fliers occupied an apartment at a Waikiki rooming house. The maids at this house later came down with what was subsequently suspected of being dengue. By August 8, 1943, Waikiki had become such a focus of infection that it was restricted to military personnel.

As dengue is common in South Pacific islands, there is always the danger of its introduction again into Hawaii. There are two commercial airlines connecting Honolulu and Australia, stopping over on Canton Island and Fiji Island. The Philippines and the Orient are also endemic regions for dengue. The day mosquito control program in Honolulu is a preventive measure to keep the dengue vector population at such a low level that an epidemic may not occur again in case dengue should enter into this crossroad of the Pacific.

Airlines crisscrossing the Pacific have reduced distances in term of flying hours. One can now reach Australia in less time by plane from Honolulu than it takes to make an inter-island trip on boat to the port of Hilo on one of the neighboring islands within our Territory. The South Pacific is not any more a remote spot far away from the rest of the world. It will be still closer as connecting airlines link some of the more remote islands to major airports.

The South Pacific Commission is actively attacking the program of filariasis and of mosquito control as part of its health activities. Along with the researches and field studies carried on by the Institute of Medical Research in Tahiti, the joint anti-filariasis campaign is already showing good progress in the control of this mosquito-borne disease in the South Pacific.

REPORT OF THE A.M.C.A. COMMITTEE ON RESEARCH AND DEVELOPMENT OF MOSQUITO CONTROL AND RELATED PROBLEMS

Assembled by
B. B. PEPPER

INTRODUCTION

At the direction of President Don Rees, there was appointed a special committee on research and development of mosquito control and related problems. The members of this committee were as follows:

Harold F. Gray, Alameda Co. Mosquito Abatement District, Oakland, California.

William E. Bickley, University of Maryland, College Park, Maryland.

J. A. Mulrennan, Florida State Board of Health, Department of Entomology, Jacksonville, Florida.

B. V. Travis, New York State College of Agriculture at Cornell University, Ithaca, N. Y.

B. B. Pepper, New Jersey Agricultural Experiment Station, Rutgers University, New Brunswick, N. J., Chairman of Committee.

The purpose of this committee was threefold. First, to select some of the more important contributions from the current literature and to suggest the possible significance or application of this information. Second, to prepare a list of some of the more important problems confronting mosquito control workers at present, that should be solved to implement control work. And third, to include other pertinent information which the committee felt would assist mosquito control workers.

The committee was given a free hand on the development of its report. An outline was prepared and the members of the committee each prepared a section of the material.

It was the opinion of this group that the report should not be a review of the literature or a detailed report of mosquito work during 1951, since these topics are covered by Dr. F. C. Bishopp, and others in their "Review of Contributions to World Mosquito Problems" published annually in the Proceedings of the New Jersey Mosquito Extermination Association and by Dr. H. H. Stage and H. Sollers in their "References to Literature of Interest to Mosquito Control Workers" published in *Mosquito News*. Therefore only a brief summary of the current work will be given. Suggestions on some of the problems needing attention are listed.

The committee wishes to express its appreciation for the cooperation of Drs. Bishopp, Stage and Knipling in supplying abstracts of current literature and for valuable suggestions. The committee is also indebted to Drs. Nielsen and Provost for their excellent outline which is appended to this report.

Significant contributions to knowledge of mosquitoes and mosquito control in 1951

Taxonomy and Morphology

It is often difficult for practical mosquito control workers to see how fundamental research in general and taxonomic and morphological studies in particular will have any relation to their immediate problems. Indeed there are instances in which an outstanding piece of work can have no claims toward practical application, but no apologies need be offered. This section of the report, instead of describing contributions to knowledge in 1951, will refer to a few examples of research work and attempt to indicate actual or potential values to those engaged in mosquito control operations.

A thorough study of culicine pupae of the Northeastern United States now makes it possible to identify these mosquitoes in the pupal stage. If certain species in a given area do not need to be controlled, this makes greater selectivity possible. Similarly a method, described in 1951, for identifying the early stages of some anopheline larvae is useful in a "species sanitation" program. Investigations dealing with the systematics of the subgenus, *Melanoconion* (genus, *Culex*) in Central America and Northern South America, studies of the *Aedes punctor* subgroup in the North American Arctic, and additions to our knowledge of *Aedes* mosquitoes in Texas and the American tropics are extremely worthwhile for those who must survey and plan control work in those areas.

Biology and Ecology

All investigations which increase our understanding of mosquito biology and ecology are important in the evaluation of the relative importance of different species as pests or as disease vectors. Several outstanding studies of flight range and dispersal were reported in 1951. Some of these made use of radioactive isotopes. It is now possible to make adult mosquitoes radioactive by feeding them aqueous solutions of P^{32}.

The number of broods of three species of *Aedes* in California rice fields was observed, and this information should have direct application in control work. Likewise a host of new data was obtained relative to the ecology of mosquitoes breeding in irrigated pastures in California.

It was reported that dipping may be of uncertain value as a technique for establishing the presence of anopheline larvae when populations are very low. A study of the mechanism involved in floating anopheline larvae at a water surface showed that two ear-like structures on the thorax enable the larvae to float the anterior end of the body and indicated that the palmate hairs are auxiliary floating structures. This has implications in the direction of the development of new larvicides. Much progress was reported in 1951 on some basic questions regarding responses of female *Aedes* mosquitoes to water vapor, carbon dioxide, chemical compounds found in body exudations, temperature, and colors. It seems obvious that investigations on attractants have practical value and that the results are especially useful in furthering the search for better repellents.

Studies of the behavior of certain species of *Anopheles* have been reported. These contribute to an understanding of the factors involved in the development of resistance to DDT and other insecticides as well as help in increasing the effectiveness of insecticidal applications. Experiments were conducted to determine the hazards to wildlife when DDT was used to control mosquitoes on a New Jersey salt marsh. —W. E. BICKLEY.

DISEASE TRANSMISSION

The year 1951 represents roughly the fifth year since DDT became generally available for mosquito control throughout the world. Because of the unique susceptibility of *Anopheles* to this insecticide, especially when it is used as a residual deposit of considerable effective duration on surfaces within dwellings, there has generally been a dramatic and rapidly accelerated reduction in malaria in those areas where it has been extensively applied. At the present time well over fifty millions of people in various parts of the world are largely dependent on an adequate supply of DDT (or insecticides having a similar effect) for their working capacity and even life.

But it would appear that too great a pre-occupation with the problem of malaria eradication via the DDT residual spray route may lead to a possible future disaster, in view of the present unsettled conditions of the world. Shipments of adequate amounts of insecticides could be interrupted by war. Some thought should be given to alternative control methods, including the reduction of larval habitats, and the effective use of alternative materials as larvicides. An enforced return to either natural pyrethrins, paris green or petroleum derivative oils is not inconceivable. It may also later on prove to be a mistake to have abandoned the concept of screening as a malaria control measure.

Since it is possible that the anophelines may yet develop the degree of resistance to DDT and its analogs which has appeared in a number of *Culex* and *Aedes* species, a degree of caution should pervade any predictions as to the possibilities of extirpation of mosquito-transmitted diseases in tropical areas. Two possibilities can be foreseen: (1) the development of resistance to insecticides by the vectors; (2) due to unstable world conditions any large scale war may interrupt the delivery of necessary insecticides to large areas of the world. The present preoccupation by many workers with insecticidal measures as the sole control method could lead to disastrous results in such cases.

Even the concept of complete extirpation of an arthropod-transmitted disease, now seen to be an actual fact or a definite possibility within a few years in circumscribed areas, may need qualification. As long as all goes well, extirpation is a definite goal of great promise, but what if a war interrupts operations? A population no longer tolerant to a specific disease will have been developed, and the re-introduction of the disease and its vectors from outside areas could easily end in an enormous epidemic in a non-resistant population.

On the other hand, the use of native resources in labor and materials, for drainage, clearing, stream flushing, shading, salinification, and other well established control measures, in conjunction with insecticides as needed, would in the case of interruption of delivery of insecticides, or in the case of development of vector resistance to insecticides, leave the human populations in tropical areas with at least some means of protection, which could be intensified to whatever degree is necessary to minimize disease incidence.

We should also recognize that while we have (at present) a very potent weapon in DDT and its analogs, nevertheless malaria has been extirpated from extensive areas of the world without any conscious attack on the vector, and in fact in the continued presence of at least moderate numbers of the vectors (Upper Mississippi, Ohio and Missouri River Valleys). In the last two hundred years *Aedes aegypti* and yellow fever have disappeared from the north Atlantic coastal area of this continent, even though Halifax was formerly its apparent northern limit at the time. Is it not possible that we have not fully studied these unfavorable changes for either the vector or the parasite? Could not more be learned and applied concerning the modification of the environment for the purpose of disease prevention?

But, irrespective of the long-range viewpoint, spectacular results in the control of mosquito-transmitted disease continue to be reported. Giglioli reports the virtual extinction of *Anopheles darlingi* and the almost complete eradication of malaria in British Guiana, by means of residual DDT spraying of dwellings as the only control measure. Gabaldon reports on the great reduction in malaria in Venezuela with a concurrent reduction in the general death rate and an increase in the birth rate in the past five years. Pinotti also reported that in Brazil the operations of the National Malaria Service have been so encouraging that eradication of malaria from Brazil may be achieved eventually.

Rao has reported on an interesting facet of control in the Eastern Province of Afghanistan. Malaria was effectively controlled in a hyperendemic area by residual DDT sprays in the houses, even though the population largely slept out doors. The local vectors are *Anopheles culicifacies* and *A. superpictus*.

Downs and Bordas have also reported excellent results in the endemic area of Xochimilco-Mixquic at an elevation of 7400 feet in the Valley of Mexico, using DDT residual sprays. Parasite rates have dropped to nothing and the spleen rates were greatly reduced.

An important conference on malaria in Africa began on November 30, 1950 at Kampala, Uganda. This was reported in Technical Report Series No. 38, "Malaria Conference in Equatorial Africa," by WHO in April, 1951. Among the subjects discussed by some sixty experts from various parts of the world were: the distribution and prevalence of malaria in Africa; the species of *Plasmodia;* the species of vectors; the economic importance of malaria; and methods for its control.

A valuable tool in the diagnosis of malaria (Nat. Inst. Health Bul. 180—Microscopical Diagnosis of Malaria) has been revised and brought out as a second edition.

Considerable work continues to be done on the plasmodia of birds, rodents and monkeys. Although not of immediate practical applicability, the study of these parasites and their relations to both host and vector may ultimately produce data of fundamental value in human malaria. Such studies deserve continuance and encouragement.

The problem of myxomatosis in rabbits continues to excite interest in Australia. The mosquito vectors appear to be fairly well defined, but there is a definite question as to whether this disease can be safely encouraged as a means of reducing the rabbit population, if there is a chance that virus encephalitis may be increased in the human and equine population. A report from W. C. Reeves on this problem is expected in 1952.

Additional experiments tend to further incriminate *Culex tritaeniorhynchus* as a vector of Japanese B encephalitis, but there appear to be many factors in the transmission of the disease still unsolved.

Very little of significance as to either yellow fever or filariasis occurred during 1951.

Research is particularly needed in the field of insect physiology, partly to explain the mechanism of DDT resistance in general, and also to explain the difference in the rate of acquisition of resistance between *Culex* and *Aedes* species on the one hand, and *Anopheles* on the other. In the long run we may find that true research in general insect physiology, as contrasted with technical investigations directed only against the immediate problem, may prove to be more valuable in providing an ultimate answer to some of the present problems.

In the field of chemistry there appears

to be an opportunity for the development of a potent insecticide which is radically different in its chemical structure from the chlorinated hydrocarbon group of which DDT is a type, and with much less toxicity to warm blooded animals than the organic phosphate group (Parathion, etc.). Such an insecticide could be substituted for the DDT group when resistance to the latter has developed to an appreciable degree.—HAROLD F. GRAY.

Significant Contributions to the Chemical Control of Mosquitoes in 1951

Numerous papers were published during 1951 that presented useful information on the chemical control of mosquitoes. Any attempt to summarize such a large amount of data must, because of space limitations, omit some rather significant papers and details. This summary will include only the references in which results are given on new and uncommonly used techniques, equipment, or materials. Also data will be included for species for which information is either meager or not in the literature.

LARVICIDES: Immediate Control.—Ginsburg compared allethrin and pyrethrins in both colloidal water solutions and in oil emulsions with laboratory tests against *Aedes aegypti*. He found that against larvae the pyrethrins were two or more times more toxic than allethrin. He noted no material increase in the toxicity of allethrin when synergists were added. Kinsey with field tests in New York State found that it was necessary to apply DDT in oil or in emulsion form weekly to polluted water around a public dump to control the *Culex* larvae. One treatment with chlordane emulsion lasted three months and two treatments lasted from May to October. Trapido made field tests with *Anopheles claviger* in Sardinia and the mainland of Italy. He found that the amount of DDT required to kill 95 per cent or better of the larvae was one part in 10 million parts of water or about one-twentieth the amount needed for *Anopheles quadrimaculatus*. He also found that after about four years of intensive treatments in Sardinia that *A. claviger* was no more resistant to DDT than this same species from the Italian mainland.

Soroker made a series of tests against *Culiseta incidens* with emulsions of a number of the newer organic insecticides. Heptachlor, aldrin, parathion and a DDT emulsion with Lethane 384 used as a solvent were all superior to DDT.

REPELLENTS: Skin applications.—Applewhite and Cross presented data to show that dimethyl carbonate and propyl N,N-diethyl succinamate were the most effective of a series of repellents tested in Alaska. Travis presented laboratory tests on the 30 most effective repellents out of 4,313 tested against *Anopheles quadrimaculatus*. This anopheline was difficult to repel. Only four materials, p-isopropoxybenzaldehyde, alpha-amylcinnamaldehyde, methyl beta-diethylaminocrotonate and N-amyl succinimide were effective for as long as three hours. Dimethyl phthalate was the only one of the commercially available repellents that was sufficiently effective to be included with the top 142 materials. *A. punctipennis* and *A. freeborni* were repelled for much longer times, and *A. gambiae, A. albimanus* and *A. aquasalis* for shorter times, than *A. quadrimaculatus,* with the same materials. Travis and Smith summarized the available data on 14 repellents and on 12 mixtures that are deemed safe to use on man. Data are presented for several *Aedes* species and for *Anopheles quadrimaculatus*. The three most promising chemicals against *Aedes* species were propyl N,N-diethyl succinamate, Repellent 6–12, and dimethyl carbonate. Against *Anopheles quadrimaculatus* only dimethyl phthalate was outstanding.

Clothing applications.—Smith and Cole conducted laboratory tests against *Aedes aegypti* and *Anopheles quadrimaculatus,* and field tests against *A. taeniorhynchus* and *A. sollicitans*. In the laboratory 2,4-nonanediol, N-butyl-1,2,3,6-tetrahydrophthalimide, 2-butyl-2-ethyl-1,3-propanediol, dimethyl phthalate and Repellent 6–12 were effective 8 to 20 days. The best material, mixture M-1960, was effective for

30 to 31 days. The mixture contained equal parts of 2-butyl-2-ethyl-1,3-propanediol, N-butyl-acetanilide and benzoate. Applewhite and Cross found that in Alaska their most effective material was 2-[2-(2-ethylhexyloxy)-ethoxy] ethanol.

Special studies.—Sarkaria and Brown describe a technique for testing repellents against mosquitoes by an olfactometer method. The method was designed to test the correlation of vapor pressure with repellency. It was concluded that repellency of compounds could not always be correlated with vapor pressure.—B. V. TRAVIS

Control—Adult, Larvae and Pupae

BIOLOGICAL CONTROL. The annals of mosquito control are well documented concerning the value of surface feeding fish as predators of mosquito larvae. Of the large number of invertebrate parasites and predators of mosquitoes relatively few reports are available. It is well known that many insects, mites, nematodes, coelenterates, and protozoa attack mosquitoes. However, only in a few cases are the parasite or predator-host relationships fully understood. Perhaps equally important and even less understood are the diseases of mosquitoes caused by fungi, bacteria, and viruses. Little has been published on biological agents during the past several years.

PHYSICAL CONTROL: Water Management. In view of the fact that some species of mosquitoes are showing resistance to the chlorinated hydrocarbon insecticides, water management may regain the popularity it held prior to the advent of DDT. One of the most thorough evaluations of water management and the ramifications connected therewith presented in 1951, was given in a symposium in the Proceedings of the 38th Annual Meeting of the New Jersey Mosquito Extermination Association. The symposium consisted of the following: "Introductory Statement," by L. A. Stearns; "The Relationships of Water Management and Drainage to Other Forms of Mosquito Control," by D. M. Jobbins; "Water Management and Drainage in Open Salt Marsh Areas for Mosquito Breeding Control," by Fred A. Reiley; "Mosquito Control on An Enclosed Salt Marsh," by George E. Powers; "Fresh Water Swamps with Reference to Surface Drainage," by Robert L. Vannote; "Water Level Management for the Control of *Anopheles quadrimaculatus* in the Tennessee Valley," by T. F. Hall.

Each participant in the symposium reviewed the particular problems involved in his area. In summarizing the entire discussion on water management, it becomes apparent that when properly done, it destroys mosquito breeding in areas where other less permanent measures are impractical or too costly. It was also emphasized that installations for controlling water if properly planned and executed will last for considerable periods of time.

After a few observations of the hazardous effects of chemicals, one realizes the importance of water management on the preservation of the natural environment.

GENERAL. a. Organization and Administration. During the past year several papers were presented on the organization of mosquito control or abatement districts. The general tone of these discussions was the re-evaluation of the organizational setup. The legal obligations of a mosquito control commission or abatement district were stressed.

b. Limitations in Use of Methods. Economics appears to be the chief limiting factor in the prosecution of control activities based on many different reports from the various sections of the country. High labor and material costs have made it necessary for many agencies to adopt less costly methods at the sacrifice of efficiency. In some areas of the country, labor was exceedingly scarce. In order to carry out the bare essentials unskilled and inexperienced labor had to be used. This has apparently led to more mechanization with simplified equipment.

c. Hazards. 1. Wild Life. Although it has been recognized that the synthetic organic insecticides presented a hazard to certain forms of wild life, most of the research has been associated with agricultural and forestry operations. In 1951, Springer and Webster (Mosq. News Vol. II, pp. 67–74) report large scale experiments conducted on salt marsh areas in which varying dosages of DDT were used. In general, their studies show that considerable damage to fish and crabs resulted at dosages of 0.5 pounds or more per acre. Birds showed little or no direct effects of the spray.—BAILEY B. PEPPER.

Outline of Research Needed in Advancing Knowledge of Mosquitoes and Their Control. (Biology)

BIOLOGY SUBDIVISIONS.—a. *Ethology:* life history under natural conditions. 1. Habits of post-embryonic stages: eggs, larvae, pupae. 2. Habits of adults: emergence, phases of behavior at different adult ages, active and passive periods, resting places, copulation, migration, swarming, food (bloodmeal and other natural food), longevity, oviposition.

b. *Ecology:* the animal in its relation to the environment. 1. Synecology: as a part of a biocoenose. 2. Autecology: as a reactor to external factors. Simultaneous studies of microclimatic conditions in the habitat and reactions in the laboratory of all stages; main factors to consider—temperature, humidity (eggs and adults), salinity, pH, food, parasites, predators, population studies. Preference: activity as influenced by different factors.

c. *Physiology:* the understanding of the biological mechanisms of the animals. 1. General indicator: respiratory metabolism. 2. Biochemical aspect: osmoregulation of aquatic stages, digestion, enzymatic and hormonal influence, reproduction, ecdysis, diapause. 3. Reflex biology: taxis, basic reflexes, chain reflexes, "Instinct-Dressur-Verschrankung," appetite behavior, plasticity.

d. *Technique:* proper methods and tools. Collecting, sampling, microclimatological methods, physiological methods, statistics.

EXAMPLES. Any subject could be approached in all four (a to d) ways, above, e.g.: 1. A student of the larval biology of *Aedes sollicitans* may work out actual findings in the field (a), mortality and length of stages at different salinities (b), the osmoregulatory mechanisms (c), or find a new method to determine chloride content of water (d).

2. An investigation of resting places of *Aedes taeniorhynchus* would produce findings elucidating the general ethology of mosquitoes (a), microclimatic factors in autecology (b), possible metabolic rhythms (c), and probably giving a clue to new sampling techniques (d).

3. A study of the food habits of *Mansonia perturbans* would throw light on activity and flight rhythms (a), the relation of adults of this species to the flora as a possible direct source of food or as a habitat for warm-blooded vertebrates yielding blood food (b), the role of metabolism in orienting the movements of the adults (c), and conceivably a new statistical approach to the problem of establishing true food preferences (d).

4. The establishment of an insectary colony of *Psorophora confinnis,* or any species for that matter, would assuredly yield much biological information beyond merely adding new techniques. Almost all subdivisions of the outline could be advanced by the proper interpretation of observation incident to the successful establishment of such a colony.

(Examples of problems)

A. TAXONOMY AND MORPHOLOGY.—Problem: Search for improved method of separating *Culex* group. Definition of complexes if such exist. Ex. *pipiens—salinarius.*

B. BIOLOGY AND ECOLOGY.—Problems: (1) Thorough study of U. S. eastern *Culex.* Biting habits, necessity of blood meal for reproduction. Influence of humidity and temperature on movement and urge to enter dwellings. (2) Clarification of alleged ability of *Aedes cantator* to breed in fresh water. (3) Biology of mosquito ova. Study of conditions required for hatching eggs of salt marsh *Aedes* species. (4) Flood water mosquitoes—oviposition site preferences. Why, if any?

Are entire marshes seeded for margins only? Do salt marsh margins produce heavily because conditions for hatching are more frequently favorable? Factors affecting selection of oviposition site of *Wyeomyia smithii.* (5) *Mansonia perturbans.* Biology with reference to distributions in a "favorable" marsh; attachment preferences of larvae; larval food preferences; larval migration; completion of general life history, especially chronological development of overwintering larval stages. (6) The relationship between mosquito habits and the development of insecticide "resistance," resting and flight habits with regard to accessibility of mosquitoes to insecticide applications. (7) Techniques—colony rearing of *Aedes sollicitans* and other species in study of biology and potential disease vector significance.

C. MOSQUITOES AS DISEASE VECTORS.—Problem: Survey of *Aedes sollicitans* and *Culex pipiens* and other common species for presence of certain viruses.

D. CONTROL.—Problems: (1) Mosquito ovicides, an open field. (2) Study of the effect of certain insecticides applied for mosquito control on plankton and food organisms of mosquito larvae and associated aquatic life. (3) Chemical residues in soil of areas treated to suppress mosquito breeding and their effect on the biological balance of marshes. (4) Further observations on the effect of chemicals used for mosquito control on wildlife, fish, birds, shellfish. (5) Insecticide "resistance." Is rotation of dissimilar chemical toxicants in formulations an answer? (6) A reexamination of predaceous fishes and their management for mosquito control on tidewater meadows. (7) New sampling procedures and equipment for evaluating mosquito prevalence and movement. (8) Reexamination of the potential use of fungi, bacteria, etc., in the control of mosquitoes. (9) Many equipment needs—and exploitation of possible techniques developed for related fields, etc., etc.—ERIK TETENS NIELSEN AND MAURICE W. PROVOST.

All persons interested in mosquitoes and their control should have a reference copy of AMCA Bulletin No. 2, "Ground Equipment and Insecticides for Mosquito Control" before the start of another season. Order from Mr. C. T. Williamson, Suffolk Co. Mosquito Control Commission, Yaphank, N. Y. Price $2.00.

See page 219 for information on next annual meeting, to be held at Daytona Beach, Florida, in April.