Dr. Beltran has been able to sell his eradication program and if there were results to support it. Dr. Villaseñor replied that they were opportunists—they had a leader, a salesman in the person of Dr. Gustavo Rota, who knew how to sell the tick program. Also, the economic moment was favorable. Government changes made it difficult to obtain money so that public opinion had to be mobilized and then the government convinced. Dr. Villaseñor added that there is a need for data on losses caused by the parasite and its diseases and to persuade the government to control them. The idea has to be sold. Eradication should not be proposed from the beginning, first the tick must be controlled.

Dr. Graham stated that eradication in the United States took from 1906 to 1943 to be successful.

Dr. R.J. Bawden (FAO, Uruguay) stated that Australia has dropped its eradication campaign which cost them more than US $ 2 millon per year. They now believe that ticks are out of control and that eradication is not a practical measure.

Dr. Ibañez (Paraguay) asked what would be an acceptable tick level. Dr. Bawden replied that tick infectivity with hemoparasites is low in Uruguay, therefore, it is necessary to define the areas in which ticks are infested. Furthermore, there is a need to define tick distribution in the country and its impact on weight losses.

Progress in Screwworm Eradication in the United States

Donald Williams *

Screwworms are the larvae, or maggots of the screwworm fly. They are a serious pest of warm blooded animals—livestock, pets, wildlife, and even humans. They closely resemble common blowfly maggots but unlike blowfly maggots which feed on carrion or dead or diseased tissue screwworms consume the healthy flesh of the warmblooded animals they infest.

Screwworms are found in open untreated wounds. The female fly lays a mass of eggs on the edge of a wound. Larvae hatch from these eggs and burrow into the flesh, where they feed. Mature larvae drop to the ground and pass through their pupal stage in the soil. Later, usually in about 10 days, but sometimes as much as 60 days, depending on the weather, they emerge from the soil as flies. Within days the flies mate, and begin infesting livestock with a new generation of screwworms.

Screwworms seriously injure, maim, or kill infested animals particularly if wounds are untreated and become reinfested. Screwworm larvae feed continuously. They grow from nearly microscopic size to about one-half inch in length, and in the process greatly enlarge the wound. This destructive parasite was a major pest throughout the southern and southwestern states and, today, is still found in Mexico, Central and South America and the Greater Antilles Islands.

The destruction caused by screwworms has been greatly reduced in the United States and in parts of Mexico compared with what it

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was before the cooperative eradication program was initiated using the sterile male eradication technique.

Scientists of the U.S. Department of Agriculture (USDA) artificially raise millions of screwworm flies, and make them sexually sterile by exposure to atomic radiation. The sterile flies are then released over infested rangelands, where they mate with the native fertile screwworm flies. Eggs from such matings will not hatch. Since the female screwworm fly usually mates only once in her lifetime, screwworm reproduction is stopped entirely when there are enough sterile males to mate with all fertile females.

The sterile male eradication technique was first used successfully in a pilot project on the Caribbean island of Curaçao. It then was successfully applied in the southeastern and southwestern United States, Puerto Rico and the Virgin Islands. The continuous release of sterile flies throughout the United States-Mexico border area creates a barrier zone against migrating screwworm flies that might reinfest the United States.

Screwworm eradication programs, past and present, have succeeded only when the sterile flies greatly outnumber the native fertile flies. But this favorable sterile-fertile ratio can be achieved only when livestock owners support the eradication program with their own efforts. They must help prevent infestations by not wounding animals during screwworm season, spraying with preventative materials, treating all wounds and infestations, and submitting samples of larvae from infested wounds for identification by trained program specialists. Every step taken to prevent, eliminate, or report a screwworm case reinforces the overall program to eradicate screwworms.

The history of the screwworm in the U.S.A.

The screwworm fly is known scientifically by the name **Cochliomyia hominovorax** (Coquerel), but not until 1933 was any clear distinction made between this parasitic insect and the common blowfly species **Cochliomyia macellaria** (Fabricius), which had been known since the late 18th century. For over a hundred years, it had been assumed that maggot infestations in living animals were those of blowflies, feeding on the decaying tissues around wounds and sores just as blowflies feed on the carcasses of dead animals. These larvae, or maggots, were called screwworms because of the circular rows of spines around their bodies, which made them resemble the common wood screw.

Screwworm infestations in living animals were reported in the Western States as early as 1825. Destruction caused by the pest increased over the years to the point where livestock production became unprofitable in some areas. Home remedies for treating infestations were ineffective. By the turn of the century, ranchers were appealing to the government for help.

The U.S. Department of Agriculture started research on screwworms in 1913, but these early studies failed to show the distinction between the parasitic and non-parasitic infestations. Realizing the need for increased efforts, the U.S.D.A. Bureau of Entomology and Plant Quarantine in 1929 established a research station at Menard, Tex., under the direction of entomologist Emory C. Cushing. This station was subsequently moved to Kerrville, Tex., and expanded.

At the new research station, insect toxicologists and entomologists concentrated on measures to protect wounds against screwworms—an effort that advanced rapidly when the team developed a way of artificially rearing large numbers of screwworms, thereby obtaining an adequate test population. Among the various toxic chemicals tested, No. 62 (diphenylamine) proved the most effective as a wound dressing. When dissolved in benzol and thickened with a turkey-red-oil wetting agent, this became an effective larvacide. The preparation was further stabilized with the addition of lampblack, and became the well-known "Smear 62"—for years the standby preparation for treating screwworm infestations. Organophosphorus compounds have replaced Smear 62 in recent years, but this preparation marked the first significant relief from screwworms.

Even with an effective wound dressing, however, screwworm infestations continued. Constant vigilance was needed to protect livestock. Trapping immense numbers of blowflies over several years brought no appreciable reduction in the number of infestations. At this point, Director Cushing concluded that somewhere in the research some vital information about this livestock pest had been overlooked and that a complete review of its ecology was necessary.

Cushing undertook a course of graduate studies in medical entomology in England at the University of Liverpool School of Tropical Medicine. Under the direction of professor W.S. Patton, he collected and studied samples of the various species of American blowflies. Athough externally the flies appeared identical, he observed distinct differences between the sexual organs of the blowfly **C. macellari** and those of flies reared from maggots found in infested wounds. Thus, in 1933, the culprit was at last identified and given the name **Cochliomyia americana**, subsequently changed by other specialists to **C. hominovorax.**

Identification of this parasitic blowfly species came none too soon. By that time, livestock shipments during the drought years had spread screwworms to Florida and other southeastern states, where they caused heavy losses among livestock, pets, and wildlife. As in the Southwest, even humans occasionally became infested. Livestock production in the southwestern states had come almost to a standstill because of the immense screwworm population.

Research on an effective method of screwworm control or eradication was suspended during World War II, but resumed immediately thereafter under a team of entomologists that included Dr. S.F. Knipling; Dr. R.C. Bushland; Dr. A.W. Linquist; A.H. Baumhover; A.J. Graham; D.E. Hopkins; Frank Dudley and Weston New.

It was observed that the female screwworm fly usually mates only once in her lifetime. This mating fertilizes all eggs that she will subsequently produce. Dr. Knipling proposed that if large numbers of male screwworm flies could be sexually sterilized and distributed throughout infested areas, natural reproduction would be stopped by the mating of sterile males with fertile female flies, which would lay sterile eggs.

An intensive search was launched to find an effective and economical means of sterilizing large numbers of male screwworm flies. Dr. Bushland and Mr. Hopkins discovered that screwworm pupae, just before they develop into flies, could be sterilized by exposure to X-rays. Further research, with assistance from the Atomic Energy Commission, showed that sterility could be produced through exposure to gamma rays, using Cobalt-60 as a radioactive source.

Eradication

Research provided the foundation for control or eradication of screwworms. Now the time had come to see if the theories would work in practice. USDA scientists sought out an infested place that was isolated by natural barriers from other infested areas, so that the problem of reinfestation by migrating flies could be eliminated from the experiment. In 1954, the Dutch West Indies Island of Curaçao, 50 miles from Venezuela, was selected for a screwworm eradication experiment. The release of sterile screwworm flies over the island had the predicted effect. Screwworm egg masses, collected from wounded animals, showed a rising percentage of sterile masses compared with those that were fertile. The number of infestations dropped steadily, and after four months no more egg masses could be found and no infestations were reported. Curaçao became the first place to be liberated from the screwworm menace and it is still free today.

Success of the eradication experiment in Curaçao excited the interest of southeastern livestock producers. If screwworms could be eliminated within a small isolated area, could they not be eradicated over a large isolated area such as the southeastern United States? Until 1933, the southeastern States had been free of screwworms. The movement of infested cattle into southern Georgia gave screwworms the free ride they needed to spread into Florida, where they became established and survived the year-round. From then on, they were a major pest of the region, often ranging Northward during the warm seasons into all the Southeastern States.

In 1957, preliminary tests in Florida showed promising results. The Florida legislature appropriated $ 3 million to defray part of the costs of a statewide screwworm eradication program to be conducted in cooperation with U.S. Department of Agriculture over a two-year period. This effort was further supported by Georgia, South Carolina, Alabama, and Mississippi in a region-wide cooperative program authorized by Congress, which began in 1958 under joint direction of USDA's Agricultural Research Service and the Florida Livestock Board.

The massive number of sterile flies needed for the Southeastern screwworm eradication program was provided by a sterile fly production plant, constructed at Sebring, Fla. For the first time, a parasitic flesh-eating insect was mass-produced and sterilized in an industrial type of operation. Twenty aircraft were used to disperse the sterile flies from small cardboard boxes. Livestock inspection stations were established along the Mississippi River to keep the area from being reinfested by the movement of infested livestock from the West. Producers cooperated by inspecting their animals, treating wounds, spraying their herds, and sending in samples of maggots for identification so that program officials could pinpoint the location and severity of screwworm infestations.

By the end of 1959, the Southeast was free of screwworms. Total costs of the two year campaign amounted to about $ 11 million as compared with annual $ 200 million in losses caused by screwworms in the southeastern states. A total of 3.1 billion sterile flies were released; 6,288,000 pounds of whale meat was fed to larvae; 169,450 gallons of fresh blood was used; 12 to 15 planes flew 39,244 hours and 5 minutes over more than 3 million miles.

Success of the Screwworm Eradication Program in the Southeast led western ranchers to request similar efforts in their region.

Elimination of this destructive pest would relieve the region of an estimated loss in excess of $ 100 million annually, For the first time in more than a century, there was hope that the United States could be free of this destructive pest.

But the hope of screwworm eradication was clouded by several problems not present in the isolated southeastern region. Screwworm overwintering areas in the Southwest were larger, and they extended continuously southward into Mexico. Screwworm migrations across the 2,000 mile U. S.—Mexico border presented a tremendous potential for reinfestation. Climatic conditions in the arid Southwest and the large numbers of livestock were entirely different from the situation faced in the Southeast.

Nevertheless state and federal officials decided to go ahead with the Southwest Screwworm Eradication Program with authorization of Congress and the wholehearted support of the livestock industry. In addition to federal and state appropriations, southwestern livestock producers voluntarily raised $ 4.5 million to eradicate screwworms, donated through the Southwest Animal Research Foundation (SWAHRF).

The southwestern eradication program began in February 1962 with two principal objectives: (1) to eradicate the screwworm fly from overwintering areas of the Southwest; and, (2) establish and maintain a screwworm barrier zone along the U. S.-Mexico border through the year-round release of sterile flies to stop northward migration of the pest.

A sterile fly production plant was constructed at the former Moore Air Base at Mission, Tex., largely from funds donated by SWAHRF. Federal expenditures were matched by those of the five States comprising the original eradication area—Texas, New Mexico, Arkansas, Louisiana, and Oklahoma. The new plant was outfitted for the rearing of more than 150 million sterile flies per week, drawing heavily on the experience gained in the southeastern eradication effort.

As in the southeastern eradication program, success was tied closely to the support provided by ranchers in the management of their livestock. In order to reduce the number of fertile native screwworm flies to the lowest possible level giving the sterile flies a better chance to compete, livestock producers were asked to check their animals regularly, to treat every wound and infestation and to send in samples of the maggots they found in wounds.

The eradication program proved to be an outstanding success. By September 1963, screwworm infestations within the original five state area had been reduced by 99 percent, and an artificial barrier zone had been established along the Rio Grande through the cooperation of the Mexican government. This zone was extended along the entire 2,000 mile border when Arizona and California joined the program in 1965

By 1964, screwworms had been eradicated from the original five state eradication area, and by the end of 1966 the last self-sustaining screwworm populations had been eliminated in the Arizona and California overwintering areas.

The barrier zone

Screwworm eradication in the Southwest did not guarantee the region against annual reinfestations when screwworm flies migrated Northward from Mexico. The screwworm barrier zone was established to prevent or minimize such reinfestations which would occur unless sterile flies were released constantly wherever screwworms were reported or their migrations could be reasonably anticipated.

The barrier zone operated on the sound strategy of: (1) maintaining surveillance and screwworm prevention throughout the region; (2) confirming all suspected cases with worm samples or egg masses; and, (3) the aerial release of sterile flies over all infested areas and every site of a confirmed screwworm case.

Cooperation by ranchers, veterinarians, county agents, livestock inspectors and others was an essential element of a successful barrier program. If wounds became infested and remained untreated, screwworms could build up to numbers too large for the continued effectiveness of sterile fly releases. If ranchers failed to send in samples of larvae or egg masses (which can be identified only by experts) program officials could not trace the spread and buildup of screwworm cases and plan effective sterile-fly release patterns.

The necessity for a barrier zone is obvious, considering that a screwworm fly can travel at least 180 miles to find and infest a suitable host animal. A single infestation can produce more than three hundred flies within 21 days. And any warm-blooded animal with an untreated wound even as small as a tick bite is a potential host for this deadly parasite.

The barrier zone worked exceptionally well. Screwworm cases, which once numbered in the millions, dropped to only a few hundred cases every year. Even after the threat of massive infestations had passed, many ranchers remained alert to the possible danger, especially when cases were reported within nearby counties. Worm samples continued to come into the plant at Mission so that screwworm eradication treatments could be made wherever necessary.

Problems did arise in 1968, however, when unusually moist and mild weather created conditions ideal for screwworm survival and spread. Nearly 10,000 cases occurred within the southwestern states. Although this was only a fraction of screwworm flies before the program, it served to remind everyone of the continuing danger whenever screwworms built up to large numbers in northern Mexico.

The hardest blow to the barrier zone program occurred in 1972, when some of the wettest weather on record in northern Mexico caused screwworms to build up to a record level in early spring. The predictable migrations occurred to such an extent that the sterile flies could not overwhelm the fertile population to the degree necessary to halt their reproduction. The difficulties were compounded by a lack of cowboys and laborers necessary to treat all the infestations; thus many animal wounds remained untreated and added to the already epidemic numbers of screwworms.

Special regulations were issued requiring the inspection and certification of all livestock moving interstate from the infested areas. Spraying or dipping was required for shipments to the southeastern states. The dispersal of sterile flies had to be limited to the areas where they were most needed on the eastern edge of the outbreak area and in the southern border areas where potential overwintering populations had to be reduced before the advent of winter.

The toll from screwworms in 1972 exceeded 9,000 confirmed cases in 11 states. Even the regulations against shipping screwworm-infested animals did not prevent few cases from appearing in several southeastern states. These infestations were eradicated by emergency release of sterile flies and by extensive inspection and spraying operations in each outbreak area. There were 14,976 cases reported in 1973 and 7,267 in 1974.

The disastrous 1972 season clearly demonstrated the need for a more effective barrier zone. This could best be established across the narrow Isthmus of Tehuantepec in southern Mexico, following an eradication program throughout the northern two-thirds of that country. This proposal, which had been discussed for years, is now moving toward reality with the establishment of a joint program by the United States and Mexico for the eradication of screwworms.

The screwworm plant at Mission, Texas

The Southwest Screwworm Eradication Program and the expanded eradication activities in Northern Mexico are directed by USDA's Animal and Plant Health Inspection Service (APHIS) from the sterile fly production plant at Mission, Tex. Since 1962, this facility at the former Moore Air Force Base has served as the focal point for receiving reports of screwworms in the southwestern states. The mailing address is: Southwest Screwworm Eradication Program, APHIS, U.S. Department of Agriculture Box 969, Mission, Texas 78572.

The artificial raising and distribution of 200 million sterile screwworm flies each week is a highly complex operation that taxed the abilities of entomologists, engineers, pilots, veterinarians, and administrators; yet the result of their efforts is a highly efficient industrial operation that has operated around the clock, seven days a week since the start of the program. Some 400 employees, working three shifts, collect and propagate fertile screwworm eggs, feed the larvae, store the pupae, irradiate them at the proper time, and package the sterilized flies for release from the program's fleet of aircraft.

The plant, which has over 81,500 square feet of floor space, is sealed tightly against any possible escape of fertile flies or contaminated material to the outside. All employees and visitors must change into uniforms and pass through a special security section in order to enter the plant and they must shower before leaving. All materials must be incinerated or "sterilized" before leaving the plant. Heavy hardware must pass through a special "hot room" before it may be removed.

The operation of the plant involves many refinements that have been developed over the years since the first plant was constructed at Sebring, Fla. The eggs from which the larvae are hatched are obtained from the fertile fly colony. Eggs hatch and larvae feed in warm, shallow vats on a medium which simulates the flesh of warm-blooded animals. The mature larvae crawl from the vats, fall into channels of flowing water that carry them to a separator. They are, then, placed in sawdust-filled boxes for pupation. Pupae are then separated from the sawdust and held in a temperature and humidity-controlled room for about six days. At the proper age they are placed in locked metal canisters for radiation. The pupae receive approximately 7,000 roentgens of gamma radiation emitted from radio-active Cobalt-60 or Cesium-137. Canisters of irradiated pupae are conveyed automatically to the packaging section where the pupae are measured into cardboard release boxes. The boxes, ejected from aircraft, release the adult flies that have emerged from their pupal cases.

Field survey and identification, methods development, plant and aircraft maintenance and administrative sections are all important parts of the total program, in addition to the sterile fly rearing operations.

Media used for screwworm larval culture - 1962/1975

Since 1972, screwworm larvae have been raised on horse meat, nutria meat, bovine and swine lung, and liquid media. Horse meat was used through 1968. Nutria was first used in 1962 and several million pounds of this media are utilized each year. Swine and bovine lung were also used off and on through 1963 to 1970. A liquid medium, a mixture consisting of dried blood, dried milk replacer for calves, dried whole eggs, dried cottage cheese, cotton, and formalin was first used in 1962. At the present time, the Mission, Texas, plant is feeding the larvae on this medium.

In evaluating which of the two media is the best, consideration must be given to two factors: first, the quality of fly produced; second, the cost of the medium. Both the liquid and the meat media produce a fly of equal quality .The cost of nutria-based media and liquid media is about the same. Nutria is available on seasonal basis and several million pounds per year are usually obtained. Sufficient nutria is not harvested in the United States to keep the plant at Mission on a nutria meat medium for the entire year. When the supply of nutria is exhausted, the production in switched to liquid media. Any other meat media, such as horse meat or beef, is so costly that its use would be prohibitive. The ingredients used in liquid media are not only easily obtained but are easier to store, requiring no refrigeration. Of all media used in the Southwestern Screwworm Eradication Program, pork lung is the least desirable.

Sterile fly release operations

Flies are released from the aircraft through specially constructed chutes that eject and open the boxes at predetermined rates. Normally, the planes fly on parallel routes, or swaths approximately 5 to 10 miles apart. Other aircraft fly "hot-spot" and strategic" sterile fly release missions. These operations are supported by livestock inspectors who visit ranches in the infested areas, marking the sites for aircraft where necessary and encouraging ranchers to inspect their livestock, spray their herds, and submit larvae samples for identification. The importance of the owners' cooperation and screwworm-prevention husbandry practices cannot be overemphasized. Sterile flies alone will not eradicate screwworms.

General responsibilities

The fly distribution section schedules, conducts and records the distribution of sterile screwworm pupae or flies which are received from the packaging department. Pupae are delivered in air-conditioned bulk containers to the Douglas distribution center by airplane or truck to locations determined by the epidemiologist in charge.

Scheduling distribution of pupae and flies

The amount of pupae delivered to the Douglas center is determined by a Program Director at Mission based on total plant production and the current screwworm situation in the United States and northern Mexico.

Routine scheduling of fly distribution from Mission is conducted by the epidemiologist in charge based on screwworm sample submission by ranchers, field reports from livestock inspectors, personal field observations, weather reports and predictions as well as the weekly plant production and the past history of screwworm infestations in Texas and northern Mexico. Weekly fly distribution schedules are subject to the advice and review of the veterinarian in charge of Field Operations, the Program Director and the screwworm staff at Hyattsville, Maryland.

Distribution of pupae and flies

Pupae are delivered to the Douglas, Arizona, Distribution Center by C-47 aircraft twice each week to minimize the time that the pupae must be kept chilled. Pupae for each delivery are collected by the packaging department over a period of 18 hours and placed in trays (one canister of pupae or 5.6 liters per tray) which are put in racks. As each rack is filled it is moved to a cold room (temperature 50° F.) until the load is completed which is usually about four hours before departure time. The pilot scheduled to fly the load checks weather conditions, makes a pre-flight check of the aircraft and when "all systems are go" notifies the packaging department to start the loading process. The pupae are poured from the trays into bulk shipment boxes which hold five million pupae each. The boxes are constructed to allow for chilled air to be pumped through the pupae mass while in flight. Pupae temperatures in flight range from 55° to 70° F. At the Douglas distribution center the pupae are again placed in trays and then packaged over a period of two days.

Flies for distribution from Mission are packaged at the rate of 2,000 pupae per box, held at temperatures ranging between 75° to 80° F. until they are about 90 percent emerged and then placed in a cold room at 60° F. for 8-12 hours prior to loading for dispersal.

Two types of aircraft are used for fly dispersal: the Beechcraft C-45 which holds 1,000 boxes of flies and requires one pilot and one disperser; and the Douglas C-47 which holds up to 4,000 boxes and requires a pilot, co-pilot and two dispersers. Boxes for the C-47 are packed in carriers of two sizes (24 or 84 boxes) to expedite loading. Usually, the C-47 aircraft are loaded and depart early in the morning to take advantage of the relatively cool temperature. The C-47 flights average about five and a half hours per day.

The C-45's make two or more flights from Mission each day from one to four hours and can be shaded and air conditioned while loading to minimize heat build-up. The C-45's are also used at auxiliary distribution centers where they are loaded directly from refrigerated trailers. Auxiliary distribution centers are used reduce "deadhead" flying.

Three aerial dispersal methods are used. These are termed grid patterns, hotspotting and strategic releases.

Grid pattern This is used to disperse flies over a large area. The grid consists of flight lanes of varying lengths five miles apart, and is covered twice each week by flying alternate lanes 10 miles apart so that, by the end of the week the area has been covered on lanes five miles apart. The number of sterile flies dispersed on the grid varies and is determined by the epidemiologist in charge.

Hotspotting Each ranch which submits a positive screwworm sample is treated for three to five weeks from the collection date with sterile flies. Hotspots within the grid pattern receive about 50 boxes and those outside the grid about 100 boxes. When the number of active hotspots in an area exceeds 30 per 600 square miles, individual hotspotting often becomes impractical so a hotspot grid is used. The approximate number of flies which would have been released on individual ranches are then released on a grid pattern, in addition to the regular grid. All active hotspots are treated each week.

Strategic releases. These are releases of sterile flies along rivers, streams and canyons in the drier regions of the United States and Mexico where animal populations tend to concentrate close to water courses where forage is most available. Reported screwworm cases from these areas follow the same pattern. All scheduled strategic releases are completed each week.

Ground releases Starting in 1974 each newly reported case is treated by a ground release of sterile flies. The flies are delivered to a number of central locations around the state either by refrigerated truck or by aircraft. Ranchers, state and federal livestock inspectors, and county agents pick up and deliver the flies directly to the location where the infestation was found. Ground releases are also made at ranches where repeat cases occur three or more weeks from the last ground release..

Recording fly distribution The fly distribution section keeps a record of each flight. From the individual flight records a daily release report is made and sent to the survey data section which compiles a weekly summary of fly dispersals from both the Mission and Douglas Distribution Centers.

Fly release cartons and release methods In the southeastern program sterile flies were released from small perforated cardboard cartons (approximately 2" x 4" x 6" in size) containing 400 sterile flies. Cartons were released from aircraft flown on lanes two miles apart. Lanes were closed in to one mile on alternate weeks providing fly release every mile each two week period.

In the southwestern program, fly releases were made from the small cartons on lanes four miles apart with lanes two miles apart on alternate weeks. Introduction of a larger carton (approximately 4" x 6" x 8" in size) containing 2,000 sterile flies was made the third year of the program (1965) and the lane widths were increased from 4 - 10 miles.

A screwworm outbreak in 1968 precipitated questions that the fly distribution was inadequate; however, in the years 1969 through 1971 the larger cartons and wider flight lanes proved entirely satisfactory. Since 1972, however, there have been more extensive outbreaks of screwworms in the United States. For this reason, flight lanes have been reduced from ten to five miles apart and in the hot summer months the number of flies per carton was reduced from 2,000 to 1,500.

The rate of sterile flies per square mile varies with the severity of screwworm outbreaks. Generally speaking, 1,000 sterile flies per square mile are released on flight lanes over areas with limited infestations.

Operation of the methods development section

Quality control

Quality control operations are divided into two areas of fly production. These can be roughly separated into tests and checks in the plant during rearing sequences and those similar activities conducted on the finished product, i.e. sterile flies.

Quality control operations in the plant are being instituted to establish check points in the rearing cycle to determine when deviations from optimun rearing conditions or other impinging factors occur. This permits localizing and pinpointing trouble before it grossly affects production. These routine checks will include determining sex ratios of flies in colony cages, hatching, ratio and quantity, and obtaining larval weights at various points during the larval stage. Age of the pupae at the time of radiation will be routinely monitored. Temperatures need to be taken from selected rearing vats both in starting rooms and the main rearing floor during each shift. In addition to that described above, it is necessary to explore various avenues to initiate, refine and upgrade the described checks and tests. There is no doubt that more critical routine examinations can be made.

Routine evaluations outside the plant commence upon the receipt of sterilized pupae. A representative sample of pupae (about 20) is removed from each canister after irradiation. Samples are combined from each irradiation source per shift. These pupae are held until adult emergence and an emergence percentage determined. These adult irradiated flies are held at 80° F. (26.5° C.) and 65 percent RH for an additional seven days. At this time they are force-egged by placing about 15 insects into a glass tube with a small quantity of horse meat. The tube is stoppered with cotton and held for three hours at 92° F (33.3° C) in an incubator. After this interval the tube is examined briefly for the presence of eggs. If an egg mass is noted (which occurs two or three times in 10 years) all of the flies are transferred alive to a holding cage to be tested and dissected. Otherwise the flies are destroyed and the meat is examined under the microscope for single eggs. If any eggs are apparent, the tube is held an additional 24 hours at 80° F, (26.5° C) to determine if hatch will occur. Appropriate record keeping is essential in this operation.

Mortality tests are conducted twice weekly on randomly selected sterile pupae. In this operation two 100-pupae samples are set up in test cages containing adult food and water. The adults are permitted to emerge at 80° F (26.5° C). After full adult emergence, the pupal container is removed and the number of non-emerged is determined. The adults are held for seven days at 80° F (26.5° C.). The dead and alive are determined. Sex ratios are established for those remaining alive.

A heat stress test is run once a day. A randomly selected sample of eight dispersal boxes are obtained at a stage of 40-60 percent emergence. All emerged flies are released. The remaining pupae are held one hour; those emerged are anesthetized, sexed, and the males divided into four groups of 100 insects per group. Each group is held in small wire cages for 16 hours at 98° F. (36.7° C). At the end of this time, mortality percentages are established.

A daily sex ratio is determined by obtaining a randomly selected box of flies ready for a dispersal flight. This is returned to the laboratory and the flies killed by freezing. The sex ratio is determined from this sample. From the same box an additional determination is made, i.e. the number of mutants such as yellow or white eyes and sickle wing. Four boxes are taken from each aircraft after dispersing flies and flies capable of flight are released. Dead flies remaining in the box are counted and removed. Each dispersal box is closed and held at 80° F. until the following day. At this point the boxes are placed in the freezer to kill all viable forms. The number of adults emerging overnight and the emerged-nonemerged ratio are determined.

A series of experimental non-routine tests are also conducted in the Quality Control Unit. These may vary from detailed studies on radiation sources to counting spines of fly maggots. Conducting a certain portion of field tests may also form a part of the activities. This subsection prepares life cycle kits and other informational material. A number of miscellaneous duties are performed, such as cage making, instrument maintenance, janitorial work, etc. Record keeping and reporting is a key function in all operations.

Currently, at the Mission plant, several new types of quality control tests are being explored. Some of these are biochemical in nature and must be simplified in such a way that applicable information can be obtained by minimally trained personnel. These tests would include gross determinations of lipids, fatty acids, and glycogen content of either larvae or adults. It is assumed that these are essential compounds related to flight capability and longevity in adult flies. There are a number of other possible tests to be explored at the Mission plant.

Plant and field testing

The methods development section basically contributes to three goals: (a) increased operation efficiency; (b) decreased costs; and (c) delivery of a better product on the ground. The section serves as a focal point in the transmission of research findings, new ideas, new engineering approaches, etc. to the operational mode. It conducts the necessary tests and evaluations at the plant, laboratory, and field levels. It actively participates in technical crises solving, and acts in an advisory role as requested on entomological matters. The following descriptions are representative, but not all inclusive, of the types and diversity of section activities.

Experimental studies on larval diet components and methods of feeding diet material are an essential and continuing effort. Much of this work is accomplished through the cooperative efforts of plant production personnel. A great deal of investigation remains to be done on diet substitutions for cheaper operation or for alternatives to biologics which may become scarce. Waste products produced by feeding larvae appear to be a major impediment in the rearing of larger adult flies. The removal or inactivation of the material should substantially increase the quality of flies and is presently being investigated. The Methods Development Section is also called upon to check or establish standards for biologic material. When inadequate laboratory facilities and/or competence is lacking, it is the section's responsibility to have such material tested by outside laboratories for comparison with the standards. Considerable testing needs to be accomplished in order to establish the quantity and quality of fertile flies used to maintain colonies in the plant. Concurrent with this, studies are presently being conducted on food maintenance materials in the colonies to insure greater fly longevity and egg production.

During the past year studies of several fly colony strains have been conducted. These studies have included field tests to determine dispersal rates and distances. Other tests have included laboratory and field longevity as well as mating patterns. Other field tests have included trapback studies to determine dispersal rates, dispersal patterns, fly longevity for chilled flies and chilled pupae as well as testing elevation and swath width distances. Other tests are planned to test topographical features with references to both sterile and wild fly populations. All flies collected from such tests require hand sorting to establish results and subsequent interpretations. Beginning this past spring, an effort was made to establish the effectiveness of our sterile fly releases by monitoring sterility through the use of sheep pens; however, this had to be discontinued due to the lack of vehicles. However, efforts are presently being made to re-establish a monitoring system so that a reasonable effort can be made at monitoring program success.

There are a number of concepts in the idea, research, or development stages which will require further experimental work. An example of an item at the developmental level is the chilled-fly release concept. Field tests have established that flies collected shortly after adult emergence, chilled, boxed, and held at low temperature (38°- 40° F) until delivery, survive better in the field than our current system of release. Under the chill system, the current packaging system would just about be eliminated and better dispersal achieved. Present impediments to rapid progress in this area are bio-engineering problems mostly associated with a feasible aircraft adapted delivery system.

Eradication of screwworms from Puerto Rico and the Virgin Islands

It was observed that Puerto Rico and the U.S. Virgin Islands were the only parts of the United States territory where screwworms continued to be a serious problem. Prior to the start of the eradication program, screwworm infestations cost the consumer and the livestock producer an estimated $22.5 million per year. These losses were the result of weight losses and carcass damage at slaughter of screwworm-infested animals, cost of medications for treatments, death losses, damage to hides, and costs of husbandry labor. Cases in humans were occasionally reported. Puerto Rican animal health officials and various livestock producer organizations requested that the Animal Health Division of Agricultural Research Service (ARS) enter into a cooperative program with them which could lead to the eradication of screwworms from Puerto Rico. Experience to be gained in the eradication of screwworms from a tropical environment such as Puerto Rico with a high density of livestock would also provide valuable experience which could applied in the tropical regions of Mexico, where screwworm eradication will soon be undertaken.

Because screwworm flies could readily travel distances to the Virgin Islands and between them, and as they could be introduced on infested livestock carried on boats coming from other infested islands in the Caribbean, the nearby U.S. Virgin Islands and the British Virgin Islands were included in the eradication program. This would insure that Puerto Rican livestock would not be easily exposed to reinfestation by fertile flies from the nearby Virgin Islands.

It was not possible to determine when the screwworm first invaded Puerto Rico. No doubt the parasite had been present for long time. It was considered that the isolated populations of screwworm flies could have evolved to the extent that the Puerto Rican strain of flies might not mate with sterile insects developed from mainland strains. To check this possibility, ARS scientists made three collections of Puerto Rican screwworms which were tested in the laboratories at Mission, Texas. These tests, conducted in small cages in the laboratory, proved that the sterile males being produced at Mission did effectively mate with native Puerto Rican female screwworm flies. The program was based on the assumption that sterile males released from airplanes over Puerto Rico would mate in the field with native Puerto Rican female flies as they had done in the laboratory. These gravid females would lay their eggs on animal wounds, and the resulting eggs would not hatch. For the program to work effectively, sterile males must outnumber native males and must also be able to compete successfully with native males for the opportunity of mating with the native female flies. The continued release of sterile flies was designed to bring about the reduction and ultimately the eradication of native screwworm flies in the area.

Livestock in Puerto Rico is made up of the following species listed in Table 1.

TABLE I **The screwworm host population of Puerto Rico (1966 census).**

Cattle	550,000
Swine	200,000
Horses	14,000
Goats	10,000
Sheep	500
Total	774,500

Puerto Rico has an area of about 3,500 square miles. This represents about 225 domestic livestock per square mile, not including the domestic and feral dog populations. When considering the land used for crops and the cities and towns, the number of animals per square mile is even higher. The climatic conditions in this tropical area are conducive to screwworm survival. This, along with the large number of potential hosts (wounds) made the eradication job much more difficult.

Role of the U.S. Air Force

The U.S. Air Force provided support for aerial release of sterile flies for the program on Puerto Rico and the Virgin Islands. Personnel of the U.S. Air Force Special Air Warfare Center (TAC) at Eglin Air Force Base, Florida, together with U.S. Air Force Headquarters personnel based at the Pentagon, Washington, D.C., cooperated with the U.S. Department of Agriculture, the Commonwealth Government of Puerto Rico, and the Governments of the U.S. and British Virgin Islands in the design and the planning of the screwworm eradication program in Puerto Rico. The Air Force was interested in the screwworm eradication program because one of the missions of the Special Air Warfare Center was the application of modern techniques and air power to assist other governments in solving problems with the proper application of aircraft. This program was similar to other successful programs that the Air Force has undertaken in different countries throughout the world. In July 1973, the Air Force group at Eglin Air Force Base was replaced by units from the U.S. Air Force Reserve, who became responsible for the aerial operation of the program until the final fly release activity on May 3, 1975. All Air Force participation was characterized by an extremely high level of professional competency and safety. Without Air Force cooperation, this successful program would not have been a reality.

Strains of flies

In June 1971, the program in Puerto Rico and the surrounding islands was initiated, using a "Mexican strain" of fly being produced at the Mission, Texas plant on a semi-solid diet which included nutria. In September 1972, released flies were changed to a mixture of a "Texas strain" and a "Puerto Rican strain". During 1973, these two strains varied in quantity, but the Puerto Rican strain was only released on the island of Vieques in January 1974. At that time, the Puerto Rican strain was discontinued and the "Tex-Mex strain" was used only until replaced with the "FF-8 strain" in February 1974. The "Tex-Mex strain" was developed with flies collected from Mexico and the United States. The "FF-8 strain" was developed from later field collections. It should be noted that screwworms were eradicated from the British and American Virgin Islands and the island of Culebra while the Mexican strain was used. Flies on the island of Vieques and perhaps Mona were eradicated while the Puerto Rican strain was being used. The western portion of Puerto Rico was freed of screwworms with a mixture of the Tex-Mex and Puerto Rican strains.

Sterile fly release operations

Sterile screwworm flies were produced at the sterile screwworm fly production plant located at Mission, Texas, and operated by the Veterinary Services of the Animal and Plant Health Inspection Service.

Beginning in June 1971, the irradiated pupae were packed in trays and racks contained in a large environmental chamber chilled at 45° to 55° F and shipped via C-123 aircraft operated by the U.S. Air Force. The flights from Mission to Ramey Air Force Base, at the northwest corner of Puerto Rico, took 14 to 16 hours, excluding stops for fuel and crew changes. Pupae were packaged at Ramey Air Force Base and held until the adult flies emerged, and were dispersed by small, single engine U-10 aircraft. The payload was relatively small about 150 boxes per sortie. For most of this period, 2.5 million pupae were shipped on a weekly basis. This quantity was increased to 5 million in September 1972 and to be further increased to about 15 million in February 1973. During the period when 2.5 million pupae were being airlifted, screwworms were eradicated from the United States and Virgin Islands as well as from the Puerto Rican Commonwealth island of Culebra, lying 26 miles off the eastern coast of the main island. A similar neighboring island, Vieques, nine miles off the eastern coast was free of screwworms by July 1973. During some periods, up to 22,000 sterile flies per square mile were distributed over Vieques. Mona Island, 45 miles due West of the western coast, was also freed of infestation. Screwworms were believed to be eradicated from the western quarter of Puerto Rico during the first 28 months of the program.

Starting in July 1973, the transport aircraft C-123 was replaced by the faster and longer ranged C-130 aircraft and sterile, already boxed pupae were shipped to Puerto Rico. Pupae were selected so that only a few flies emerged on the 6½ hour direct flight to Roosevelt Roads Naval Base in eastern Puerto Rico. This flight was usually made on Friday of each week. The aircraft was pressurized to 5,000 feet and the flies held in temperature controlled conditions to preserve fly quality during transportation.

Upon arrival at the distribution center, the dispersal boxes were placed in a modular air-conditioned chamber maintained initially at 78-80°F. When 90 percent emergence had occurred, the temperature was lowered to 65-68° F. Distribution of these flies commenced early the following morning. Two C-7A craft, each loaded with about 3.5 million flies per sortie, distributed flies on the predetermined flight lanes and on special areas as directed. Any flies remaining were held at 60-65° F, until released. They were released later in the day or on subsequent days.

Careful examination of the condition of the flies was conducted at each stage of this operation. Since July 1973, fly quality improved with a higher percentage of eclosion and an apparent increase in longevity. Quality control tests were made routinely to monitor fly quality. During most of 1974, 14.5 million sterile flies per week were released over Puerto Rico and Vieques. About 10.5 million flies were dropped on the lanes, resulting in a release rate of slightly more than 3,000 sterile flies per square mile. The island was transected longitudinally by 16 lanes, two miles apart. These lanes were bisected every other week. Special drops over outbreak areas required an additional 3.5 to 4 millon flies per week. Ground releases were also made in canyons and at the bases of mountains in order to insure that sterile flies reached these areas. Air Force personnel developed special fly release equipment to insure that the required numbers of sterile flies were released over infested areas. This equipment included an electronic counter which counted each box of sterile flies released and registered these numbers in the cockpit of the C-7 so that the pilot knew exactly how many boxes had been released at any time.

During the program, sterile flies were released over Puerto Rico, Vieques, and the Virgin Islands as indicated in Table 2.

TABLE 2 Sterile fly release dates and quantities.

Date	Flies released
June - December, 1971	77,600,000
January - December, 1972	180,860,000
January - December, 1973	701,440,700
January - December, 1974	722,400,000
January - April, 1975	169,008,000

Screwworm detection effort

There was no efficient lure to attract screwworm flies into fly traps. To date, the best such attractant available was decomposed liver, and it attracted only the female screwworm fly. This lure was not specific for screwworm flies in that it attracted several hundred ordinary blowflies for every screwworm fly caught. This made identifying trapped flies a laborious task. Likewise, there was no efficient way to measure the wild populations of screwworms nor the behavior and efficiency of the released flies in the field. The best practical method to measure program efficiency was the number of laboratory confirmed screwworm cases. Reports of cases unaccompanied by larval samples from the wounds were not given full credence. Only those case reports of myiases accompanied by larval specimens were considered when determining screwworm incidence. Screwworm incidence is shown in Table 3. At least 75 percent of the screwworm samples in 1974 were collected by Puerto Rican or United States livestock regulatory personnel. The remainder were obtained by owners or their employees.

TABLE 3 **Confirmed screwworm samples including fertile egg masses.**

Calendar Year	Puerto Rico (Inc. Vieques, Mona, and Culebra)	U.S. Virgin Islands	British Virgin Islands
1971	1,833	94	13
1972	2,240	2	16
1973	1,303	0	0
1974	168	0	0
1975	0	0	0

The last case of screwworms in Puerto Rico was reported on November 5, 1974. As the program progressed, the reporting of non-screwworm samples was used to evaluate the efficiency of the screwworm case detection system in Puerto Rico. In the first six months of 1975 there were no screwworm cases reported but there were 15 laboratory-confirmed non-screwworm cases. Continued vigilance has failed to reveal evidence of any additional screwworm cases in Puerto Rico.

Problems

There were three major problems facing the program during the first two years of fly release. These problems involved fly quality, ground support activities, and public information.

The first problem involved delivering good quality sterile flies for release over Puerto Rico. Apparently, the logistic difficulties involved in hauling the flies from Mission, Texas to Puerto Rico in a non-pressurized and non-air conditioned, slow-flying aircraft of limited range was damaging to the pupae. Accumulation of heat generated by their own metabolism probably caused the most serious damage. This was further compounded by the fact that the flies had to be packaged in Puerto Rico and stored up to 10 days prior to release. A small, single engine U-10 aircraft (Helio-Courier) further delayed release. Laboratory tests showed decreases in longevity of adult flies corresponding to increases in holding times in the pupal stage. Delay, prior to release, is believed to have weakened the flies and limited their effectiveness.

This problem was alleviated in July 1973 when the U.S. Air Force replaced the C-123 aircraft with the larger pressurized C-130 as a pupae-hauling aircraft. All flies released after that time were packaged at Mission and shipped to Puerto Rico by C-130 aircraft. The C-7 (Caribou) aircraft replaced the U-10 for fly distribution. The C-7 was not-air conditioned, but the flies were cooled by air circulation, since the rear of the aircraft was opened in-flight to allow adequate ventilation. Routinely, flies were released at an altitude of 1,500 feet above the terrain. These measures enabled the program to release long-lived and more vigorous sterile flies over Puerto Rico.

The second problem which had to be solved after the first two years of fly release, was to improve the ground support activities of the program. This was accomplished by establishing a system of livestock inspections around screwworm-infested herds. Herds containing infested animals and nearby herds were sprayed with a 0.25 percent coumaphos (Co-Ral) spray. A total of 73,374 animals were sprayed during 1973 and 49,255 in 1974 as compared to only 2,987 animals sprayed during 1971-72 as shown in Table 4. This spraying was of inestimable value in reducing screwworm populations in outbreak areas and proved to be a valuable adjuvant to the sterile male technique.

Livestock inspectors equipped with Cap-Chur guns immobilized those animals which were suspected of having screwworm infestations. Any wounds found were treated with insecticide smears. Navels of new-

TABLE 4 **Livestock sprayed with coumaphos in the screwworm eradication program, Puerto Rico.**

Year	No. of cattle sprayed
1971	0
1972	2,987
1973	73,374
1974	49,255
1975	11,300 (thru June)

born calves were also treated in this manner. On Vieques, 194 animals in 1973 were immobilized with Cap-Chur guns and treated for screwworms.

Epidemiology

Epidemiological investigation played an important role in the eradication of screwworms from Puerto Rico and the Virgin Islands. After the first year of sterile fly release the islands were still infested with screwworms. Entomologists and veterinarians working on the program began to suspect that screwworm flies, both sterile, and fertile, finding an abundance of tropical vegetation, moisture and shade did not have to move far to find food. There were plenty of flowers growing in all areas of Puerto Rico to provide a source of nectar and pollen as food for the adult flies. This, together with the fact that there were about 225 head of livestock per square mile, many of which had wounds attractive to screwworm flies, fortified the theory that flies did not migrate as far in Puerto Rico as they did in southern Texas. This theory, though never proven, made program officials more determined to find cases and to make sure that sterile flies were released over all areas of the island, including the most inaccessible canyons and mountains on the island. Epidemiological field studies often revealed that packs of stray dogs were causing bites whose wounds helped perpetuate screwworm populations. Dogs gathered around garbage dumps in search of food. They were eliminated by a humane dog population program before screwworms were finally eradicated (a single case in a horse, which went undetected and untreated for several weeks, helped to prolong the infestations in one part of the island).

The only standard regulatory technique that was not used in the Puerto Rico program was the restriction of animal movement from quarantined premises.

The third problem was that of motivating the livestock owners to cooperate with the program by inspecting their livestock and sending in larval samples. This was solved in great measure by the Extension Service in Puerto Rico. Midway in the program, officials requested that the Extension Service take charge of the public information activities. Public information professionals of both that service and APHIS quickly increased use of the news media with novel ideas, such as giving a US. $25 reward for the last sample submitted during the program. This accelerated information program was largely responsible for improved producer cooperation during the final two years of the program.

Another problem was the eradication of screwworms from Vieques. This nearby island was 20 miles long and two to three miles wide with a land area of 52 square miles. It had a population of about 7,000 people. There were more than 20,000 head of livestock on the island. A large portion of the island consisted of a restricted area used by the U.S. Navy for military training. A significant number of livestock would wander into the restricted area, where they were wounded by explosions and residue of paraphernalia used in training. These animals were a constant source of screwworm infestation and, ultimately, had to be rounded up with helicopters for inspection and treatment. Helicopters were used because of the numerous unexploded shells in the shell impact area, which made it unsafe for personnel to enter. After the animals were removed from the impact area, the fence surrounding the impact area was repaired constantly to prevent livestock from re-entering.

Good epidemiological field work is a "must" in any attempt to eradicate screwworms from a given area.

Program Against the Cattle Screwworm in Mexico *

Marco Antonio Villaseñor **

Introduction

In Mexico there are many problems concerning animal health of which the more serious are: rabies transmitted by chiropterous ticks, general parasitosis, brucellosis, anthrax, malignant edema, etc. A misleading parasitosis is myiasis, known as "cresa" or "queresa", "worm nest", "wound worm" or "screwworm".

We have all seen a wormy wound in an animal and we also know that a good cowboy always carries a bottle with some worm killer in his saddle. This shows how accustomed we are to this parasite. Therefore, we do not even realize the extent of damage to our livestock and wildlife.

The cattle screwworm is a free-living insect parasite during its adult stage but infests animal wounds in the larval phase. It belongs to the **Cochliomyia hominivorax** (Coquerel) genus and species.

This dipterous fly goes through a complete metamorphosis (from egg into larva, pupa to fly) and is an obligatory parasite during the second stage. The cycle lasts an average 21 days under favorable climatic conditions.

Animals affected

Only warm blooded animals are affected, i.e. bovines, equines, ovines, caprines, porcines, some wild animals and man.

* Taken from comments on slides.

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The screwworm lives in tropical and subtropical areas of Central America, South America, Caribbean Islands, Mexico and the Southern United States.

The economic impact of the screwworm in our country is due to the numerous infestations of cattle and wild animals; an infested wound if untreated can cause the death of a bull or adult deer in seven days. In cattle, infestation can start in any wound including a tick bite. The worst damage can be done in a newborn's navel. As any wound, the navel serves as a proper medium for the fly to deposit her eggs. Once the animal is infested, it must be treated immediately to save its life, although sometimes secondary infections also cause death. In infested areas, up to 90 percent of newborn deer die.

The flies are attracted to open wounds in which they deposit 200 to 400 eggs which rapidly develop into larvae. They feed on live tissue which is torn with their oral hooks. Thus, the wound becomes wider and deeper, the smell also being more fetid attracting more flies for oviposition. In a few days thousands of larvae can be seen, and the wound may look as big as a balloon in the bovine. In tearing the muscular and connective fibers (all larvae move in a characteristic manner), organic fluids exude constantly on which the larvae feed.

Not only do they cause death of some animals but also damage and expenses amounting to large sums which are sometimes difficult to qualify in strict profit and loss terms, i.e. man-hours to locate cattle, tie them up and to treat them, the purchase of "worm killers", hide damage, the maiming of an animal (many times permanent), secondary diseases and the cost of antibiotics, the decrease in milk and meat production, constant vigilance on the farm and when moving from other places, seasonal restrictions on branding, castration or dehorning, etc.

Public health

The screwworm is also a menace for man; inhabitants of tropical areas are more exposed since this insect is more likely to live there.

Probably man was severely infested in early times; and during violent, revolutionary epochs, but only very few cases have been reported in the literature.

Cochliomyia hominivorax, the scientific name of the screwworm, indicates that the species was denominated homini-vorax (man devourer) because the first records were of human infestations. Myiasis in cattle was known long before that of humans but the causal agent was believed to be a different insect. In Mexico, some human cases, (although scarce), are regularly reported. Some have also been reported in the United States.

Prevention and treatment of cases

Traditionally, screwworms have been treated with simple or combined insecticides, and with some irritating fluids like creoline. However, this treatment does not eliminate the pest and severely inflames the wound, thus infestations may return.

The sterile male technique, developed by Dr. E.F. Knipling in the United States during the thirties, created a new method to eradicate the pests which reduces the use of insecticides, thereby decreasing pollution. After the work carried out in Sannibe, Curaçao Islands, Florida and Texas, the United States and Mexico considered a joint eradication program along their borders.

Work was started in 1962 in southern Texas and at the end of the same year in northern Mexico. These programs included the production of several million sterile flies at the plant in Mission Texas. The flies were released by airplanes over all the neighboring areas on the border, where screwworm cases were reported. To localize such cases, groups of inspectors checked the zones to investigate each ranch and motivate the farmers to report the pest.

Due to the success obtained, the zones were broadened and in 1965 all the southern states of the United States and all the northern states of Mexico were included in the inspections and sterile fly distributions. In this country, the area of eradication was approximately 1,000,000 km^2, which also represents, more or less, 50 percent of the whole Mexican territory. To distribute the flies, 31 airplanes were used and 46 inspectors were employed for field promotion. Flies were released from the planes in cardboard boxes, which opened at the time of release, dispersing the sterile insects over all the affected areas.

The sterile flies, both males and females, fly to the ground searching for a mate. This mating produces infertile eggs thus eliminating the probability of development of the species. In an area where a thousand wild flies exist, 100,000-200,000 or more flies must be released to increase the probability of sterile matings. Within a few generations the reproductive potential of the species is reduced to a minimum and, if sterile fly distribution is continued, final eradication will be possible.

Extension of the program against the cattle screwworm throughout the Republic of Mexico

Because natural migrations of fly populations repeatedly infest the free areas of northern Mexico and southern United States, the governments of both countries decided to enlarge the working area to the whole Republic of Mexico establishing a new control barrier at Tehuantepec Isthmus to take advantage of the geographic barrier there.

The 28th of August 1972, an agreement was signed to eradicate the screwworm from the whole north and west side of the Isthmus. With production of only 200 million flies per week at the Mission plant, expansion was necessary. A new plant was built in Tuxtla Gutièrrez, Chiapas, with a capacity of producing 300 million sterile flies per week.

Elements of the program

To eradicate or completely exterminate this pest up to the Isthmus by 1976, the program will have the following elements:

(a) the plant to produce and sterilize flies;
(b) a variable number of planes to distribute the fly;
(c) 220 inspectors and supervisors in the field (these personnel are already contracted);
(d) a total of 1,200 employees including administrators, investigators, epidemiologists, etc. After three or four years of production, a barrier of sterile flies will be established at the Tehualtepec Isthmus, to stop migration of the insects to the South.

The plant

The plant for sterile fly production is built of concrete and steel and covers an area 200 by 90 meters which is the equivalent of four football fields. Most of the building will be completely self-contained to prevent the escape of flies from the interior and also to prevent the entry of other insects. It will be air conditioned to keep temperature and humidity at screwworm requirements. The plant will also have Cesium 137 irradiators for sexual sterilization of flies.

The plant will be supplied with the necessary nutritional elements for the flies and other materials from a storehouse of 5,400 m^2.

In the same architectural complex there will be: an office and a machine shop, fire station, gas station, electrical services, well water, etc., and two lakes for water purification by oxygenation of water wastes from the atomic plants. In total, the plant and its annexes will occupy 33 hectares. Construction should be finished in 1976. The flies produced are being sent by airplanes to three distribution centers from which the whole working area is covered.

To motivate the farmers and to facilitate the reporting of cases, the program is distributing pre-stamped collecting tubes in which collections of screwworms can be sent.

From these reports it will be possible to establish areas with a bigger infestation rate; the stationary sequences and fly distribution zones will also be determined. In the collecting tubes, envelopes with insecticide 4072 will be given to the farmers, with which they can prevent and cure the infested wounds.

Through this program it has been proved that the two countries can and must refine their efforts to fight plagues which do not respect political barriers, and in this way, prevent the waste of animal protein in a world starting its fight against starvation.

Summary of Discussions of Papers Presented by:

Donald Williams
Marco Antonio Villaseñor

Dr. Richard Bawden (FAO, Uruguay) asked what technique was used to measure the screwworm fly overwintering line. Dr. Donald Williams (USA) stated that in the United States the measurements were carried out by a specialist who interviewed people connected with cattle production. In winter months the percentages of cattle infested by screwworms were studied.

Dr. João Gonzalez (Brazil) asked if there were information about the presence of blow flies, i.e. flies, other than the screwworm fly. Dr. Donald Williams (USA) stated that information was used from farmers about other types of flies. Dr. Marco Antonio Villaseñor (Mexico) noted that their interest is only in the screwworm fly. Although secondary flies feed on dead tissue, they are not considered important since they do not cause deaths, except in birds.

Dr. Marcelo Rojas (Peru) asked Dr. Villaseñor what will the screwworm eradication program in Mexico cost and how long it would continue. He stated that the cost might correspond to 1/6 or 1/7 of the maintenance cost of the barrier with the United States since the eradication program for the screwworm must be permanent.

Dr. Williams stated that the cost of the screwworm eradication program (which cost US $ 20 million per year) in the southwest United States during a period of 17 months, has risen to US $ 11 million. A great investment has been made since 1962, including some allowances for Mexico. Two funds have been operating (one for the United States and one for Mexico) and the cost-benefit ratio was good.

Dr. Williams also added that according to the information given by the farmers there is a loss of US $62 due to annual infestation (1/2 drugs, 1/3 others). The total cases (1 or 2 million, for example) would be multiplied by the individual cost.

Dr. Villaseñor, noted that initially, the studies on the losses caused by the screwworm were very subjective. In 1962, the losses amounted to (Mex.) 350 million pesos. The contribution of the United States and Mexico to the eradication program has been proportional to the losses in each country. He thought that the investment would be amortized in two years.

Dr. Ronald Smith (Illinois University, Mexico) indicated that there have been some problems in the maintenance of the fly colony (sterilization, male competitiveness in the field). He wondered if males from the field should be introduced into laboratory colonies. Dr. Villaseñor stated that he did not know of any problem inherent to the fly lines. One sole genetic line could, through many generations, create a fly with genetic defects. Such defects would debilitate it in the environment, i.e. blindness, short flight, etc. One or ten unfavorable factors could be introduced into the fly lines, at the plant in Texas or the one in Mexico, but there is adequate protection against such failures.

Ecology and Control of DERMATOBIA HOMINIS in Colombia

Guillermo Mateus *

The presence of the larval stage of **Dermatobia hominis** under the skin of domestic animals and man constitutes one of the major problems caused by arthropods in tropical Latin America. The problems this parasite causes in cattle are summarized as follows:

(1) Retardation in calf growth and predisposition to other diseases such as: omphalitis, myiasis, wounds and death (although only indirectly).
(2) Slow daily weight gain; the parasitized males gain between 9 and 14 percent less than those not parasitized.
(3) Low milk production; if the **Dermatobia** infested cows are treated, milk production will rise 18 to 25 percent or more.
(4) Partial or total hide damage.
(5) Acclimatization is difficult for selected breeds.
(6) Commercial value of the animal is lessened by its poor physical shape and appearance.

In humans this parasite can cause wounds, deformities, even blindness.

Economic losses caused by **Dermatobia** in Colombia are calculated to be 960 million pesos or US $ 31 million per year. Annually in Latin America, these losses exceed US $ 260 million.

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On the American continent, **Dermatobia hominis** is found from the Tehuantepec Isthmus in southern Mexico through all of Central America, some Caribbean islands such as Trinidad and Tobago and all the South American countries.

Dermatobia affects mainly bovines but it can also affect dogs, pigs, chickens, horses, mules, deer, other wild animals and man. The experiences described here relate almost exclusively to the bovine.

The parasitic stage of **Dermatobia** is known in every country with a different common regional name. Here are some of them:

Nuche in Colombia.
Moyocuil in Mexico.
Colmoyote in Guatemala
Torsalo in Nicaragua.
Berne in Brazil.
Mirunta in Peru
Hura in Argentina and Paraguay.
Borro in Bolivia.
Gusano de zancudo in Venezuela.

The parasite exists only in tropical Latin America and the human cases reported in North America have been acquired in the Latin American tropics.

To identify the parasite and avoid mistakes, **Dermatobia** is classified as follows:

Class	Insect
Order	Diptera
Family	Oestridae
Sub-family	Dermatobinae
Genus	**Dermatobia**
Specie	**hominis**

In Colombia, **Dermatobia** is found distributed between 160-2,000 msl. The major incidence occurs in the geographic area known as the "coffee zone" which is found between 600-1,000 msl. In this zone, some conditions such as temperature, humidity, rainfall and the sandy texture of the soil favor the development of the parasite. The average temperature for **Dermatobia** is between 18 and 28° C.

The life cycle of the **Dermatobia** may be summarized as follows:
Egg 6-15 days (laboratory conditions include the hatching stage which lasts 4-6 days).

Larva (parasitic stage) 39-50 days.
Pre-pupa 18-24 hours.
Pupa 32-43 days (in the field).
Adult 1-9 days (laboratory conditions).

The most important biological phenomenon in the **Dermatobia** life cycle is that it does not deposit its eggs directly on the host. It uses arthropods as mechanical vectors which transport the eggs during the hatching stage. Later, they carry and deposit the larvae on animals.

In the field, the flies lay their eggs on active arthropods such as mosquitos and flies of such diverse genera and species as:

Mansonia sp.
Mansonia lynchi
Aedes serratus
Culex sp.
Psorophora cingulata
Anopheles boliviensis
Sarcopromusca arcuata
Stomoxys calcitrans
Liperosia irritans
Criptolucylia sp.
Orthelia pruna.

In the field, the theory that **Dermatobia** deposits its eggs on plants, or directly on animals does not appear to be true, but under laboratory conditions the situation can be different.

The hatching stage lasts four to six days. White eggs show they have been recently deposited on a vector; as they mature they become a brownish color. This period is shortened if the eggs have been laid on a live vector; the higher the temperature, the shorter the hatching time. The type of vector is also related to the hatching period; those vectors with long flight ranges offer a greater chance for a short hatching period than those with slow and shorter flight ranges. When the hatching period is short there are more possibilities for the larvae to reach their hosts.

The number of eggs which will adhere to the vector's abdomen depends upon its size. Generally, mosquitos can carry 6-10 eggs; big flies between 40 and 60 eggs.

The floating population of **Dermatobia** (on vectors) calculated both in the percentage of vectors and the size of their loads can serve to evaluate not only the effectiveness of a control program but also the potential danger for livestock in a particular area. This data can also lead to investigations to find out if within a given area the **Dermatobia** life cycle takes place on animals other than bovines.

The site in which larvae localize on animals depends more on the carrier's habits than the larvae themselves. The licking (or sucking) vectors stay on wounds or places with secretions where they have the opportunity of unloading the larvae. The biting vector can land on any part of the animal and leave the larvae.

Dark colored bovines always have a larger amount of larvae than those with a lighter color. In animals with well defined white and black spots like the Holstein, **Dermatobia** infestations are greater in the darker places of the hide. If the hair of a completely white animal is dyed with special tints the number of larvae become greater in the dark places of the animal. In controlled tests, the proportion was 3/29.

In bovine herds, it is more common to find the larvae on males than on females (this is related to the handling of animals on the farm).

The amount of larvae on the bovine depends on the breed, color and age of the animal and also on the type of predominant vectors in the area. The degree of susceptibility of the different bovine breeds can be classified as follows: Zebu, very resistant; Blanco Orejinegro (BON) slightly resistant; Costeño con cuernos, very susceptible; and, Holstein and Brown Swiss, highly susceptible.

The number of **Dermatobia** also depends on the cleanliness of pastures; when these are free of bushes fewer larvae can be found on the cattle. Proximity to forests and bushes also increases the amount of larvae. The rainy seasons also increase the number of larvae. Although, the dry season shortens slightly the pupal state, it is not favorable for adult **Dermatobia.** During this season, the adult fly seldom goes to clean pastures but remains in the forests.

Dermatobia larvae in the larval stage under the animal's skin do not emigrate. The presence of two, three or more larvae inside the same larval sack is due to their proximity. (The initial larval sacks stuck to each other as the larvae grew, thus the nearby larvae emerge together through the same respiratory hole.)

During the larval stage which lasts 39-50 days in bovines, the parasite undergoes three different phases. In the first stages the larvae are very dynamic and active, growing fast, eating more and causing great pain. By the third phase the parasite is quiet, eats less and causes fewer problems for the animal. When the larva reaches its maximum development and prepares to leave the animal, the respiratory hole is widened and the larvae crawls out helped by round hooks covering its body. Larvae prefer to leave the bovine early in the morning, perhaps because the temperature is lower or there are fewer enemies in nature. The pre-pupa stage is initiated when the larva leaves the animal and drops to the ground. There, it will search for an adequate place where it will develop into a pupa.

The pre-pupa stage is very critical for **Dermatobia** since at this stage their natural enemies can interrupt the cycle. Among these enemies are: the yeasts; a fungus **(Sporotrichum schenkii)**; a fly **(Megazelia scalaris)**; ants; rats; other rodents and birds of prey. These agents have not been studied in detail as possible organisms for biological control of **Dermatobia.** It is an area that must be investigated.

After the pre-pupal stage the parasite enters the pupation stage, which takes place about six centimeters under the soil surface where it finds the proper temperature and humidity (loose or sandy soils are more favorable for pupae than the clayish ones). The pupal stage lasts 32-42 days but a slightly higher temperature shortens this period. An extreme drought destroys the pupa.

The adult stage of **Dermatobia** has been studied under laboratory conditions but there are many unknown aspects of its life under field conditions. The adult fly is not active; it spends long periods resting and it is very difficult to alter the state. Changes in light and temperature do not seem to affect the adult fly—it flies little and prefers to remain in very restricted areas.

Females begin copulation 24 hours after emerging, and copulate for several minutes with one or more males. To lay eggs, the female prefers live vectors. Egg laying is initiated several days after copulation.

The adults do not go into the open fields, preferring to remain close to the forests and bushes. They are never seen in pairs and only the females make contact with the bovines. In the field, 3/4 of the flies are females.

Dermatobia control became possible with the arrival of the organic phosphate compounds with systemic action and their use is indispensable. With them, it is possible to maintain the **Dermatobia** population low enough to try other techniques, such as biological control through male sterilization or the use of some biological agent such as bacteria, fungi or flies.

The effectiveness of a control program for **Dermatobia** can be easily demonstrated when one chooses an area which is protected with natural barriers (crops, high mountain ranges, rivers, areas free from bovines for years) and bovines with **Dermatobia** larvae are not allowed to enter.

The larval stage is the most vulnerable of the entire life cycle. There are chemical products on the market which are highly effective and moderately harmful to bovines which can kill several larvae in one treatment. Periodical treatments condition a population of larvae of the same age, and same degree of susceptibility. Then bovine handling for treatment is relatively easy.

The system in which the larvae are extracted (exerting pressure with the fingers in manual extraction) or with mechanical devices occupies time and is very painful for the animal. Furthermore, with this method, the larvae drop to the ground. Those ready to pupate then burrow into the ground if no measures are taken to destroy them.

A control program of **Dermatobia** must take into account the following steps:

(1) A study of the larval period (minimum and maximum time).
(2) Massive campaign of rural education.
(3) Identification of carriers.
(4) Protection of animals and man against insect vectors.
(5) Use of a phosphate product of well known effectiveness against the larvae.
(6) One hundred percent treatment of bovines two or three times successively, with an interval equal to 90 percent of the minimum larval period. Time of bovine treatment must not exceed 10 percent of the minimum larval period.
(7) Periodic examinations of bovines, with a frequency interval equal to 10 percent of the minimal larval period. This examination must be repeated six times successively.
(8) Individual treatment of each parasitic animal from periodic examinations.
(9) Individual treatment of bovines entering the control zone.
(10) Milk cows in production and animals going to slaughter must be cleaned of larvae by manual extraction and these larvae incinerated.

(11) Evaluation of the larval population using dark colored or black sentinel bovines. This evaluation can also be accomplished through vector collections.
(12) Examination of other domestic and wild animal species to eliminate the presence of the parasite.
(13) To demand at supermarkets and fairs, animals that are free of larvae.
(14) To impede the transportation of parasitized animals.
(15) To establish sanitary posts where the parasitized animals can be treated, as long as they are not destined for the slaughter house.
(16) To encourage cattle owners to maintain their animals free of **Dermatobia** larvae.
(17) To have pastures free of bushes.
(18) To select within each breed lines resistant to **Dermatobia**.

Comparative Experiences with DERMATOBIA in Latin America*

Antonio D' Alessandro **

"I am convinced," said Dr. D' Alessandro, "that there are no valid limits between human and animal doctors; on the contrary, the experiences of one are useful and interesting for the other."

Dr. D' Alessandro presented the subject of **Dermatobia hominis** from a medical point of view. He stated that there are three basic types of myiases:

(a) Accidental: produced by fly larvae which contamimate by ingestion or penetration of the gastrointestinal or urinary tract.
(b) Semispecific: oviposition or larvaposition in tissues, stimulated by bad odors from infested wounds or pustules. (They are not obligate parasites.)
(c) Specific: provocated by larvae of obligate parasites, such as: **Cochlyomia hominivorax, Hypoderma bovis, Oestrus ovis** and **D. hominis**, among others.

Larvae penetrate the body through the healthy skin, their presence causing a furunculoid lesion which has a respiratory orifice. Among all the treatments used in humans, we have several drugs which kill or anesthetize larvae; tobacco, pig's oil chloroform and ammonia.

Dr. D' Alessandro related the cases in which he was an active participant. He had extracted eight **Dermatobia** larvae from an Ar-

* Summary of address presented as no formal paper was received.

** Associate Director, ICMR of Tulane University, in Colombia.

gentinian man whom no one believed when he said he had worms under his skin. The other case had to do with the child of a local couple. The child went to the United States where the problem was identified, but without a definite diagnosis. The child was later brought back to Cali where a larva of **Dermatobia** was extracted from his leg.

Slides were shown of two cases reported at the Departmental Hospital (Valle)—one a girl with **Dermatobia** larva in her eyelids and a second—a man with a **Dermatobia** larva in his penis.

Summary of Discussions of Papers by:

Guillermo Mateus
Antonio D' Alessandro

Dr. Marcelo Rojas (Peru) asked when the benefits obtained with the control of the **Dermatobia hominis** larvae were analyzed, was the variant considered which was introduced by the effect of the systemic product used on the gastrointestinal nematodes. Dr. Guillermo Mateus (Colombia) replied that the cost of the treatment per animal of 300 kilograms is US$0.25; the cost of three treatments is US$0.75. Therefore, the cost is low compared to the increase in production. The effect of these treatments on gastrointestinal parasites was not considered but, in animals of more than three years of age gastrointestinal parasitism is not a big problem.

Dr. Rojas also inquired if the experimental pattern used could be explained. Dr. Mateus stated that one should not speak of an experimental pattern but of a planned treatment since this was a control program. The frequency with which the three treatments are carried out is given by the formula already explained. The time between treatments should be less than the minimum larval stage. After three consecutive treatments, surveys should be made with the same frequency.

Dr Rojas inquired if the dosis used was always the same or were different doses of the product tried. Dr Mateus stated that the dosis was 60 cc of a mixture consisting of one part Ruelene (crufomate) to nine parts water for every 100 kilos of weight. The inspections every 35 days served to detect carriers, even if they had a small load. Some use Neguvon (dipterex) applied directly on the wounds which would be less expensive.

Dr. Ivan Londoño (Colombia) commented that in a period of 1½ years at the Parasitology Department of the Faculty of Medicine at the Universidad de Antioquia, Medellín, 11 cases of myiasis have been presented. All the patients were men and professionals. Most of them worked in the field. A leprosy patient had nasal myiasis with perforation of the nose ridge due to **Cochliomyia**. The etiological agent of leprosy was associated with the larvae even in their internal structures.

He asked if there were any relation between the larvae and the etiological agent of leprosy. Dr. Antonio D'Alessandro noted that his comment about septicemia referred to the myiasis wound being contaminated with bacteria producing septicemia. But the larvae producing myiasis cannot be directly related to the etiological agent of leprosy.

Dr. Roger Drummond (USA) stated that Dr. Mateus talked about lines of cattle resistant to **D. hominis** and requested some comments related to cattle developing resistance with age, which would lead to the probabilities of using immunological control processes. Dr. Mateus replied that in the field, middle age adults are more commonly affected than calves. In Blanco Orejinegro cattle there are lines which are less susceptible.

Dr. O. H. Graham (USA) stated that Dr. Mateus mentioned other possibilities for control (fungi, release of sterile males, etc.). However, Dr. Gonzalo Luque (Colombia) noted that there are great limitations confronting cultivation of larvae for experimentation in Bogota soil. It is easier to do in areas where **D. hominis** exists.

Dr. Helio Espinola (Brazil) stated that in Brazil horses are not infested with **D. hominis**, and inquired if this happened in Colombia. Dr. Mateus noted that only on rare occasions does one find a horse infested with one or two larvae. In general, **D. hominis** is not a problem with horses.

Dr. Luque inquired about simultaneous control of **D. hominis** and ticks. Dr. Mateus explained that in Brazil they are treated simultaneously with a mixture of Asuntol (coumaphos) and Neguvon (dipterex). In Colombia, they are also treated with this mixture; then an application of Asuntol alone, and finally they are treated with the mixture again.

Dr. Luque asked about the use of irradiated larvae for **Dermatobia** control. Dr. Graham replied that ten years ago some work was done in Honduras of which four or five papers were published. Pupae were sterilized by irradiating them when they reached 80 percent of development. The dosis used was 5,000 rads and radiation did not affect the longevity or the activity of the adult. Therefore, sterilization appears possible in the laboratory. The problem is the capability of the females to multiply cumulatively.

Dr. Mateus inquired if Colombia would be successful in obtaining funds from the Food and Agriculture Organization (FAO) for a **D. hominis** control campaign. Dr. Ralph Bram (FAO, Italy) stated that FAO is always interested in these problems and is always willing to help. If a government of a country proposes a plan and agrees to spend a determined sum of money in the campaign, United Nations Development Programme (UNDP) would consider it. FAO is the executor organization of the plan. Generally the initial planning is made for two or three years. The same plan is applicable to tick-borne diseases. The solicitant government must provide them with counterpart support (work facilities, etc.).

Hematophagus Diptera as Vectors of Diseases in Colombia*

Hernando Groot **

Dr. Groot discussed mosquitos as disease vectors in Colombia. He made special reference to equine encephalitis, yellow fever, dengue and their vector **Aedes**.

He stressed the importance of these diseases, what is still unknown about them, and the conditions of transmission in which mosquitos play the most important part. Venezuelan equine encephalitis is transmitted by a mosquito and infection can pass from animal to man, hence, the human infection is always a subsequent phase to equine infection.

He noted that veterinary and human medicine are interrelated in the clinical history of Colombia. There have been serious outbreaks of malaria, whose eradication is difficult, and most of the failures are the result of problems related to the ecology and biology of its vectors.

Colombia, by its climatic and ecological conditions, is a country favorable for the production and development of these pests. Mosquitos thrive in the tropical jungles in slow running streams which are an ideal environment for the development of the **Culex** larvae. In addition, the country has large rice lands which makes development easy.

It also happens that at the forest periphery, foci of equine encephalitis, horses, are naturally immune. It has been experimentally

* Summary of address presented as no formal paper was received.

** INPES, Centro Administrativo Nacional, (CAN).

demostrated that these animals form a sanitary barrier around these infested areas. However, mutants generally leave the sylvatic cycle and enter the surrounding areas causing equine epidemics and death. In the sylvatic cycle, the virus is interchanged by a mosquito in the relationship animal-rodent-man. Thus, man develops a disease similar to that of the equine.

In 1969 in Ecuador, 1 percent of 31,000 equine cases of encephalitis died. These losses in human lives, medical assistance, control measures and agricultural production were outstanding.

We only need to know that one of the main products of Colombia is coffee and that the horse is used for transport. This makes the percentage of equine encephalitus a vital figure with such production. The cost of replacing horses that died was 4.2 million dollars in 1967. The combined animal morbidity and mortality rate from encephalitis was also high (76%), i.e. in 1967. In Colombia the number of sick animals fluctuated between 67,000 and 104,000. This disease caused income losses, expenses for veterinary service, and out-of-pocket expense for replacement of the animals.

It is necessary to understand the epidemiology of encephalitis to be able to prevent it in the future since vaccination has not proved to be effective. Of 400 children vaccinated, 200 caught the disease. The encephalitis virus that caused the epidemic was the sylvatic virus which was not pathogenic for horses. Dr. Groot seemed to indicate that if the equine virus is eradicated the human disease would also be eliminated.

Referring once again to **Aedes** mosquitos, Dr. Groot stated that between July 1971 and July 1972, Colombia had an outbreak of dengue. The first warning came from Barranquilla, when a group of doctors from the Universidad del Valle Medical School diagnosed the cases. The Public Health authorities were practically unaware of the problem, but curiously the population understood. They gave the disease the folkloric name "red tobacco" since the disease was characterized by fever and skin eruption. Serological testing showed that 20 percent of the people affected had dengue. It is believed that 22 percent of the 2.1 million people in Barranquilla must have had the infection but, interestingly, only 500 cases were reported. Thus the vector **Aedes** re-entered this country.

Yellow fever had been eradicated from Colombia but, in August 1975, foci of the virus were found near Cucuta and Bucaramanga thus infesting the country again and putting the urban populations in danger of an outbreak of yellow fever. This disease is transmitted by the mosquito **Aedes aegypti.** Dr. Groot speculated that the infestation of **Aedes** was provocated by two principal factors:

(1) The need for storing water in the home—a custom of people on the North Coast of Colombia. The water is stored under unhygienic conditions thus providing an ideal medium for mosquito multiplication.

(2) The disease came from neighbouring countries already infested. It was known that there were focal points of infestation in Venezuela and the Caribbean Islands. Thus, it was possibly carried on the tires of passing vehicles or in ships' cellars.

The Ministry of Health at present is reviewing the situation. However, there is not yet sufficient technology to eradicate the virus nor an efficient method for **Aedes** control, hence there is a need for new research programs leading to these developments.

Hematophagus Diptera as Disease Vectors in Colombia *

Pablo Barreto **

Dr. Barreto stated that flies, as bloodsucking insects, were good representatives of disease vectors, causing with their bites, health hazards to man. He mentioned **Stomoxys calcitrans** which is known to transmit the virus of an infectious anemia of horses, the anthrax bacillus, and several pathogenic trypanosomes.

The Tabanidae is a large family of bloodsucking flies of which several genera have been blamed as disease vectors. These flies cause deep wounds with considerable flow of blood, and blood loss in livestock may be a problem. The Tabanidae are associated with the anthrax bacillus, tularemia, **T. evansi** and **Anaplasma marginale**. In addition, **Chrysops** is the only known vector of Loa loa (Cobbald), an African eye worm that is found in tropical rain forests. The disease is characterized by parasitosis in the subcutaneous tissue of man with transient itching and Calabar swellings.

Lepiselaga is a common horsefly in this country which grows in swamps. It is thought to be the vector of one of the cattle trypanosomes.

Culicoides: is a mosquito that is very small. Its importance resides in the transmission of several diseases such as the "blue tongue" in sheep and equine encephalitis. In field studies in 1972 along the Pacific Coast of Colombia many **Culocoides** were captured, without

* Summary of address presented since no formal paper was submitted.

** Professor, Department of Microbiology, Universidad del Valle, Cali, Colombia.

the virus though. Nevertheless, this does not mean they don't transmit the disease. All these mosquitos are dangerous because of the dermatozoonosis they produce. They have a great variety of habitats. They are found from the Atlantic Coast to Leticia, the Pacific Coast, and eastward all the way to Venezuela. They are hard to control because of their small size. They also are voracious biters depending on the zone in which they have developed.

The Simuliid family are small flies, millimeters in size. Among them, worth mentioning are the buffalo flies, a name which has been given to them because of their exaggerated development of the thoracic muscles. They are voracious biters and constitute a pest wherever they are found. They will always link themselves to water currents, i.e. torrents of water with good oxygenation. Simuliids are of medical importance. They transmit infections that cause blindness in man; they are probably linked with some viral diseases; they produce dermatitis and will attack during the day.

In Colombia, expressed Dr. Barreto, we have much more to learn in the field of entomology. When all the Diptera have been identified, it will be possible then to plan more in-depth studies.

Summary of Discussions of Papers by:

Hernando Groot
Pablo Barreto

Dr. Carlos Sanmartin (Argentina) stated that: in some places the epidemics of veterinary equine encephalitis (V.E.E.) follow the use of apparently inactivated vaccines, but which are virulent; in Colombia the use of such vaccines is prohibited. There are two big centers producing modified live virus vaccines, one in the United States and the other in Mexico. Colombia produces modified live virus vaccines in lesser quantities. He referred to a paper by Dr. Carlos Leon from the Universidad del Valle, in which the aftermath of the disease was discussed: in children with neurological symptoms the results were serious and probably permanent. Dr. Ricardo Ochoa (Colombia) noted that: Vaccinations against (V.E.E.) help to spread equine infectious anemia due to a lack of precaution with needles and asked what are the disease effects during pregnancy and the consequences for the fetus. Dr H. Groot (Colombia) mentioned that in Maracaibo, some years ago fetal malformations were attributed to the virus, but these were not confirmed.

Dr. Sanmartin added that: Dr. Wagner in Maracaibo reported anencephaliacly, but no serological studies on the mothers were made, nor was the virus isolated. However, these effects cannot be discarded, since the embryonic nervous tissue could be more susceptible.

Dr. Gonzalo Luque (Colombia) inquired about the role of birds as reservoirs for the virus. Dr. Groot commented that in Panama, a green heron circulates the virus. About one year ago, he found that the probable vectors of the epizoodemic equicide form belong to six genera and 20 species; the virus has been found in them but there is no evidence that all are biological vectors. The genera are:

Mansonia, Aedes, Deinocerites, Psorophora, Culex and some **Anopheles**. The transmitters of the jungle form are restricted to: **Culex (Melanoconium), Psorophora** and **Aedes**. The Cali group proved the possibility of mechanical transmission by **Simulium**. In the near future the role of the **Tabanidae** will be studied.

Lepiselaga sp. was associated with an epidemic in Tolima, but many **Culex** were also found; therefore, it was presumed that **Culex** was the vector but the virus was not isolated; the virus causing the epidemic was the jungle type.

He noted that despite the availability of good vaccines, epidemiological and entomological studies cannot be abandoned.

Dr. Eduardo Aycardi (CIAT, Colombia) asked if the massive use of the modified live virus vaccine had been tested on humans in the zones highly susceptible to the virus. Dr. Hernando Groot (Colombia) replied that it has been used but has been limited to those people who are highly exposed to the virus (such as laboratory personnel). He stated that everything seems to indicate that if we prevent the disease in equines it can be controlled in humans.

Dr. I. Londoño (Colombia) commented that the Universidad de Antioquia in Medellin, Colombia is studying the role of **Simulium** as a mechanical vector of V.E.E. They also have some references (Levi, Castillo) on **Culicoides** infections.

Dr. Sanmartin declared that he is interested in this work since **Simulium** is difficult to cultivate and maintain in the laboratory. Dr. H. N. Espinola (Brazil) noted that Brazil was infested by **A. aegypti** which was eradicated in the 40's. A few years ago it reappeared in Belem. Once again, Brazil is free of the pest but many countries in Latin America still suffer **A. aegypti** infestations and while one country remains infested there will always be the danger of reinfestations. To this, may be added the problem of insecticide resistance; control of **A. aegypti** must be carried out on a large scale.

Dr. José M. Payno (Bolivia) noted that: **Stomoxys** sp. has constituted a problem in the East of Bolivia where it has been associated with sugar bagasse and he asked if this bagasse is important for the development of these flies. Dr. P. Barreto (Colombia) replied that the eggs are deposited in decomposed organic material and not in fluid materials. The larvae do not inhabit a fluid media, either. The pupae develop in drier materials. Dr. Roger Drummond (U.S.A.) then added that in Mauritius, the humid sugar cane seems to be a good breeding place, as well as decomposed sea weeds. Dr. Guillermo Mateus (Colombia) commented that on the Atlantic Coast of Colombia, when the African palm tree fell to the ground and decomposed, it constituted a very good breeding place, becoming a problem for the neighbouring animals.

Dr. Beltran indicated that **Stomoxys** is a serious problem in Mexico. He noted that small control tests have been initiated but there have been no definitive results.

Dr. Carlos Quiroga (Bolivia) asked Dr. Pablo Barreto (Colombia) if he had any information concerning the role of the **Stomoxys** in E.I.A. transmission, however, he indicated that he did not.

Dr. Luque noted that Tabanidae appear to be possible transmitters but that there has been no research on this. Dr. Barreto noted that while it is true, there are other more important transmitter arthropods.

Dr. Luque asked if there were information from other countries on **Liperosia irritans** control.

Dr. Drummond answered that there is a pilot plan for eradication on the island of Hawaii. The insecticide Altosid (methoprene) used at 0.5 - 0.01 ppm is introduced in the drinking water which then comes out incorporated with the feces. The larvae of the horn fly contact the insecticide and do not develop. In combination, sterile males are released. They have been raised in the laboratory and irradiated with 25,000 rads of gamma rays. One and a half million males are released per week. Using this technique it is hoped that the problem will be eliminated. On one farm, they were eradicated in 13 weeks.

Dr. Payno inquired if Neguvon (dipterex) were efficient against cutaneous habronemyasis. Dr. Hernan Duran (Colombia) noted that in Caldas, Neguvon has been used locally for three days, at 15 grams per 300 kilograms but it is not 100 percent effective. In some cases, it is necessary to revert to surgical treatment. Allowing the manure to ferment in wells and spraying the wells with aldrin or dieldrin helps in the control.

Dr. R. M. Teruya (Bolivia) asked if there were a case of onchocercosis in Colombia. Dr. Barreto stated that there have been cases on the southwest Pacific Coast, on the banks of the Micay river. Dr. A. D'Alessandro (ICMR, Colombia) indicated that there have been 44 cases of onchocercosis. Dr. Ivan Londoño (Colombia) also added that in Medellin **Onchocerca valvulus** was found on a patient from Tolima who was visiting Choco.

Dr. Gustavo Lopez (Colombia) suggested that recently, muscarine was isolated from the domestic fly, and toxins from **Bacillus turigensis** which could used in the control of onchocercosis.

Acaricides and Resistance of Ticks to Acaricides

Alexander S. Tahori *

Pesticides are materials which kill pests or which prevent, inhibit, destroy or otherwise mitigate the effects of noxious animals and plants. They may also exert an attractant or repellent action or control populations by means of limiting reproduction or preventing epizootics. The term insecticide is derived from Latin words meaning "insects" and "to kill". Insecticides generally are the first line of defense in the control of insect outbreaks. They have been employed because:

(1) They are highly effective.
(2) Their effect is quick.
(3) They can rapidly bring large insect populations under control.
(4) They can be employed only when needed.

Alternative means of control can seldom be found that will provide all these features.

Insecticides, however, are not without limitations. Ticks become resistant to them. They may disrupt the ecosystem with adverse effects on the insect complex, wildlife, and other desirable species. Residues remaining on cattle products may pose health hazards.

The contribution of insecticides to human health is impressive. About 30 known diseases are caused by organisms whose arthropod vectors can be greatly reduced or eradicated by insecticide treatments. The list includes such age-old scourges of mankind as malaria, yellow fever, filariasis, bubonic plague, typhoid fever, and encephalitis.

The need and use of insecticides and acaricides are certain to increase, despite the adverse publicity to which these chemicals have been subjected in recent years. The hope of mankind to escape hunger and disease is closer to reality today than ever before. This hope

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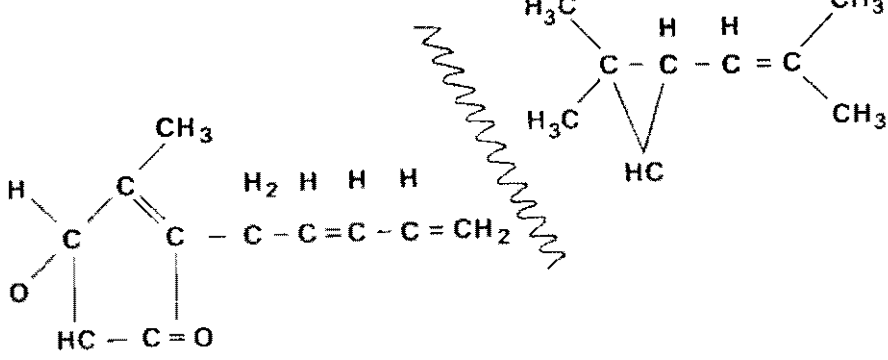
rests, to a large degree, on continued resear and development efforts directed toward the production of safer and more effective insecticides.

You classify insecticides either by their chemistry such as chlorinated hydrocarbons, carbamates or organic phosphorus compounds; or by their mode of entry into the insect body, such as stomach poison, contact poisons, fumigants; or by the stage of insect against which they are active, for example, ovicides against the eggs, larvacides against the immature stages and adulticides against the mature stages. The best insecticide classification would be their mode of action, but with the exception of O-P compounds and carbamates too little is known about their mode of action. Today, 30 years after the widespread use of DDT, we still are not sure about its mode of action.

Pyrethrum

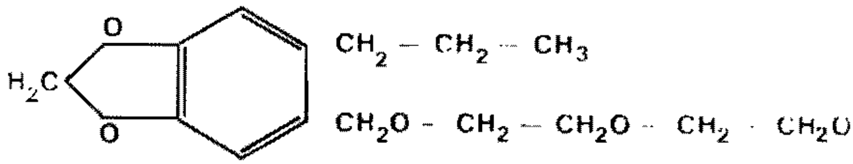
Pyrethrum is one the first insecticides ever used. It is believed to have been discovered by accident in Persia, and later introduced in Europe in the 19th century. There is a record that even in the 1st century, the Chinese knew of pyrethrum as a botanical insecticide. The daisy-like flower of the **Chrysanthemum cinerariaefolium** grows wild in Dalmatia. The active ingredients, "pyrethrins", are extracted from the flowers. Pyrethrum is practically non-poisonous to warm-blooded animals and since it possesses no residual effect, no poisonous deposits accumulate. It causes almost instant paralysis in the insect coming in contact with the compound. Today pyrethrum is grown mainly in Kenya and Tanzania, but also in Ecuador and New Guinea. Its main disadvantage is the relatively high price and instability in air and light. Pyrethrum is an ester and therefore liable to rapid hydrolysis; its alcoholic moiety also contains double bonds which are easily oxidized, after which the compound loses its insecticidal activity. Figure 1. shows the chemical structures of Pyrethreland and chrysanthemum monocarboxylic acid.

Figure 1. **Pyrethreland and chrysanthemum monocarboxylic acid.**



Recently a number of analogues of pyrethrum have been synthesized. Some of these possess much higher insecticidal activity than pyrethrum itself, and others are more stable, however, they are still too expensive for practical use yet. Owing to the high cost of pyrethrum, it is very seldom used by itself but together with synergists; the most common one is pyperonyl butoxide, (Figure 2).

Figure 2. **Pyperonyl butoxide.**



DDT

DDT has probably had a greater effect on reducing disease and hunger than any other man-made chemical substance. DDT was first synthesized in 1874 by Zeidler, who did not recognize the importance of the substance. In 1939 it was resynthesized by Müller in Switzerland for which he received the 1945 Nobel prize in medicine. Its major advantages were: a high toxicity against a broad spectrum of insects; relatively low toxicity against warm-blooded animals (120-300 mg/kg) and plants; its persistent action requiring few applications, and most importantly its very low cost of production. DDT applied indoors may remain effective up to a year, becoming ineffective only when covered by an accumulation of grease and dirt; in field conditions with maximum surface exposure it slowly decomposes under the influence of solar ultraviolet irradiation.

The mode of action of DDT is not yet fully understood. It primarily affects the nervous system. It is highly soluble in fatty materials, resulting in its storage in animal fats and its subsequent appearance in milk.

DDT appeared on the public health scene during World War II and dramatically halted a typhus epidemic in Naples. It also brought about radical changes in the method of malaria control. A worldwide program of malaria eradication, based on the use of persistent insecticides, mainly DDT, was initiated by the World Health Organization in 1955. One billion people now live in areas freed of malaria. DDT was also revolutionary in the control of other vectors of diseases such as tsetse flies, blackflies and fleas.

The disadvantage of DDT is that many insect vectors have developed resistance to it. Today, it is practically impossible to find in the field a housefly strain which is not at least partly resistant to it. Another important disadvantage is its nonbiodegradability; it accumulates in the food chain. The DDT present in lower forms of life such as bacteria, insects, worms, plankton and algae is passed on and often concentrates as it goes up the food chain. Birds, near the apex of the food chain, especially those that prey on fish and other birds, have suffered grievously from this accumulation.

A great controversy is now raging as to whether DDT should still be used. Many countries such as Sweden, (which once conferred the Nobel prize on the discoverer of DDT) Germany, the USA, Canada and others, have banned its use and manufacture. However, withdrawal of DDT without any appropriate substitute has led to disaster. In Ceylon, malaria had been reduced to very low levels and the cessation of DDT spraying operations in 1964 brought about new epidemics with a total of over 2½ million reported malaria cases during 1968-69. Currently, available funds of the World Health Organization (WHO) are insufficient to pay for DDT substitutes. Therefore, WHO recommends the continued use of DDT for indoor spraying to control malaria mosquitoes and indoor dusting for plague fleas and typhus lice, rather than risk another outbreak of these diseases. Nevertheless, outdoor uses, especially application to waters should be restricted.

Other chlorinated hydrocarbon insecticides (Cyclodiene)
Lindane

This is the gamma isomer of benzene hexachloride, a compound which was first synthesized by Faraday in 1825, but the insecticidal properties were only discovered during World War II. It is more biodegradable than DDT; it is more expensive but less toxic to humans.

Dieldrin and Aldrin

These compounds are much more insecticidal than DDT, but also more toxic to warm-blooded animals (LD_{50} approximately 40 mg/kg). Recently, they have been suspected of being carcinogenous and their use has been forbidden.

Synthesized for the first time by Faraday in 1825, in 1912 Van der Linden showed that the compound contained four isomers. However, the insecticidal effect was shown only in 1941-42 independently by French workers and by Slade of ICI, England. The technical product contains eight isomers, but only the isomer known as lindane, in honor of Van der Linden, is important, since it has practically no smell. The compound is quick-acting, and also possesses a fumigant effect. The toxicity of dieldrin (LD_{50}) for rats is 60 mg/kg, acute oral and 100 mg/kg, acute dermal. The acute oral toxicity of Aldrin is 55 mg/kg. Acute dermal is 200 mg/kg. Lindane is stored in the fat but not as long as DDT.

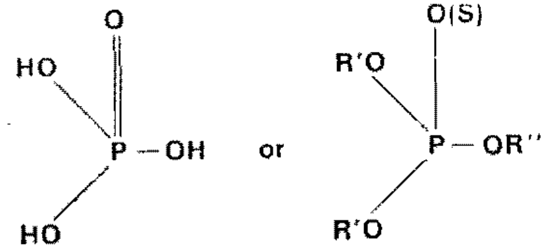
Organic phosphorous compounds

Many of the insecticides now used belong to this group. The basic research in this group of pesticides was carried out by Gerhard Schrader at Bayer, Germany prior to World War II. Those compounds which showed high human toxicity such as somen and tabun were developed into war gases; those with lesser human toxicity were developed as insecticides (for example, parathion). The O-P compounds easily penetrate the skin of the insect or mammal. They inhibit the action of the enzyme acetylcholine-esterase (AChE). In the animal body this enzyme splits acetycholine (ACh) which is essential for the transmission of nerve impulses. When a nerve is stimulated, the stimulus travels along the axon until it reaches a synapse. Transmission over the synapse is possible by means of a chemical compound, ACh. After the stimulus has passed the synapsis, AChE appears, splits ACh into choline and acetic acid, and the nerve and synapse return to their original status.

An O-P compound binds itself with AChE and forms a complex, which is stable for a long period. Thus no AChE is available to split the ACh, which remains at the synapse indefinitely, and the animal dies from the continuous effect of the ACh at the synapse.

The O-P compounds are derivatives of phosphoric acid H_3PO_4 or where R' is shown there is usually a methyl or ethyl group, (Figure 3).

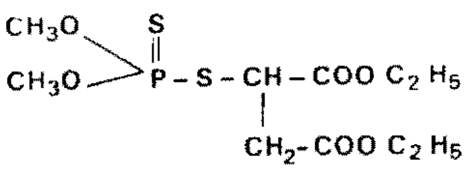
Figure. 3. **O-P compounds which are derivatives of phosphoric acid, H_3PO_4.**



Only the compounds which contain the P=O group and not the P=S are active as AChE inhibitors. But this is only theoretical. In practice, all P=S compounds contain isomers with P=O and are therefore also toxic.

In order to inactivate the AChE the P=S compound must first undergo oxidation to P=O. This process occurs in the animal body, and we call it intoxication. It is also a suicide mechanism. The animal's body oxidizes a "non-toxic" compound to a very toxic one which then kills it. As we have seen, the O-P compounds are esters and therefore liable to hydrolysis. Hydrolysis is influenced by pH, but also by the presence of suitable enzymes. An O-P compound which undergoes hydrolysis loses its anti AChE activity, since the products of hydrolysis, mainly phosphoric acid, do not inhibit AChE. Thus two processes occur concurrently in the animal body, one is intoxication (P=S to P=O) the other one is detoxification (hydrolysis of the phosphate ester). The insect toxicologist is interested in synthesizing compounds which are preferentially intoxicated in the insect body and more rapidly detoxified in the mammal body. This is possible in theory as well as in practice. The organic chemist may add certain radicals such as C_1, CH_3, etc., and thus intensify the electrophilic character of the phosphorus atom and consequently the reactivity of the P=OR" bond. The biochemistry of the insect and mammal body is also different. Mammals contain more carboxyesterase than insects. This explains the preferential selective toxicity of malathion to insects and its low toxicity to mammals. In order to be active malathion has to be oxidized to malaoxon, this is the process of intoxication. On the other hand, concurrently, phosphatases and carboxyesterases work on malathion to hydrolize it (detoxification). The speed of detoxification is greater in mammals than in insects, whereas the speed of intoxication is greater in insects than in mammals; this explains the low toxicity of malathion to mammals. Before it is oxidized in the mammal's body to the active compound malaoxon, it is detoxified by carboxyesterases and phosphatases. However, in the insect body malathion is more quickly oxidized to malaoxon, before it is hydrolized, and thus kills the insect before it is detoxified. The chemical structure of malathion is shown in Figure 4.

Figure 4. **Malathion.**



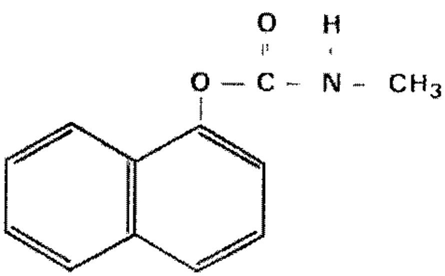
Carbamates

Compounds in this group are being actively developed as insecticides. A number of heterocyclic carbamates such as pyrolan and isolan by Geigy were introduced about 15 years ago. However, these compounds had a limited spectrum of activity and high mammalian toxicity, and they have been replaced by O-P compounds.

The introduction of carbaryl (Sevin), a broad-spectrum insecticide, gained renewed recognition for this class of insecticides. Since the advent of carbaryl a great number of other carbamates have been introduced, among them Baygon, Mesurol and Zectran. The mode of action of carbamate esters in insects is analogous to that postulated for the O—P compounds, namely inhibiting the cholinesterase(s) of the nervous system. However, the resulting carbaryl esterase is apparently less stable than the analogous phosphoryl esterase. The carbamate ester is hydrolyzed in the process of decarbamylation of cholinesterase. Cholinesterase inhibition may not be the sole poisoning mechanism responsible for the toxic action of certain carbamates.

As with the phosphates, carbamates are readily degraded **in vivo** and in the environment; many have low toxicity to mammals, are selective and fit well into integrated control programs. The carbamates along with O—P compounds offer perhaps the most promising chemical control agents synthesized and developed today. Figure 5 shows the chemical structure of carbaryl (Sevin).

Figure 5. **Carbaryl (Sevin) with the structure 1-naphtyl-N-carbamate.**



Resistance

The criterion most commonly used to identify insecticide resistance has been the failure of the customary programs to provide practical control, even when the dosage was raised or the frequency of application increased. While this is not a satisfactory basis for the measurement of resistance in a quantitative sense, it constitutes a very convincing criterion. Bio-assay tests provide good quantitative measures to assay resistance. The chosen effect may be any detectable change due to the toxicant, but in practice it is either knockdown or death.

How should dosage be measured? The common units employed such as known amount of kilos of insecticide per 100 liters of spray bear no direct relation to the amount of toxicant reaching the insects. Even the exact technique of topical application does not measure how much enters the insect body and gets to the critical areas where the toxic effects are produced.

The WHO Expert Committee has defined resistances as follows: resistance to insecticides is the development of an ability in an insect strain to tolerate doses of toxicants which would prove lethal to a majority of individuals in a normal population of the same species. The key word is "development" for this signifies that the condition is characteristic of the population before exposure to the chemical. In contrast "tolerance" describes a condition of insensitivity to insecticides before the use of the chemical.

Over 100 species of insects important for public and veterinary health have developed at least one type of resistance; for agricultural insects the number is also over 100. Today four types of insecticide resistances are important: to DDT; to the cyclodiene group; to O—P compounds, and to carbamates. The greatest number of species have developed resistance to the cyclodiene group. Multiple resistances of two, three or even four types together occur frequently in insects of public health importance. Resistance has most frequently developed in the Diptera.

What is the importance of resistance in the field? Cotton production is threatened in the USA. The cattle industry of Australia is endangered by the appearance of O—P resistance in the tick vector of cattle diseases, in addition, to already widespread dieldrin resistance. The German roach in the USA is now almost completely resistant to chlordane and is becoming diazinon resistant. Bedbugs have developed DDT and cyclodiene resistance in Israel, but fortunately the bedbug does not constitute a problem here anymore. However, in India, bedbug resistance to chlorinated hydrocarbon insecticides constitutes a major health problem. The housefly has become DDT - resistant the world over, and is also resistant to cyclodiene insecticides. The development of O—P resistance in California, Florida, Denmark and Italy spells trouble for fly control. It is in mosquitoes that resistances to insecticides have developed most serious dimensions. **Culex pipiensis** the vector of filariasis, has developed resistance to DDT and the cyclodiene insecticides and is also becoming resistant to O—P compounds. **Aedes aegypti,** the vector of yellow fever, dengue and chicunguya virus, had become DDT - resistant in the Caribbean area in 1954 and dieldrin resistant in 1959. Recently increased tolerance to malathion has been encountered there. Of the anopheline vectors of malaria, 12 species have developed DDT - resistance and 34, dieldrin resistance. Sometimes DDT - resistance can be successfully combatted with dieldrin, and dieldrin resistance treated with DDT. However, some mosquito populations have developed both types of resistance; for example **A. albimanus** in Central America. In these cases O-P compounds such as malathion and fenthion and the carbamates, carbaryl and Baygon, have been tried as residual sprays.

Genetics of resistance

Is resistance due to preadaptation or to postadaptation, i.e. was the gene (or genes) responsible for resistance, already present in the insect population or did they appear only as a consequence of the exposure to the insecticides? The consensus today is that resistance is a preadaptation phenomenon since:

(1) Exposure to harmless doses in early life does not make an insect any more tolerant of decisive doses applied later in its life cycle.

(2) Colonies in the laboratory exposed to sub-lethal levels of toxicant never developed resistance, even after 100 generations of exposure. Only when the dose was raised so as to cause mortality, did resistance develop.

(3) Exposure to toxicants of isogenic strains of **Drosophila,** which lacked the necessary preadaptation gene, did not induce resistance. Insecticide resistance is thus developed by Darwinian selection of pre-existing genes. However, DDT- resistant alleles may be produced by mutagens such as X-rays.

Genetic studies of the four different resistance types have shown that they are caused by a single gene. Many resistance genes have now been precisely located on the chromosomes by linkage studies with marker strains.

DDT-resistance usually develops after an initial latent period of several generations before it increases steeply. The whole genome must be remodeled, so that insects with the DDT - resistance gene are no longer handicapped. They must have been so at first for otherwise they would have been initially DDT-resistant. Cyclodiene resistance on the other hand develops without delay, without new supporting alleles. O-P resistance in insects develops very slowly. It is also liable to revert, since the O-P resistant individuals are usually handicapped by low fertility. Carbamate-resistance also develops slowly.

The higher the selection pressure and the wider the area covered by the insecticide the faster resistance develops, since fewer susceptible individuals are left to dilute the resistant survivors. Residual insecticides are more liable to induce resistance, because they continue to select long after they been applied. Resistance also develops faster in tropical and subtropical climates than in temperate ones, due to the greater number of insect generations per year.

What makes one insect population insecticide resistant, while another one is susceptible. Most studies have dealt with DDT resistance in the housefly, which may serve as an example for other insects. Neither reduced penetration through the integument, nor larger body size, or higher lipid content, etc., explain the phenomenum. However, a high degree of correlation exists between resistance to DDT and enzymatic dehydrochlorination. Most resistant fly strains have shown greater ability to convert DDT to DDE **in vivo** and **in vitro** than their susceptible counterparts. Another DDT metabolism route is via hydroxylation, to dicofol, for example, in **Drosophila** and in **Triatoma infestans** by "mixed function oxidases".

O-P resistance may be characterized by the degree of inhibition of AChE and/or aliesterase enzymes, and by differences in the rates of activation and inactivation of the toxicant. Decreased sensitivity of nerve fibers and ganglia is also a factor in ticks and mites. For example, greater hydrolytic efficiency is a characteristic of the O-P resistant insect. Thus ronnel, dicapthon, chlorthion, parathion, methyl parathion and diazinon are hydrolyzed in **Periplaneta americana** via phosphatase action yielding dialkyl phosphates and thio-phosphates. Malathion is extensively hydrolyzed in the fly and in **Culex** mosquitoes via phosphatase attack at the P-S linkages yielding several breakdown products, and also, via carboxyesterase hydrolysis of the diethyl succinate moiety resulting in nontoxic mono-and dicarboxylic acid derivatives of malathion. EPN, a carboxyesterase inhibitor, synergizes malathion against resistant **Culex tarsalis**, thus establishing the importance of carboxyesterase activity in this species.

Carbamate resistance

The ineffectiveness of a particular carbamate may be due to its rapid disappearance from body tissues, either by hydrolytic attack or by excretion. For example, carbaryl is metabolized by resistant houseflies at a faster rate than by susceptible ones.

Any kind of stress such as abnormal environment, deficient diet, unusual abundance of enemies, etc., will sort out those individuals who are handicapped, and will permit only the more vigorous to reproduce. This effect of general vigor will operate in a nonspecific manner. Thus an insect may show a certain degree of resistance to any toxicant. This is called vigor tolerance.

Cross resistance

The term **cross-resistance** is used to imply that a single property ensures cross - protection to various toxicants. **Multiple resistance** on the other hand refers to the coexistence of different defense mechanisms in the same insect strain, **duplicate resistance** occurs when at least two mechanisms exist in the same strain, protecting it against the toxic action of a compound by two mechanisms, for example against DDT by (a) dehydrochlorination, and (b) hydroxylation.

Exposure of an insect population to one insecticide may lead to cross-resistance to chemically unrelated insecticides, even to insecticides with different modes of action. It is now possible to recognize certain patterns of cross-resistance which have important implications for pest control programs:

(1) Selection for resistance to DDT involves cross-resistance to DDT analogues, unless the chemistry of the latter does not allow enzymatic dehydrohalogenation. Cross-resistance does not usually involve lindane, cyclodiene insecticides, O-P compounds and carbamates.

(2) Selection for resistance to insecticides other than DDT, results in cross-resistance to DDT more readily than the reciprocal case by DDT selection. For example, resistance to malathion has resulted in high levels of DDT-resistance.

(3) Selection of resistance to any member of the cyclodiene group invariably results in cross-resistance to all members of the group, but not to insecticides outside the group. Resistance tends to be highest to the compound used for selection.

(4) Selection for resistance to an O-P compound involves relatively specific cross-resistance to certain compounds only of the same group. It may, however, lead to cross-resistance to DDT.

(5) Selection for carbamate resistance involves relatively high and specific resistance to the compound used for selection, and slight cross-resistance to other members of the carbamate group. There may be very high cross-resistance to DDT, lindane and the cyclodiene-derived group.

(6) The addition of a synergist to a carbamate may temporarily restore its effectiveness against the resistant strain.

The practical implications of these observations are: resistance to DDT as a result of using only this insecticide is unlikely to affect the usefulness of other pesticides. Resistance to one member of the lindane-cyclodiene group is likely to nullify the usefulness of all members of the same group. Resistance to a member of the O-P, or to a member of the carbamate group, does not necessarily affect the usefulness of other members of the same two groups. Resistance to a member of these groups may, however, involve serious cross-resistance to the chlorinated hydrocarbon group. Prospects for the reintroduction of the chlorinated hydrocarbons after the interim use of O-Ps or of carbamates are therefore not good.

Tick resistance

The first record of chemical tick control was the use of arsenic in Queensland, Australia in 1895. Arsenic gave good control until 1935, then arsenic resistant tick strains appeared in Australia, South Africa and Argentina.

DDT was first used in 1946, and in 1955 a 20-fold DDT-resistance was reported in Australia. However, in most places DDT-resistance developed only slowly and could still be used until 1962.

Then lindane was introduced, but in both Australia and South Africa resistance to BHC developed within 18 months. Resistance to lindane in **Boophilus** has always extended to toxaphene and the cyclodienes.

O-P resistance was only found in Australia where it was exclusively studied. There, the many strains exhibiting resistance to a wide range of O-P and carbamate chemicals have created a serious problem for cattle owners. O-P compounds had been used since 1956, but in 1963, one year after the banning of the chlorinated hydrocarbon insecticides for use on cattle, a Ridgelands strain showed resistance to all O-P compounds and carbamates used.

What can we do to control resistant insect populations? This is one of the most difficult problems today, and we do not possess a ready solution to the problem. One of the causes of insect resistance is survival of the insect due to an insufficient individual dose in the first place. If the insecticide could be applied or formulated in such a way so that the insect either received a lethal dose or none at all, then the survivors would be lucky rather than resistant. The dose of toxicant picked up by a crawling or resting insect, would be a function of the time spent on the insecticidal surface. Anything to increase this time will therefore increase the effectiveness of the insecticide. Recent years have witnessed some important advances in this area by studying pheromones. The method of baiting lures and traps with sex attractants to which small concentrated amounts of a biodegradable toxicant have been added, is one future way to control resistant insect populations.

Research into Alternative Arthropod Control Measures Against Livestock Pests (Part I)

Rachel Galun *

Introduction

With 19th century growth of urban populations throughout the world there was a steady increase in the demand for beef, hide and dairy products. Vast virgin grasslands in the Americas, Africa and Australia attracted pioneer graziers eager to exploit this abundance of cheap pasture. During the latter half of the 19th century there were great movements of cattle in and out of these areas as ranches grew and cattle were driven long distances to be slaughtered and sold. These cattle movements not only sustained and supported indigenous tick populations, but also played a part in widening their geographical distribution. **Boophilus microplus**, for example, is believed to have been introduced into Australia in 1872 by a herd of Brahman cattle brought across from Java to Darwin.

It has been estimated (Shaw, 1970) that about 80 percent of the present day one-billion world cattle population is exposed to risk of infestation with cattle ticks. Most countries situated between latitudes 35°S and 35°N support one or more species of ticks. **B. microplus** is the most widely spread species, found in Australia, Southeast Asia, South Africa and South America. **Boophilus decoloratus** is confined to South Africa. Species of the genus **Amblyomma** are found both in South Africa and the Americas. **Rhipicephalus appendiculatus** and **R. evertsi** occur in Africa, South of the Sahara. Species of **Hyalomma** are found in Africa, Asia minor and southern Europe.

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Ticks can damage their hosts in four ways:

(1) They are are voracious blood feeders, thus causing retardation in cattle weight gain as well as in milk production.

(2) Ticks damage hides by making puncture wounds with their mouth parts. These wounds are frequently exacerbated by localized tissue reactions to which the animal responds by licking, kicking and scratching. Frequently, the wounds become septic and may also become flyblown.

(3) Ticks can inject toxins via their saliva which, in the case of some species, e.g. **Ixodes holocyclus** and **I. rubicundus,** can give rise to severe paralysis. In the case of **Hyalomma truncatum,** the toxins can cause sweating sickness.

(4) Ticks can transmit certain protozoan diseases: babesiosis, anaplasmosis, and theileriosis. These diseases often prove fatal, particularly to non-immunized stock. No effective vaccine is available for some of these diseases.

Control of free-living stages

Attempts to control ticks have been directed at the free-living stages on the pasture, as well as against the parasitic stages on the bovine host. Only the latter attempts have so far met with any success.

Burning-off grassland in an attempt to kill off free-living tick stages and removing alternative rodent hosts have not proved practical. Treatment of pastures with acaricides may have some practical merit in restricted areas; obviously the treatment of vast areas of grassland is out of the question. Past attempts at biological control by the the dissemination of tick predators have proved disappointing. Attempts to starve the free-living tick stages by removal of their bovine hosts have been made in Australia (Wilkinson, 1955). But this "pasture spelling" is feasible only where alternative hosts are not present since free-living ticks can survive many months of starvation. In addition, this method imposes strain on the economic use of the pasture.

Flooding tick populations with sterile males does not seem to be an economical control method. Adult irradiated ticks cease to be competitive much earlier than normal ticks, as they become aspermic due to inhibition of the spermatogenic cycle (Galun **et al.**, 1974).

The free-living stages must attach to their hosts in order to feed, molt and produce eggs. They tend to aggregate in huge numbers on several blades of grass, awaiting passing hosts. It is suggested that these huge tick aggregates occur as a result of assembly pheromones.

Identification of such pheromones may help in the control of the free-living stages. So far assembly pheromones have been demonstrated only for soft ticks (Leahy **et al.**, 1973) but their chemical identity has not been elucidated.

Control of parasitic stages

Effective methods of limiting tick depredations have been achieved by treatment of the infested bovine host with acaricides which are applied in one of two ways, either by dipping cattle or by spraying them with aqueous solutions or suspensions. Recently, some compounds have been developed which are poured onto the cattle, absorbed, and exert their effect systemically.

Tick populations have consistently been shown to possess a genetic pool containing the potential to resist a wide range of chemical poisons. The introduction of a new acaricide followed by its widespread use has all too frequently resulted in the appearance of a tick population resistant to that chemical. In various parts of the world ticks have progressively become resistant to sodium metarsenite, DDT, BHC and toxaphene. Since the mid-sixties, ticks have shown resistance to organophosphorous compound carbamates (Enders **et al.**, 1973).

It is obviously desirable that an alternative approach without reliance on chemicals be developed. One of the possibilities suggested by the Australians was the use of cattle resistant to tick infestation (Wharton **et al.**, 1971). Only a few ticks reach maturity on resistant cattle and most of the larvae are rejected within 24 hours of parasitic life cycle. The major factor in tick control is an immunological reaction (Roberts, 1968). Cattle infested for the first time are initially highly susceptible. After several days of exposure to ticks a degree of resistance is acquired. It is likely that the immune response of the host causes rejection of the larvae. Such rejection might result from damage to the larvae by host factors ingested, neutralization of feeding enzymes, or alteration of the attachment site by host reaction, so that it becomes unsuitable for feeding. Resistance of cattle to ticks is species specific. The degree of resistance of an individual animal is heritable and therefore innate, but the stimulus of tick infestation is normally required before the resistance is manifested. Roberts (1968) concluded that a successful vaccine against cattle ticks was not feasible, as each animal would develop only that degree of resistance for which it had the innate capability.

Selection to raise resistance of British breeds to **B. microplus** is a slow process as resistance heritability is low. It has therefore been suggested that British breeds be crossed with Zebu **(Bos indicus)** since Zebu cattle and **B. microplus** have been associated for thousands of years in Asia and a state of equilibrium between host and parasites has evolved. In Malaysia, Thailand and the Philippines, **B. indicus** cattle are infested only with a very small number of ticks (Wharton **et al.**, 1971). Cross breeds of Zebu generally show adequate tick control, yet the variability is great and there is a need to eliminate the more susceptible animals. In countries like Australia where there is only one tick species of major economic importance, selection for resistant cattle will probably provide the most effective long term solution for tick control (Springell, 1974). However, in many tropical countries where genetic improvement is being sought through the introduction of European stock, there is the danger that replacement of **B. indicus** by **B. taurus** genes could result in increased susceptibility to cattle ticks. The presence of several species of ticks other than **B. microplus** and of several associated tick-borne diseases are added complications.

Immunization of cattle against tick hormones

We would like to suggest a new approach to immunization of cattle against ticks by producing in the cattle specific antibiodies against developmental hormones of ticks.

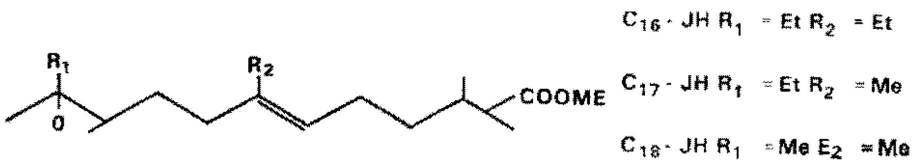
It has long been known that specific antibodies are capable, under appropriate circumstances, of neutralizing many biologically active macromolecules including toxins, enzymes, peptide hormones and others (Butler **et al.**, 1973). Specific antibodies were reported to reverse established cellular effects of insulin and thyrotropin **in vitro** (Pastan **et al.**, 1966). Recently, antibodies were also reported to be physiological antagonists to low molecular weight molecules such as steroid hormones, pyridoxall phosphate, histamine, serotomine, chloramphenicol, and cardiac glucosides (Butler **et al.**, 1973). By virtue of the specific antibodies' capacity to bind these substances, they inhibit certain physiological effects of these compounds **in vivo** and **in vitro**.

The growth and maturation of insects (and probably of ticks as well) are governed by three main hormones: brain hormone, juvenile hormone (JH), and ecdysone (NH) which are responsible for the complex series of molts that these arthropods undergo during their life cycle. The molts are regulated by the brain hormone which activates production of the molting hormone, ecdysone. Changes in titers between juvenile hormone and ecdysone determine the nature of the newly molted arthropod. Early in the life cycle relatively large amounts of juvenile hormones are present to maintain the juvenile state, and ecdysone level is low. As the molts progress, the juvenile hormone titer decreases while the ecdysone level increases, until molting into the adult is accomplished, at which time the juvenile hormone has dropped to undetected levels and ecdysone reaches its maximum.

The chemical nature of the brain hormone is not yet known. It is assumed to be a protein (mol. wt. 9,000 - 30,000) synthesized by neurosecretory cells in the brain. Pure preparations of this hormone are not yet available.

Three naturally occurring JH have been characterized. These are: sesquiterpenoid, so-called C_{18}-JH 1, C_{17}-JH 2 and C_{16}-JH 3, Figure 1.

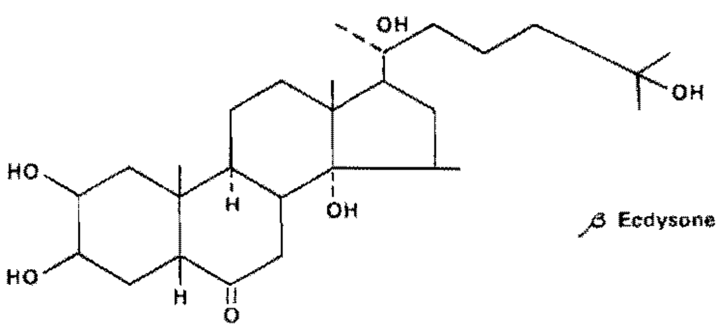
Figure 1. **Structure of 3 naturally occurring JH.**



Antibodies to C_{18}-JH have been recently produced for radioimmune assay of this hormone (Laufer et al., 1974). By conjugating the hormone to a large carrier protein (such as human serum albumin (HSA) - via the N-hydroxysuccinide) the hormone is rendered heptenic and can elicit an immunogenic response. Rabbits injected with this conjugate produce specific antibodies at a titer of 1.8 mg/ml blood. Only JH and very close epoxy derivatives react with the antibodies.

B ecdysone, the molting hormone (NH) of arthropods, is a polyhydroxy steriod with the following formula, (Figure 2).

Figure 2. **B ecdysone.**



For the purpose of radioimmune assay, antibodies against this hormone have recently been produced (Borst & O' Connor, 1972; Laufer **et al.**, 1974). Borst and O' Connor produced the conjugate, ecdysone-bovine serum albumin (BSA), by first converting the ecdysone to the oxime acetic acid ether. The oxime derivative is coupled to BSA by way of the isobutylchloroformate.

Laufer **et al.**, (1974) produced a hapten-protein conjugate of hemisuccinate derivative of **B** ecdysone with HSA. The antibodies produced were highly specific. Compounds lacking hydroxyl substitute at the C-20 position were not effective. The last method seems to produce more specific antibodies.

Radioimmune assay of ecdysone is already in use in several laboratories, yet the physiological effects of the antibodies on insect development have not been studied. We believe that if antibodies against any of the three hormones already mentioned can neutralize the physiological effect of the hormones **in vivo**, then cattle can be immunized against the tick hormones and this method can then be used as a control against ticks.

There are several reasons to believe that such a control system might be effective against ticks.

(1) Many species of ticks are almost exclusively monophagous, and feed only on domestic animals which could be immunized in a given area. Thus, every single tick in this area will will presumably be affected.

(2) The blood meal ingested by a tick is about 100-fold its own weight and therefore there is a chance that the amount of antibodies ingested with the blood meal might be sufficient to neutralize the hormones.

(3) We found that a considerable amount of the Y globulin ingested by ticks passes through the gut wall serologically unchanged. This may be related to intercellular digestion typical of ticks. Thus, it may be assumed that enough of the ingested antibodies will pass through the gut wall into the tick hemolymph where they should interact with the hormones.

(4) As these hormones are common to the whole group, a successful method for one species will most probably be effective against other cattle tick species.

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Control of Livestock Pests by Insect Growth Regulators (Part II)

Rachel Galun

The major pests of livestock are:

(1) Biting flies (bloodsucking): the horn fly (**Haematobia**), the the stable fly (**Stomoxys**), horseflies and a few others.
(2) Non-biting flies: house flies, face flies, cattle grubs (**Hypoderma**), **Dermatobia**, various bots (**Oestrus, Gastrophilus**), and more.
(3) Biting lice (**Bovicola**) and sucking lice (**Haematopinus, Linognathus** and **Solenopotes**).
(4) Mites: **Sarcoptes, Psorergates, Psoroptes.**
(5) Ticks: mainly **Amblyomma, Boophilus, Haemaphysalis, Hyalomma, Ixodes, Rhipicephalus.**

All of these pests develop during at least one stage (either as larvae or adults) in the manure excreted by their host (various fly larvae), in the tissues, or feed on the blood of the host.

Many of the common insecticides such as the chlorinated hydrocarbons, organophosphates and carbamates, which are applied to the livestock directly, to buildings housing animals, and to the animal manure, are rather non-specific and could control most of the livestock pests. Yet they cause contamination of the environment and of livestock products and some also have a relatively high toxicity to the host animals. In addition, insecticide resistance has developed in many of the pests.

The emphasis in pest control is now on agents with less persistence, greater specificity to target organisms and very high safety to the environment.

Increasing the specificity of an insecticide limits its overall market. The expenses involved in the development of an insecticide and in the elaborate registration requirements for a new insecticide, are the same whether the insecticide has a small or a large market. The industry is, therefore, reluctant to develop narrow spectrum pesticides unless the pest species is of major economic importance (Djerassi **et al.**, 1974).

I, therefore, believe that the development of control methods against livestock pests should be aimed at finding the same control agent which will be active against all pests, yet the agent should be safe to use on animals and also have a minimal contaminating effect on the environment. Such a control agent may perhaps be found in insect hormone mimics, currently referred to as insect growth regulators (IGR). These lack the extreme specificity of pheromones; therefore, their commercial applications are clearly wider. Their unique biochemical mode of action appears to limit their effect to members of the phylum of arthropods and perhaps also to Helminths (Muffic, 1969; Shanta and Meerovitch, 1970; Davey, 1971; Rogers, 1973), while rendering them relatively innocuous to man and other animals. Recent studies have indicated that some of them are les toxic and persistent than chemical control agents currently known (Djerassi **et al.**,).

It is proposed to exploit the fact that the pests to be controlled feed at the right stage of their development either directly on the host or on its feces. Thus incorporation of growth regulators into the feed of the animals will bring all these pests in contact with chemicals. If one mode of application using one compound will suffice to control all the pests, the high price of the chemical will at least partially be compensated by the cheap treatment.

Incorporation of chemicals for the control of livestock pests into animal feed has been under experimentation for many years. A project of testing systemic insecticides against ticks, screwworms, **Hypoderma, Oestrus** and a few other parasitic arthropods has been going on for years at the USDA laboratory at Kerrville (Drummond and Graham, 1965).This program has been maintained in that laboratory since 1946. A great number of compounds have been identified for their systemic properties. In the process of adding insecticides to cattle feed, Drummond **et al.** (1967) found that larvae of the horn fly developing in the manure of treated animals were controlled. These studies proved that oral administration of certain insecticides was a practical means for controlling ticks, sucking lice, grubs and some fly larvae in the manure.

Some insect growth regulators when added to fly breeding media, proved to have morphogenetic effects on the fly larvae (Writh **et al.**, 1973) and were immediately tested for their effect on the development of larvae in feces of bovines treated orally with IGR (Harris **et al.**, 1973). The early success of this method encouraged many investigators to screen the activity of juvenile hormone mimics as feed additives for the control of dung breeding dipterous larvae. Yet, unlike the studies on systemic insecticides, these studies were not extended to test the effect of these compounds, applied in the feed, on the control of pests developing inside or on the blood of the treated host.

Application of chemicals which are biodegradable to food additives limits the danger to the environment and may affect mostly non-target insect fauna which develop in bovine fecal parts, i.e. mostly Hydrophilidae and Scarabaeidae beetles. The wider the spectrum of the IGR, the more effective it is against these beetles. Thus methoprene (Altosid - ZR-515), which is more specific against Diptera, did not affect these beetles, while TH-6040, which interferes with cuticle deposition during molting in a large number of arthropods, was also active against several species of dung beetles (Pickens and Miller 1975).

It is quite likely that if we want to use a single compound for the control of helminths, ticks, lice and various Diptera, it will have to be one which is less selective and might affect some non target insects in the dung of the treated livestock—yet it is expected to be limited and short-lived due to the biodegradation of IGR.

Postembryonic development and maturation of insects are controlled by an endocrine system and are based mainly on the interaction of two sets of hormones: the molting hormones—the ecdysones which stimulate molting and juvenile hormones which control and limit differentiation or metamorphosis. It has long been proposed that either one or both of these insect hormones may be potent insect control agents, with many advantages over commonly used insectides.

Even though the possibility of using the molting hormones as practical insect control agents has not been pursued, it does merit serious consideration. The polyhydroxy steroids may interfere with immature molting, ovarian development, embryogenesis and diapause. Of the natural ecdysones, 20-hydroxyecdysone, when added to bovine blood at a concentration of 0.1 percent inhibits ovarian maturation in the housefly and stable fly (Wright and Kaplanis, 1970) The synthetic analogue 22,25 - bisdeoxyecdysone, in addition to inhibiting reproduction, also inhibits larval development in the housefly when incorporated into its diet at 15-25 ppm.

Diapause of larvae of the tick **Dermacentor albipictus** was terminated by topical application of α -ecdysone and analogue A^7 - **5B** cholestene—**2B, 3B,** 14α—triol-6-one (Wright, 1969), **B** ecdysone, ponasterone A and inokosterone, when fed to the tick **Ornithodoros moubata** adult in a concentration of 0.5 — 10 ug/cc blood, produced supermolts, or death. They also caused molting in non-molting, partially fed nymphs (Kitaoka, 1972). It was later found by Mango at the International Center for Insect Biology and Ecology (ICIBE) that the super-molted ticks retained their reproductive capacity, and if offered a second blood meal, they took a larger meal and produced a larger number of eggs. Further feeding with ecdysone induced a second supermolt of giant healthy ticks. Thus, ecdysone and phytoecdysone can cause death or precarious molt of nymphs, but can also produce at certain concentrations, "super" ticks.

Insect molting hormones and hormone antagonists have not proceeded beyond the stage of laboratory research and at present appear to be outside the realm of economic feasibility (Djerassi **et al.**, 1974).

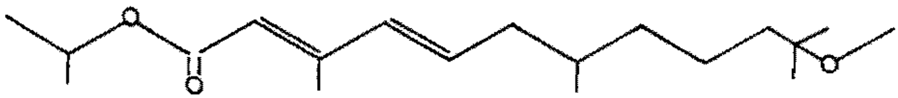
The use of modified insect juvenile hormones reached the stage that by 1972 the first application for an experimental permit for control of mosquitoes was filed. It would seem, therefore, much more promising to study the feasibility of use of JH mimics for the control of livestock pests.

Diptera

Most of the practical results obtained with insect growth regulators have been with Diptera. The data were recently reviewed by Staal (1975) and will, therefore, be mentioned here only very briefly.

The inhibitory activity of IGR on emergence of adult muscid flies has been demonstrated by topical application of wandering larvae and untanned pupae, as well as by treatment of larval media. Methoprene (Zr-515, Altosid) causes extremely high non-emergence activity. Incorporation of methoprene into the rearing medium at 10 ppm shows effective control against several strains of **Musca domestica.** But against insecticide resistant strains, concentrations of up to 250 ppm are required (Jakob, 1973). Even more sensitive to IGR than **M. domestica** are the horn flies **(Haematobia irritans)**, the face fly **(Musca antumnalis)** and the stable fly **(Stomoxys calcitrans)**, but there are substantial relative differences for these species in susceptibility to different types of compounds or variations within one type of compound (Harris **et al.**, 1973; Wright **et al.**, 1974).

Figure 1. **Structure of methoprene (Altosid).**



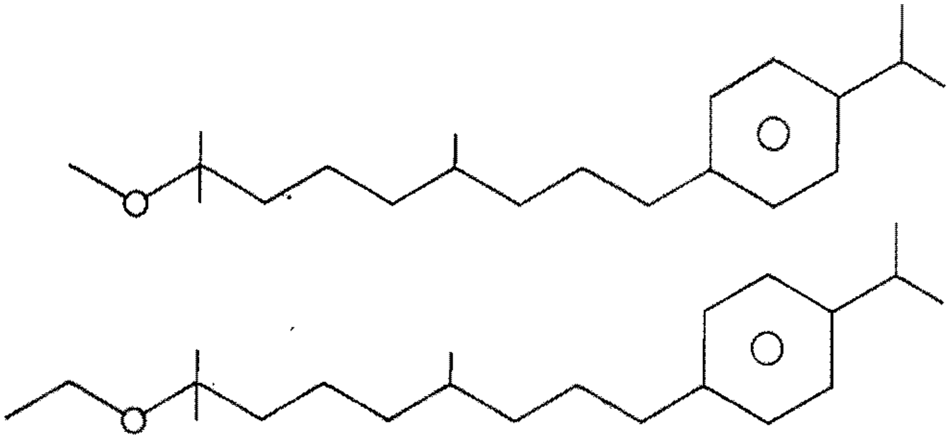
Poor control of flies is obtained when manure is superficially treated with IGR, presumably because penetration and distribution of the chemicals are poor. Oral administration of IGR survives the digestive tract, mixing through the manure and may be assumed to be homogenous. This has been proven to be a successful procedure (Harris **et al.**, 1937. Miller and Level 1973). The practical realization of this procedure will depend primarily on considerations of cost and of safety of the animal and animal products for human consumption. A dose of 0.7 mg of methoprene per day/cow provides full control of horn flies, while 100 mg per day per cow is required to control stable flies. The residual effects of the treatment are quite good: flies cannot develop in manure collected up to eight days after the last feeding of IGR.

Since the early experiments were all done with simple emulsifiable formulations, it is likely that suitable formulation could improve the efficacy of passage through the alimentary tract.

The field, activity, specificity, degradation and toxicology of methoprene have been intensively studied. When mice, rats, guinea pigs or cows are treated orally with methoprene, it is rapidly metabolized and eliminated via the urine, feces and expired breath. Some of it passes through the digestive tract unchanged, and this, as has been mentioned, is sufficient to inhibit fly development in the feces. I have no data as to the level of methoprene in plasma and tissues at various feeding regimes, information that is important for studying its potential for control of other diptera: grubs, bots or screwworms, in the treated host. Basically, as methoprene shows activity against many diptera, it could affect these insects as well, provided that the proper concentration is maintained in the host tissues.

Recently, exceptional activity of IGR having an arylterpenoid structure, was reported in muscid flies (Schwartz **et al.**, 1974), Figure 2. A dose of .25 mg/kg body wt/day was sufficient to produce 100 percent inhibition of face fly eclosion, stable fly and hornfly. Yet these compounds, which have the highest reported activity against muscid flies, are not active against **Tenebrio** or **Oncopeltus**, and it is possible that their spectrum does not include lice or ticks.

Figure 2. **An IGR containing an arylterpenoid structure.**



Lice

The chewing louse, a pest of domestic animals, has received considerable attention. Chamberlain, Hopkins and collaborators screened a great variety of compounds in several ways on **Bovicola limbatus** (Chamberlain and Hopkins, 1970; Chamberlain **et al.**, 1973a; Chamberlain **et al.**, 1973b); Hopkins and Chamberlain, 1972; Hopkins **et al.**, 1970). They concluded that the last nymphal instar is the sensitive stage and that 50 ppm of JH 1 and JH 2 in the diet prevents metamorphosis and reproduction. ZR-512 at 5 ppm is fully effective. This means that 0.1 mg of this compound per goat, administered periodically, should give sufficient control. Yet it is very doubtful if this species could be controlled by systemic IGR, as systemic insecticides do not control it either.

Sucking lice (**Anopleura**) of cattle have not been studied with IGR. Our information is based only on studies with the human body louse, **Pediculus humanus.** Vinson and Williams (1967) studied and observed the effects of a hydrochlorinated farnesoates mixture on embryogenesis and metamorphosis, which leads to high mortality when populations are exposed to wool fabric impregnated with this mixture. Some of the lice which survive the high dose develop into giant supernumeraries. This of course casts doubt on the use of these compounds. Bagley and Bauernfeind (1972) mention ovicidal effects of RO 20.3600 but state that the absence of immediate effects may preclude their use for public health purposes, but not for veterinary purposes.

Effects of incorporating IGR in the blood meal of lice have not been studied.

Ticks

Staal (1975) states that IGR have not been reported as being active against Acarina (mites and ticks) at reasonable dose rates. He further speculates that this group of arthropods may rely on mechanisms for regulation of metamorphosis and reproduction different from those of insects. I have mentioned a few cases where ecdysone was shown to terminate diapause and initiate molts in ticks. Information on the effects of JH and its analogues is rare. Yet it was recently shown that one of the JH analogues (acetaldehyde, 2-(2-ethoxyethoxy) ethyl-p-(methylthio) phenyl acetate) induced diapause termination, vitellogenesis and oviposition in female **Argus arboreus** (Bassal and Roshdy, 1974).

Several JH analogues were tested for their effect during embryogenesis of **Hyalomma dromedarii** and molting in nymphs of **H. dromedarii, Haemophysalis longicornis** and **Dermacentor andersoni** (Bassal, 1974).

The compounds were applied topically to females on the first day of oviposition. ZR-512 completely blocked embryonic development of eggs which were at this stage at the time of application. F_1 larval mortality after application of ZR-512 to parent females was 100 percent.

Other JH analogues were less effective than ZR-512. Bassal (1974) reports on the effects of JH analogues on molting of several species of hard ticks. Mrs. Mungo at ICIBE treated **Rhipicephalus appendiculus** females by applying JHA topically after they had completed engorgement, and none of the thousands of eggs hatched.

Not enough work has been done so far on ticks to be able to conclude that they are not affected by IGR. The fact that **Ornithodoros** supermolts after ingesting ecdysone, but is hardly affected by topical application, may hint that oral administration of IGR is much more effective than topical application. At present, proposal aims are for treating ticks by feeding the host with IGR: tests should be conducted by feeding candidate compounds to the ticks.

Helminths

The life cycles of nematodes are similar to those of apterygote insects. It would be reasonable, therefore, to seek in nematodes a system which involves a molting hormone and JH (Rogers, 1973).

It has already been shown that ecdysone, JH and its analogues affect growth, molting and development of reproductive systems in nematodes (Johnson and Viglierchio, 1970; Shanta and Meerovitch, 1970; Davey, 1971). **Trichinella spiralis** males show inhibition of copulatory appendages in the presence of 10^{-6} - 10^{-7}M farnesyl methyl ester (Shanta and Meerovitch, 1970).

At present a screening program on the effects of JHA on free-living nematodes is going on at the USDA lab in Beltsville, Md., but to the best of my knowledge, there has been no methodical screening of livestock parasitic worms, or of the effect of IGR on these worms when their host has been fed JHA.

Conclusion

In order to have a market large enough for chemicals to control livestock pests, it is proposed that a systemic IGR be developed which will be effective against all arthropods and helminths which inhabit the living animal or its feces. Clearance for registration will then be limited to one chemical.

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Summary of Papers Presented by:

Alexander S. Tahori
Rachel Galun

Dr. Aart van Schoonhoven (CIAT, Colombia) asked if Dr. Alexander Tahori (Israel) had any knowledge about resistance to pyrethrum or if it would develop. Dr. Tahori replied that it already exists in some fly lines. It was found in Africa and will possibly occur in other insects.

Dr. Gavin Braithwaite (ODM, Argentina) suggested that in cattle with few ticks a strategic method of dipping can be continually utilized. He asked if in such a manner the life of an acaricide would be prolonged so that, although resistance would not appear quite as soon, when it did occur it would be selective.

Dr. Tahori indicated that although he didn't have experience in that respect, it is true that with a bigger tick population the possibility of some having the genes for resistance is greater but he added that this is only a theory and he did not know if this would occur in practice.

Dr. Marcelo Rojas (Peru) thought that resistance to acaricides is due to the use of small doses and the residual effect of the chemical and he asked how long a particular solution should be accepted as useful for dipping. Dr. Tahori believed that theoretically, the solution that kills 100 percent of the ticks does not allow resistance to develop. If this is compared with another that only kills 80 percent, the acaricide gets dirty and loses power and selection of a resistant population occurs. A mortality of 100 percent must be maintained, almost independent of the concentration being used.

Dr. Stephen Barnett (England) said that geneticists have noted that when attacking a small population there is less selectivity for resistance than a larger population and he asked if it would be of any value to alternate acaricides. Dr. Tahori noted that every acaricide component needs a determinate number of generations to induce resistance. When using two different products, resistance will be developed when the number of partial generations required are added up. He noted that this is a theory and apparently it does not happen in practice.

Dr. Rachel Galun (Israel) stated that there was a group of acaricides that makes ticks drop to the ground. Dr. Roger Drummond (USA) added that some work has been done with material called Gallicrone which is not specifically toxic but makes ticks more susceptible to acaricides. These works were initiated with "spike" Fenam-madines in Australia. He suggested that it would be useful in the case of tick resistance to other acaricides. It works better with ticks with short hypostomes, but it is toxic to bovines. Dr. Tahori, also, added that the Gallicrone compounds are not stable; they are toxic and for that reason they have not been commercialized.

Dr. Nestor Lopez (Colombia) indicated that there are some organophosphates which change their radicals. He asked if the induced resistance covers the whole group or depends on the radical. Dr. Tahori replied that general resistance is not induced; resistance is induced only to certain specific compounds of that group. He also mentioned cross resistance to compounds of different groups.

Dr. Alfonso Escobar (COOPER, Colombia) inquired if induced resistance were irreversible. Dr. Tahori stated that tick resistance to acaricides has only occurred in Australia. It has been a stable resistance and they have been waiting for its reversibility. After resistance develops in the domestic fly, it also disappears, but if the insecticide is used again, the resistance comes back.

Dr. Fabio Galvez (Colombia) asked to what compound are ticks resistant in Australia. Dr. Tahori mentioned that ticks are resistant to chlorinated hydrocarbons and organophosphates and to practically all the acaricides with exception of the "spike" mentioned before. He believes that ticks will soon be resistant to all acaricides.

Dr. João Gonzalez (Brazil) suggested that there is data to contradict the idea that there are some individuals carrying the resistance gene in all tick populations. He asked if it is credible to accept that the gene can code multiple resistance infinitely. He also, asked if different responses have been found to resistance in the laboratory and in the field, and if there are different types of acetylcolinesterases in ticks.

However, Dr. Tahori noted that the development of resistance to multiple products does not mean that the same gene codes it. Research is directed not to enzymatic and genetic aspects. Resistance in the field should not be different than that in the laboratory and he considered that if it were, it would be due to a human mistake.

Dr. Alfonso Lancheros (Colombia) inquired if tick resistance were correlated to the breed of cattle which it parasitizes. Dr. Drummond thought that tick resistance was a creation of man, due to the wrong dosages of acaricides. As far as cattle of different breeds being resistant, he stated that this is inherent to each animal.. The two resistances are not related. However, Dr. Braithwaite suggested that in Argentina, studies of cattle resistant to ticks indicate that those that are resistant have a higher cholesterol content than resistant cattle.

Dr. Drummond suggested that the use of chemicals in cattle feed can have implications of contamination of human diets and a possible resistance can be expected from arthropods treated for a long time. He suggested that the same mistake should not be made which was done in Australia. There, the indiscriminate use of acaricides have caused serious problems with resistance. Dr. O.G. Graham (USA) agreed that one must be aware of the different ecological zones in which the situations and **modus operandi** are completely different and stated that the exposition made by Dr. Galun was important because the conventional methods presently used for tick control won't last much longer. More developed methods will have to be implanted.

Dr. Jose Payno (Bolivia) asked if anyone had studied hormones of the **Boophilus**. However, Dr. Galun did not find any references to them and Dr. Drummond suggested that studies have been concentrated mostly in the area of the three host ticks.

Dr. Stephen Barnett (England) inquired about the stability of pheromones. Dr. Galun stated that some are stable and others not.

The Contribution of the Basic Scientist to Arthropod Control

Kenneth Thompson *

Dr. Sanmartin commented quite correctly on one point I would like to reiterate. We have to consider those who are really interested in their field (work) for advanced training. This means we must not always select grades but ability is also of prime importance. One problem with which we are confronted is that the new Ph.D. has book knowledge but lacks practical knowledge. That is, he isn't taught from the ground level to book level but only book to book level. Therefore, as Dr. Sanmartin states many don't know how to make microbiological media, although they are adept at using the electron microscope.

Another point is the relationship between the basic scientist in the laboratory and the field personnel. One has the task of identifying the field problem and taking it to the laboratory, while the other must find a practical solution and return to the field with something that works.

The contribution to arthropod control (or eradication) will undoubtedly be in one of the following areas:

(1) Acaricides.
(2) Genetic control.
  (a) Sterilizing agents, i.e. ionizing irradiation or chemical sterilants.
  (b) Hybrid sterility.

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(3) Hormonal agents.
(4) Alteration of the environment (Effects on grass are still unknown.)
    (a) Pasture spelling.
    (b) Environmental manipulation.
        i.e. ground fire; defoliation of herbage; clearing of land.
    (c) Area control with toxicants i.e. ultra low volume application of OPC or carbamates from planes or helicopters.
(5) Breeding of resistant cattle.
(6) Finding a new antigen source for immunization against the tick.

The contribution could come from the field of taxonomy. For one thing, the keys we use are, for the most part, old and erroneous. We need new, up-dated keys in Spanish or "type species" from the same tick origin so that all countries will be able to compare their specimens.

Tick distribution maps would list all ticks and hosts (wild and domestic animals) within all countries.

A communication center would receive information or advice from all countries or just disseminate news of a discovery between each of them rapidly and accurately.

Simply, the scientist's contribution should be "to find the most economical, most practical control method in an ever changing host-parasite relationship".

Summary of the General Discussion of the Entomological Needs of Latin America

Discussion chairman: Joao González

Dr. Jose M. Payno (Bolivia) asked for a consensus on common problems. Dr. Antonio Ibañez (Paraguay) indicated the necessity of identifying areas of priority such as tick distribution maps and training of people in tick taxonomy. Dr Gonzalo Luque (Colombia) added that there is a need to review tick keys.

Dr. Ivan Londoño (Colombia) stated that studies on biological control must be intensified. Dr. Gavin Braithwaite (Overseas Development Ministry, Argentina) noted that the bio-ecological studies being carried out now in Latin America, need to be unified. Dr. Payno stated that the economic loss factors for tick and tick-borne diseases must be studied. Dr. Marcelo M. Rojas (Peru) added that the economic impact of ectoparasites on Zebu must also be studied.

Dr. Payno noted, however, that there are financial problems within Latin American countries which limit them, and furthermore, other countries are not working with **Boophilus microplus**. Dr. Londoño further asked how it would be possible to get ectoparasite information when there is none in Latin American countries to give. Dr. Herculano Cardozo (Uruguay) also emphasized the need for international help and a technical package and he concluded that CIAT and FAO could help by disseminating papers from all over the world to Latin American countries. Dr. Ralph Bram (FAO, Italy) suggested that FAO needed a resolution to set up a global acaricide resistance monitoring program in Latin America. He also indicated the need for a center that can maintain tick species for a long time which should be located in the center where the expertise can be found. Dr. João Gonzalez (Brazil) emphasized that Latin problems should be solved by Latins and he defined CIAT's role as a Consultation Center. Dr. Helio Noguera Espinola (Brazil) also noted that that Brazil has expertise in tick taxonomy and has collections of insects and ectoparasites.

Dr. Bram stated that subject to the request by the participants of the ectoparasite workshop, FAO would consider establishing a regional center for tick taxonomy available to all Latin American countries. The countries can request aid and FAO will then support regional projects in a taxonomic center.

Dr. Nels Konnerup (USAID, USA) stated that USAID would financially support a taxonomic center but would not supply funds to build one.

Dr. Kenneth C. Thompson (CIAT, Colombia) noted that subject to the approval of the Director General and the CIAT Board of Trustees, CIAT could accept the responsibility of disseminating information on the ectoparasites of cattle from all over the world to Latin American countries.

Dr. Derick W. Heinemann (Surinam) presented a statement concerning:

(1) Documentation

This meeting recommends that CIAT seek funds to enlarge its animal health documentation service to enable the regular distribution of current knowledge of ectoparasites relevant to Latin America. This should include all information pertaining to the development of resistance by ticks to acaricides.

(2) Training

This meeting recommends that CIAT coordinate the mapping of the distribution of bovine tick especies in Latin America and to this end should seek funds to hold laboratory courses in tick identification and tick survey methods.

Dr. Konnerup presented a statement of interest in ectoparasite problems:

AID gratefully acknowledges CIAT's expression of thanks for the agency's part in sponsoring this Ectoparasite Workshop and particularly calls attention to the role of the Israel Institute for Biological Research in assisting in organization and participation in these deliberations.

AID has separate and direct cooperation and agreements with the International Laboratory for Research on Animal Diseases (ILRAD), the International Center for Insect Physiology and Ecology (ICIPE) and the Israel Institute for Biological Research in sponsoring other workshops and seminars with these international institutions in Africa. AID anticipates that intercontinental involvement in such conferences as this will add materially to communications related to research advances in these fields.

I would particularly call your attention to the work being carried out by ICIPE and ILRAD. It is hoped that much closer links can be established in seminars, workshops and training programs for the future and that CIAT and the African Institutions along with Australian participation can expand the sphere of influence into Asian areas as well.

The general recommendations approved by the Ectoparasite Workshop are as follows:

(1) FAO will study facilities existing in Latin America for the establishment of a center for taxonomy and general training.

(2) FAO will also search for a suitable country in Latin America to be developed as a monitoring center for research on tick resistance to acaricides.

(3) The seminar recommended Brazil to accomplish the first two recommendations.

(4) CIAT will be the communication center for disseminating information on bovine ectoparasites throughout Latin America.

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