PANEL DISCUSSION

WATER RESOURCES PROJECTS IN RELATION TO MOSQUITO PRODUCTION AND CONTROL

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Construction, operation, and maintenance of proposed and existing water resources projects can be planned so as to prevent or reduce vector problems and the risk of vector-borne diseases. A few water resources projects have had beneficial effects of reducing mosquito-producing habitats, but many serious mosquito and other vector problems have been created by most types of water resources developments throughout the world. Mosquito control agencies, universities, health departments, and private citizens need to become involved in evaluating the potential effects of proposed water resources projects upon mosquito and other vector populations. Unfortunately, most water resources project planners are not trained to think about such potential effects, and the public disclosure laws of recent years have provided means of preventing undesirable environmental impacts. The panel members have had many years of combined experiences of involvement with the major types of water resources projects that have created mosquito problems. Each was requested to address the impacts of his panel topic on mosquito production and to describe the types of construction designs, maintenance, and water management procedures that have been proven effective in minimizing mosquito populations.

DREDGED SPOILS

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In July of 1975, studies were initiated at The Citadel to determine the national importance of dredged soil disposal sites (also termed hydraulic spoil areas) to mosquito abatement programs. A dredged soil disposal site is defined as an area of marsh or high ground diked off from the surrounding environment for the purpose of retaining a suspension of "spoil." Such sites may vary from a few acres to 4 square miles in the United States.

Following a normal pumping operation, a given dredged soil disposal site will undergo 6–7 definite successional stages. Each stage tends to produce its own characteristic insect fauna. Our research group has postulated that a normal disposal site successional pattern will usually consist of the following sere:

(a) Supernatant Water
(b) Bare Mud
(c) Incipient Fissures
(d) Mature Fissures
(e) Vegetated Fissures
(f) Weathered Fissures
(g) Climax

To determine the mosquito-producing importance of a disposal site, frequent inspections are a necessity. Present knowledge is not sufficient, even with trained inspectors, for reliably classifying spoil sites with regard to their mosquito-breeding potential. It is not uncommon for dredged spoil disposal sites that appear ecologically similar to be vastly different with regard to mosquito production.

The use of dredged soil disposal sites by birds as rookeries poses another problem with respect to the potential involvement of these areas as sites for arbovirus activity. The juxtaposition of the rookeries and the mosquito-breeding habitats is of concern to epidemiologists because of the well demonstrated relationships between nestling birds, mosquitoes, and arbovirus activity amplification.

Basic research studies need to be conducted on the ecology and the control of mosquitoes within these unique, man-made habitats. Until such studies are done, we have every reason to believe that the mosquito problem and the increased potential for vector-borne disease will continue.

IMPOUNDMENTS

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The Tennessee Valley Authority was established by an act of Congress in 1933 to develop the total resources of the depressed Tennessee Valley region. The basic developmental concept was to establish a series of dams and reservoirs on the Tennessee River and its tributaries in order to produce hydroelectric power, to provide flood control, and to provide suitable channel depth for navigation.

Malaria was highly endemic at this time in the Valley with an incidence as high as 30% in some areas. Consequently, in the early conceptional stages of the reservoir construction program, plans were made to include mosquito control as an integral part of each project. Early measures were directed at control of *Anopheles quadrimaculatus*, the vector of malaria in the southeastern United States. The program has been very effective, and no indigenous mosquito-transmitted case of malaria has occurred since 1948.

From this early beginning, the TVA vector control program has evolved, which includes activities to control not only *A. quadrimaculatus*, but all mosquitoes which breed on TVA property or are produced as a result of TVA activities and that are considered a public health or pest problem. The vector control program includes measures to control other types of blood-sucking arthropods, such as biting flies and ticks. The most common permanent pool species of mosquitoes occurring on TVA reservoirs are: *An. quadrimaculatus*, *An. punctipennis*, *Culex erraticus*, and *Cx. territans*. Of the floodwater group, the most common are: *Aedes vexans*, *Ae. sticticus*, *Psorophora varipes*, and *Ps. ferox*. Other species which occur occasionally are: *Ae. atlanticus*, *Ae. trivittatus*, *Ps. confinnis*, and *Ps. cyanescens*. These species are considered to be of only minor medical importance, although several are thought to be involved in the transmission of dog heartworm disease.

Both preimpoundment and postimpoundment measures are employed by TVA for mosquito control on impoundments. Preimpoundment control measures are designed to eliminate or significantly reduce potential habitat and include the following: (1) site survey assessment and appraisal; (2) review of reservoir construction specifications; and (3) making specific recommendations for site alterations during construction, such as deepening and filling, planning suitable marginal drainage, vegetation clearing operations, and establishment of dewatering projects. Actual operations are reviewed on site during the construction phase.

Post-impoundment measures include: (1) continuous monitoring of mosquito populations employing techniques designed to measure adult, larval, and egg densities; (2) the application of approved larvicides and adulticides when population levels reach a nuisance threshold; (3) implementation of an effective water-level management scheme; (4) maintenance of effective internal drainage; (5) marginal vegetation control; and (6) operation of dewatering projects for mosquito control.

IRRIGATION DEVELOPMENTS

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California's topography lends itself well to demands for storage and transportation of water. Irrigation in California is by far the greatest consumer of water, and the trend has been for an ever increasing acreage of land under irrigation and for total water demand. It is projected that by 1990 there will be 10.2 million acres of croplands that will require 38 million acre-feet of water. Most of this irrigated land is in the Central Valley, with supplemental areas in the Coachella, Imperial, and Salinas Valleys.

Significantly, the mosquito control agencies and the irrigation districts occupy the same areas. The area covered by mosquito control programs in California last year was 21,241 square miles, and the budgeted expenditures by these agencies were more than $8 million.

Encephalitis is endemic in the irrigated areas of California and occasionally occurs in epidemic proportions. It has been shown that irrigation provides favorable habitats for the mosquito vectors and for the bird reservoir-hosts of arthropod-borne viruses, and irrigation developments result in concentrating human populations near the habitats of virus activity. Three cases of indigenous malaria occurred during 1974 in the vicinity of Marysville, California. The malaria cases were shown to be directly associated with mosquitoes that were produced in irrigated fields.

One must be prepared to work with a multiplicity of governmental and private entities to implement programs of mosquito prevention or control in irrigated areas. Even in a straightforward activity such as providing water to farmers for irrigation and providing drainage of excess water, there is a hierarchy of governmental levels involved. Mosquito habitats associated with off-field irrigation water include improperly designed drop structures, off-grade culverts that strand water on the uphill side or scour a hole that will hold water on the downhill side, standpipes, blockage of lateral drainageways by canals or ditches, a rising water table, siphons, roadside ditches, and railroad borrow areas. On-field mosquito-producing problems are often caused by uneven fields that hold water and the application of excess water. Other features that need to be considered in the proper irrigation of fields to avoid mosquito problems include proper field layout with appropriate length of check and head of water, smoothing of fields to prevent low spots, variations in flow of water in supply canals, variations in the rate of percolation into the soil, plant requirements, leaching requirements, the physical characteristics of the soil, the amount of moisture that will be held within the root zone of the plants, mechanical difficulties with water control structures, and accidents.

Expenditures for mosquito control can be kept at a lower level in irrigated areas if certain preventive measures are placed in effect at the inception of a system. In addition to field preparation already mentioned, property lines could follow natural contours reducing problems of water supply and drainage, ditches and canals should be constructed with V-shaped inverts to concentrate low flows of water, canals and ditches should be lined to prevent seepage, borrow areas and roadside ditches should be made self-draining, and provision should be made for alternate drainage of areas in which existing drainageways are changed.

Solutions to mosquito problems in irrigated areas require not only the application of technical knowledge but also implementation of correct approaches through negotiations with land owners, associations, and several layers of governmental entities. Planned irrigation water and land management promise a threefold benefit: improvement in crop production, conservation of water, and reduction of mosquito populations.

WETLANDS

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For nearly 50 years a cooperative program has developed for wetlands management for mosquito abatement on the southeastern shores of the Great Salt Lake. The initial work was conducted by the Salt Lake Mosquito Abatement District and the Biology Department, University of Utah. The need for water management on these wetlands is evident from the report given by Dr. Don M. Rees in 1930 concerning these wetlands. He stated, "The serious trouble caused by the gun clubs is from diverting of water and flooding large tracts of land. The dikes and dams constructed for this purpose are often neglected and water permitted to stand for weeks in shallow grassy pools. This type of neglect on the part of the gun clubs is unnecessary and should not be tolerated."

In the ensuing years a great deal of effort has been put into a program designed to assist in the development of beneficial use of water and to seek the support of water users in preventing the misuse of water that creates habitats in which mosquitoes are produced. It was first necessary to convince water users that the mosquito abatement district was not in competition for ownership of water from draining lands. Members of the Utah Mosquito Abatement Association also have continuously worked and conferred with the representatives of other agencies and with individuals engaged in, or concerned with, the use of water on the mosquito-producing marshes along the shores of the Great Salt Lake.

In the Great Salt Lake area, improved marsh habitat for wildlife, increased agricultural crop yield on higher ground, and effective control of mosquitoes and other insect pests have resulted from improved water management practices, modifications of shore lines, and more effective use of predator fish. The better water management methods include confining water to impoundments where depth and flow can be regulated. The shore line modifications include removal of saltgrass margins by providing well-graded, abrupt banks at the margins of impoundments. The use of predaceous fish (*Gambusia affinis*) also was effective in reducing populations of mosquito larvae where conditions are suitable for their use.

CONSTRUCTION PRINCIPLES

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Early in the century, increased malaria transmission was frequently observed in areas of irrigation systems, impoundments, colonization projects and farm-to-market or national transportation routes. Studies showed that increases in vector densities and disease could be attributed to the existence of man-made nurseries for propagation of mosquitoes which were created during construction of such projects. Since the investigations also showed that problems of man-made malaria could be minimized, regulations for the prevention and control of mosquitoes on impounded waters were developed and subsequently adopted by many southeastern states and several foreign governments.

Interest in man-made malaria waned in the United States with progressive reductions of the disease and its eradication. In other areas of the world, problems of man-made malaria received limited attention following widespread acceptance in the mid-fifties of the concept that malaria could be eradicated in 3 or 4 years by residual insecticides.

Recently, however, there has been a worldwide revival of interest in man-made malaria because of failure of the residual insecticides to be either universally effective or applicable and because of the accelerated construction of water resource development projects in countries throughout the world. There is now evidence that some of the developmental projects in the Americas have had significant effects on malaria transmission. In some cases these have caused reverting of populations to the attack phase from the consolidation phase in malaria eradication programs; in other cases outbreaks of malaria have been observed among relocated populations where considerations of site selection were ignored.

Basic principles and practices for prevention and control of man-made malaria resulting from construction of (a) impoundments, (b) irrigation systems, (c) land reclamation and colonization projects, and (d) roads and railroads were referred to briefly. Inherent in the principles is action to be taken by health agencies while projects are being planned, designed, and constructed to permanently prevent or control mosquito production.

PLANNING

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The need for planning to avoid mosquito problems associated with water resources projects is obvious to the members of the American Mosquito Control Association; however, agencies such as the U.S. Army Corps of Engineers, the Soil Conservation Service, and the Bureau of Reclamation may not recognize this need. There is no specific legislation requiring them to do so, and potential mosquito problems and the associated risk of mosquito-borne diseases often are low on the list of priorities of agency planners when compared to other project goals.

The relationship between mosquitoes, mosquito-borne encephalitis, and water resources projects was clearly illustrated by plotting the distribution of human and equine encephalitis cases during 1975 in Colorado and Montana against the distribution of irrigation schemes in these states. The presentation of data such as these to project planners may encourage those agencies mentioned above, and others, to seriously consider potential vector mosquito problems when planning future water resources departments.

Federal legislation, such as the Water Resources Planning Act of 1965 (P.L. 89–80), which resulted in the development of the "Principles and Standards for Planning Water and Related Land Resources," and the National Environmental Policy Act of 1969 (P.L. 91–190), provides opportunities for planners to consider vector mosquito problems in connection with water resources developments. The Council on Environmental Quality's current "Guidelines" (August 1973) for preparing environmental impact statements in compliance with PL 91–190 does not, however, specifically indicate the need to consider potential impacts of proposed projects upon mosquitoes, other vectors, and vector-borne diseases. The "Guidelines" are revised periodically, and action is being taken in an effort to correct this oversight in future editions.

The Public Health Service Act, as amended by Public Law 93–461 (Jan. 4, 1975), added Title XV concerning national health planning and development. The Center for Disease Control (CDC) has submitted a statement to be considered for inclusion in the guidelines concerning national health planning policy. It recommends that standards concerning surveillance, emergency control of vector-borne disease epidemics, and a national policy providing for planned construction design and subsequent management of water and related land resource developments be formulated and implemented.

The Committee on Vector Control of the Water Resources Council is developing guidelines and criteria for planning vector and vector-borne disease prevention in relation to water resources projects. To facilitate such planning, the Water Resources Branch of the Vector-Borne Diseases Division, CDC, is undertaking a pilot study to determine whether remote sensing data obtained from earth satellites can be used to differentiate and to measure mosquito habitats associated with water resources projects.