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THE IMPACT OF MOSQUITO-BORNE DISEASES ON ORGANIZED MOSQUITO CONTROL DISTRICTS

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INTRODUCTION. The American Mosquito Control Association represents a sizeable industry in the United States. Your Secretary, Ted Raley, informs me in a letter that there are 229 agencies organized for mosquito control, that "there are 24 states blessed with at least one organized mosquito control district" and that their annual budgets add up to at least $27,000,000. In addition to the 229 mosquito abatement districts there are at least 224 other agencies concerned with mosquito control in the United States. If one adds together all these agencies there are 453 and their annual budgets total close to $35,000,000.

A review of American Mosquito Control Association Bulletin No. 4 edited by Harold Gray (Gray, 1961) and published in 1961 impresses one by the fact that, although since that date a few agencies and states have been added to the industry and the total budget has increased, the objectives, methods and concerns of the programs have not changed significantly in 10 years. In the foreword to that publication Dr. Fred Soper stated, "Public health literature, since 1901, is replete with tales of the glorious victories over yellow fever and malaria. Although malaria and yellow fever have been eradicated in the United States, much remains to be learned of the epidemiology of the encephalitides and other mosquito-borne viruses in the United States and the relationship of outbreaks here to the migrations of birds. Almost inevitably future studies will lead to the demand for more anti-mosquito work." This was a most significant statement particularly when one considers that Chapter I of the same publication restressed that "In recent years, the importance of malaria has been reduced in many parts of the world by mosquito control or eradication. Yellow fever and dengue, both important mosquito-borne diseases, are rare now because we have learned how to reduce the mosquito populations where these diseases were once common. In some areas *Aedes aegypti,* the vector of urban yellow fever, has been eradicated. Suppression of encephalitis, also a mosquito transmitted disease, is being approached through mosquito control. Many communities now exist where mosquitoes once claimed the land." You probably wonder why I have spent so much time reviewing the size and

cost of your industry and the considered judgments by several of our leading spokesmen 10 years ago. I believe the reasons will become obvious as the topic of this address is developed, namely, "The Impact of Mosquito-borne Diseases on Organized Mosquito Control Districts."

We are in a new era today with reference to the control of mosquitoes and mosquito-borne diseases as the following problems have emerged:

1. Many of your districts and agencies were formed because mosquito-borne diseases were epidemic or highly prevalent in your populations and the diseases had to be controlled. The impact of the disease whether it was malaria or encephalitis was such that public concern demanded action and a new agency supported by tax funds was formed to provide protection. You are now held responsible if the disease occurs and it is expected that you will prevent it. If for any reason you fail, the public looks upon it as your failure and explanations better be quick and convincing.

2. Some districts were formed to abate pests and this was frequently thought of as an investment to improve food production, allow land development, and remove what most people conceived as an environmental contaminant that caused annoyance and interfered with their business or recreation. Again, if you do not succeed in keeping the level of pest irritation low and land values and economy high you will be blamed.

3. We all share a common concern for the increased costs of control; the limitations that are rapidly mounting with reference to the insecticides that are available for control, either due to insect or public resistance; and the relatively slow progress with which alternative, effective, and economical approaches for control have developed.

4. Finally, when we are challenged to provide well-done economic evaluations of the cost-benefit values of control efforts we usually have not done them and it never occurred to us that anyone would demand them.

With the preceding as a preamble I am going to attempt to bring the items mentioned into perspective.

MOSQUITO-BORNE DISEASES. You recall the earlier quotes from Soper and Gray that referred to landmark victories over malaria, yellow fever, dengue and *Aedes aegypti*. The facts today lead us to be somewhat less optimistic. The headlines in the San Francisco Chronicle on March 5, 1971 stated "Bakersfield Malaria Cases." I can report to you now that investigations by local and state health authorities leave no question that malaria is epidemic in Kern County, California in 1971. Over 40 cases of malaria due to *Plasmodium vivax* have occurred in a period of the past several weeks (Kearns *et al*, 1971). These people became infected in the United States, a country where malaria has been proclaimed eradicated for many years.

The Dr. Morris Mosquito Abatement District (now the Kern Mosquito Abatement District) was formed in 1916 to combat endemic malaria and the last report of mosquito transmitted malaria in the county was in 1938. I am sure you all realize that the staff of the Kern Mosquito Abatement District is not being held responsible for this epidemic. The current outbreak centers in a chain of over 400 heroin users that includes an infected Vietnam veteran. These are signs of our times. The transmitting needles are much longer and larger than those of *Anopheles* mosquitoes. We know that Kern County is an unreceptive area for mosquito-borne malaria today but there are many areas in the United States that still have sufficient *Anopheles* to make them potentially receptive areas.

It is also a fact that we must consider that all populated areas in the United States are potentially receptive to needle-transmitted malaria. I submit that each organized mosquito control agency must establish a close liaison with its local, state and federal health agencies so it will learn at an early date of each malaria case in the district's jurisdiction. Data from annual reports of the National Center for Disease

Control reveal that over 3,000 cases of malaria are reported in each of the past several years. Incidents like the current cases in Kern County will recur and extend these numbers. What is going to be done when 30 or more cases of malaria are reported within the boundaries of a mosquito abatement district or health agency if the cases have onsets in the summer and *Anopheles* are common? I'll tell you what you will do—you will go out and kill a hell of a lot of *Anopheles* mosquitoes and spend a lot of money. It will be assumed that the disease is mosquito-borne until proven otherwise and the control agency will be forced to mount an emergency control program. The only defense to undue overreaction will be an acute and intelligent awareness by the involved health and mosquito control agencies and the rapid marshalling of resources for an epidemiologic study to identify the source of infection, the mode of spread and proper approach to control.

However, let us remember one thing, malaria is not eradicated from the United States; it is being actively transmitted today. Only mosquito-borne malaria is eradicated and we must keep it that way. Only a dedicated effort and considerable luck will prevent a future series of mosquito-borne epidemics like the one that occurred at Lake Vera, California in 1952 (Brunetti, *et al,* 1954). The cost of each of the current episodes and investigations must be determined and publicized if we are to expect an understanding of and support by the public for our efforts.

I want to turn now briefly to two diseases that for all practical purposes have been of no direct concern to mosquito control districts in the United States or Canada. These are urban yellow fever and dengue fever. If you have dismissed them from your mind please reopen your concerns. Dr. Soper and Mr. Gray were quoted earlier concerning our successes with dengue and yellow fever. I want you to know that I am also an expert in optimistic pontification, as in May, 1962 Dr. William Scherer and I wrote a report for the Pan American Health Organization in which we stated "Two classical epidemic arthropod-borne virus diseases, urban yellow fever and dengue fever, have been conquered in the Americas. These advances were made largely through intensive control programs designed to eradicate urban vectors or to immunize exposed human populations." I can assure you it warms the cockles of one's heart to be able to make such pronouncements and it chills you to the bones when in the following year (1963) there is a major outbreak of *Aedes aegypti* borne dengue fever that almost blankets the Caribbean and coastal Venezuela (Neff, *et al,* 1967; Pan American Health Organization, 1965). It chills you even more to learn that a disease suspected to be dengue had been occurring in the region the previous 3 years and that *A. aegypti* eradication programs had been decreased or abandoned in some areas in the early 1960's without your knowledge. This situation can be summarized as follows:

1. Dengue fever has been epidemic or endemic in extensive areas of the Caribbean and Northern South America since the early 1960's (Pan American Health Organization, January 1970). Cases have been detected after their arrival in port cities of the United States (Communicable Disease Center, 1964). Dr. Soper stated our concern about birds carrying viruses great distances; I worry equally about the Boeing 707 and 747 and similar birds that fly widely and carry many people to our shores from areas where dengue is reported to be active today, such as Puerto Rico and Asia.

2. *Aedes aegypti* is resurging. Reinfestations have occurred in a number of countries that had achieved eradication (Pan American Health Organization, December 1970). The United States suspended its eradication program several years ago and Dr. Pratt will be reporting to you this afternoon on the current status of this mosquito in the United States and Mexico. We must assume today that the current efforts to control *A. aegypti* in the United States are in the hands of local mosquito control and health agencies. Unfortu-

nately, we do not even have an adequate knowledge to be able to establish the target below which an *A. aegypti* population will not transmit dengue viruses and that will assure that our cities will be unreceptive to disease introduction.

3. A primary reason that has been given for decreased governmental spending in the United States and abroad on *A. aegypti* eradication is that it is questioned if a cost-benefit analysis would support the investment and until such study is done we will not know the answer to the question.

4. There is evidence that *A. aegypti* populations can become or are resistant to insecticides and that control or eradication efforts will become increasingly difficult.

5. We must assume, until proven otherwise, that an area where dengue fever is epidemic could be receptive to an introduction of yellow fever. We know that the human populations in urban areas have not been immunized to yellow fever. The areas where yellow fever is endemic in a jungle cycle continue relatively unchanged in the Americas (Pan American Health Organization, February 1970).

6. Finally, one or more cases of yellow fever in an *A. aegypti* positive port city in the Americas would be an economic catastrophy. Several episodes of epidemic yellow fever have occurred in Africa in recent years, including the report in the Washington Post this past Saturday of yellow fever in Angola after an absence of many decades.

To summarize, dengue fever, yellow fever and *A. aegypti* are not "Dodo Birds." The continued occurrence of these agents is costing us money, they defy eradication and their occurrence can become an economic or health catastrophy. Let me turn now to the other arboviruses that are common to the United States and review their impact on control programs. The arboviruses of concern to human health in the United States are summarized in Table 1. We have already discussed the dengues and yellow fever. Colorado tick fever is tick-borne and of particular concern in the far west. If this convention had been in the spring and early summer we could have loaded you all in a bus, headed for selected areas in the nearby scenic mountains, and then sat back and waited for the cases of Colorado tick fever to develop following your tick bites. Powassan virus is tick-borne and has a wide distribution but is of little demonstrated public health importance. However, as few people are attempting to control the tick vectors of arboviruses in the Untied States, the remainder of this discussion will focus on the mosquito-borne viruses that do concern us.

TABLE 1.—Arboviruses important to human health in U. S. historically and currently.

California encephalitis
Colorado tick fever
Dengue fevers
Eastern equine encephalomyelitis
Powassan
St. Louis encephalitis
Western equine encephalomyelitis
Venezuelan equine encephalomyelitis
Yellow fever

In Table 2 the statistics are summarized from the National Center for Disease Control for the 5 mosquito-borne viral encephalitides over the past 10-year period. I am happy to note that these diseases are not a major health problem in the United States when compared with many other acute infectious diseases or the major chronic noninfectious diseases. The problems that we face with the encephalitides are:

TABLE 2.—Confirmed human cases of mosquito-borne encephalitis United States, 1960–1969 *

Virus	No. cases
St. Louis encephalitis	1,290
Western equine encephalomyelitis	460
California encephalitis	310
Eastern equine encephalomyelitis	37
Venezuelan equine encephalomyelitis	1
Total	2,098

* Source: NCDC Annual Summaries, Neurotropic Viral Disease Surveillance.

1. We continue to have cases each summer and the viruses persist in their animal-mosquito cycles.

2. In the past 10 years we have had too many sporadic epidemics many of which have been in urban or surburban populations and even in areas with organized mosquito control programs. I have only to mention a few of our landmarks, St. Louis encephalitis in the Tampa Bay area in 1962, in Houston, New Jersey and Pennsylvania in 1964 and finally in Dallas in 1966. Then I can turn to western equine encephalomyelitis in Hale County, Texas and Saskatchewan, Canada in 1963 and in Colorado in 1965. Finally, there was the occurrence of California encephalitis cases in 1966 and 1967 in Ohio and adjacent areas. I could extend this list and I hope that I haven't hurt anyone's feelings by omitting your favorite epidemic in your home town.

What are our problems? How is it possible that we continue to have epidemics when we believe that our basic scientific knowledge for these diseases is such that we should be able to prevent them? The answers to these questions put in their simplest terms are as follows:

1. The majority of the epidemics are not predicted because no one is alert and looking for the premonitory conditions that favor an epidemic.

2. Everyone believes that an epidemic will not happen here and to me but it could happen there and to them.

3. We do not maintain routine measurements of the levels of populations of each of our competent epidemic vectors except in selected areas. No single method will accomplish a population measurement for all vector species and the procedures are expensive and tedious.

4. We do not make any effort to maintain a knowledge of the susceptibility status of the human population because such measurements are expensive, and difficult, and we do not have an approved vaccine that would allow us to act to change the communities' immunity status.

5. We do not maintain good and continuous measurements over large areas of the status of insecticide resistance in the populations of key vectors such as *Culex tarsalis, Culex pipiens, Culex nigripalpus* and *Culiseta melanura.* Thus it can be and is a surprise to discover that a vector is resistant to insecticides during an epidemic.

6. We frequently sit by and do not react to establish a vector control program while natural and man-made catastrophies such as floods, hurricanes, droughts, earthquakes, and irrigation developments set the scene for an epidemic.

7. We find it difficult to react or to get public support until there are a number of proven human cases of encephalitis and by that time most of the damage is done and we cannot take effective action.

8. Finally, we have very little organized data on the costs of epidemics, and cost benefits of preventing epidemics, and it turns out that these are the facts most impressive to the public and their political representatives who pay for our programs.

Let us take a look at the problems that can face a mosquito control or health agency if it appears that an epidemic is pending or has actually begun. The headlines from three newspaper articles that appeared in California in April, 1969 tell the story in sequence as they stated, "Snow Runoff Peril Mounts," "Infected Mosquito Danger" and "Encephalitis Battlers Meet." In this instance an epidemic was anticipated and the agencies put a program into action (Peters and Kramer, 1969). The data in Table 3 summarize the situation in

TABLE 3.—California—summer of 1969 snow melt forecasts as of May 1, 1969 and immediate results.

River	Percent of normal runoff	Immediate results
Kern	439	37 counties
Tule	393	eligible for
Kaweah	307	disaster aid
Kings	262	$1,500,000
San Joaquin	271	requested
Owens	240	State Health
Merced	224	requested
American	181	$2,987,000
Yuba	171	100,000+ acres
Sacramento	137	flooded

May 1969. The impact of flooding on the economy of the area was very costly. In addition, our most conservative estimate was that $1,250,000 of additional funds were spent above the approximately $10,000,000 that was already scheduled for mosquito control in 1969. The culmination of this effort was that we did not have an epidemic and the newspaper headline in October 1969 stated "Epidemic Puzzle: Why Was State Spared Encephalitis?"

I know that many of you could provide your own newspaper clippings concerning the impact of a threatened or actual epidemic. It is a difficult and costly time for control agencies as it exhausts their financial resources and reserves, challenges their ingenuity and abilities and is a thankless situation. I believe we have an obligation to bring before the taxpayers the cost of epidemics and the benefits of our programs in preventing them. The problem is that too few adequate evaluations are available to refer to. I would bring your attention to one of the very few cost evaluations that have been published and that was Schwab's (1968) evaluation of the Dallas St. Louis encephalitis epidemic. I have summarized his data in Table 4 and I believe as he did that an estimate that the epidemic cost Dallas $796,000 is conservative.

TABLE 4.—Economic cost of St. Louis encephalitis epidemic in Dallas, Texas, 1966 *

Cases 172 Fatalities/cases	Attack rates 22/172	19/100,000
Vector control		$198,800
Laboratory support and epidemiologic aid		103,200
Administrative and clerical		30,000
Information and communication services		16,500
Subtotal		$348,500
Case treatment costs		196,100
Short run morbidity losses		82,000
Mortality costs		169,100
Total cost of epidemic		$796,500

* Source: Schwab, P. M., Public Health Reports, October, 1968.

I could extend my considerations of the costs of epidemics and the benefits of preventive programs, but prefer to devote the remainder of this presentation to my concerns with the problems that relate to needs in control technology if we are to prevent epidemics and the adverse effects that epidemics have on our populations and control agencies.

FUTURE PROBLEMS THAT FACE CONTROL AGENCIES AND THE RESEARCH STAFFS THAT SUPPORT THEM. We meet here in Denver at considerable expense. The purpose of our meeting is to exchange knowledge and concepts and we hope to benefit our individual programs. We must concern ourselves with limitations in budget or technology and the views of the public back home. I believe the following points are relevant to my talk today and to your meeting:

1. The impact of an epidemic on mosquito control agencies will be much greater if we do not have effective techniques or materials to control the vector. There is increasing evidence that we are on borrowed time with reference to our dependence on chlorinated hydrocarbons, organophosphorous compounds and other insecticides.

2. We do not pretend to understand the impact of the use of insecticides generally on the many factors that control the capacity of animal and vector populations to be effective hosts for these disease agents. My colleague Dr. James Hardy and I are more than a little impressed that western equine and St. Louis encephalitis viruses have virtually disappeared from the Central Valley of California coincidental to the widespread use of organophosphorous insecticides and the development of resistance in the vector.

3. At every meeting of groups concerned with mosquito control we continue to listen with great interest to the potential of new approaches to control and the details of laboratory studies. Too frequently we look in vain for any evidence of a field trial or find there was an unanticipated or insurmountable problem when field trials

were attempted. There continue to be many promising approaches; some have been before us for ten or more years and we will hear about some new ones for the first time today. I will list only a few: integrated control, biological control with pathogens or predators, additives to insecticides to prevent insect resistance, release of sterile males, genetic incompatibility and translocations, and selections and introduction of vector populations that are gentically incompetent to be vectors. I could extend the list but the program of these meetings will accomplish this. I want it understood that I am fully in favor of the broadest possible attack on the problem, as we desperately need a major breakthrough that will allow us to live comfortably with mosquitoes or to selectively reduce them to levels that do not threaten public health or comfort. The problem is that the funding to support this research is drying up before field applications can be evaluated. Time as well as money is a precious commodity. The economists and other persons who make decisions on the allocation of financial resources are increasingly looking at our projects and results and weighing the investment to be made against the benefits to be achieved. There are many competitors for that money.

There is one thing we know for sure. You cannot put our present resources in trained manpower, equipment and materials into a deep freeze to be pulled out when they are needed to prevent or control an epidemic. Even if this were possible it would be a most ineffective and uneconomical approach to the problem. We know that our principal problems will continue to be the need to convince others that they must act to minimize mosquito production, that they must support abatement actions and that a continuing research effort is essential to the health and well-being of the community.

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