PRESENT STATUS AND FUTURE POSSIBILITIES OF BIOLOGICAL CONTROL OF MOSQUITOES

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It is indeed unfortunate that so many investigators deserted the field of biology when extremely effective insecticides were developed beginning about 1945. For some strange reason the idea arose almost universally among entomologists that insecticides such as DDT, benzene hexachloride and others were so very effective in the control of insects that it was unnecessary to be concerned in any way with the biology of the insects.

Some of this attitude came into being in the 1920's when paris green was found to be so effective against anopheline mosquitoes. The literature contains thousands of references prior to 1945 dealing with all kinds of naturalistic or biological control of mosquitoes (Bates, 1949; Boyd, 1949). Yet today one not only finds a rather minimum utilization of these control measures but likewise the literature pertaining to the biological control of mosquitoes has almost completely disappeared from our scientific journals.

For the purpose of this discussion, it will be necessary to exclude reference to chemical control for the direct control of mosquito larvae and adults. Likewise it will be necessary to exclude discussion on the use of indirect control for mosquitoes such as the alterations of environmental conditions by the use of herbicides; and the use of water management as related to the removal of water either by drainage or by fills. Papers on these subjects are filling our literature today and certainly everyone is aware of their possibilities. Therefore, there is no need to do more than refer to them. If all such items are excluded what is left to discuss? There are left at least three main topics: (1) environmental control, (2) predators and (3) parasites.

ENVIRONMENTAL CONTROL. Environmental control here will include only such procedures as fluctuating water levels, making use of wave action, altering the chemical composition of water and the utilization of plants. All of these procedures have been used in the past to limit the size of mosquito populations and some are being used at least in a minor way today.

Fluctuating Water Levels.—The best example of water level fluctuation is the program of *Anopheles* mosquito control used by the T.V.A. in their water impoundments. Certainly everyone must be aware of their method of controlling the water level of the artificial lakes with the outlet gates on the impoundment dams. Perhaps the main benefit of the fluctuation is that the shore-line debris can be stranded on the shore. Also the water line can be lowered below the line of emergent shoreline vegetation. Without the protection of the debris and the emergent vegetation the larvae cannot survive.

Wave Action.—The failure of the larvae to survive in the T.V.A. water impoundments is to a large part due to the inability of the larvae to withstand wave action. Wave action breaks the contact of the larvae with the air so frequently that the larvae drown.

In many communities the shore lines of the lakes and ponds are carefully prepared to discourage emergent vegetation, thus exposing the mosquito larvae to wave action. In Orlando, Florida, for instance where there are more than 30 lakes within the city limits, few mosquitoes are produced largely because of the clean shore lines.

Locally, here and there throughout the world, use is made of wave action either by clean shore lines or by arranging drain pipes into ponds so the outlet end is several feet above the water level of the pond. The water then falls on the surface of the pond instead of flowing in more gently along the shore. The falling water creates wave action that prevents mosquito production.

Altering Chemical Composition of Water.—It is well known that some species of mosquitoes cannot tolerate salt water. On the other hand, other mosquitoes do not consistently produce large numbers if the salt is absent. The principal group where the manipulation of the salinities has given considerable control has been in the anophelines. There have been limited areas where it has been possible to open up freshwater lagoons or marshes to tidal waters. As the salinities of the water in these marshes and lagoons became greater the mosquito species that could tolerate the salt were gradually excluded. Granted of course that it was common for species that tolerate salt to move into the same areas and to produce undesirable numbers of mosquitoes, what has happened is that the species that have moved in are not as important in the transmission of malaria as the species that have been excluded. Therefore, even though the total number of mosquitoes is not lowered, the disease problem has been reduced.

Here and there in the literature one finds another water manipulation method for the control of mosquitoes. This is the pollution of water, particularly in small ponds and small marshy spots. The pollutions render the environment unfavorable for the producing of the anopheline species. Here again most of the attention has been directed at the control of malaria-bearing mosquitoes. As is well known, many mosquito species favor polluted waters for development, and enormous populations can result. The pollution has been created mostly by dumping into the water various plant materials such as grasses, logs and leaves. Such pollutions are not particularly undesirable from a public health point-of-view. Naturally, pollutions with garbage and sewage that might create health hazards would not be desirable.

Utilization of Plants.—The utilization of plants to control mosquitoes is somewhat limited, but if one has the situation that fits the control procedure it is quite satisfactory.

It has been well known for many years that some species of *Anopheles* prefer water that is well exposed to sunshine. This is particularly true for species whose larvae occur along the margins of slow moving streams. Good control of these species has been effected by encouraging the natural growth of plants, or by planting shrubs and trees to shade the margins of the streams. Shading in this way makes the environment unsatisfactory for mosquito larvae, thereby reducing the production of mosquitoes.

Some mosquito adults prefer either shade or sun, and there are more shade-loving that sun-loving species. This means, as shade is increased, the mosquito population is increased. The increase of shade does not increase the mosquito production, but does improve the harboring places. The shrubbery around the home thus gives mosquitoes protection from the wind and may increase the local mosquito problem. This problem can be alleviated by trimming the shrubbery high to allow air circulation and likewise by not plant-

ing the thick low growing types of shrubbery.

Some aquatic plants control production of mosquitoes by covering water surface so completely that there is not enough surface to accommodate large populations of mosquitoes. Plants such as duckweed and water-fern may completely cover the top of the water. Also in certain environments it is not uncommon to find floating algae growing in such dense and large mats that the mosquito larvae have only a limited suitable environment.

The *Mansonia* mosquitoes should not be forgotten in a discussion on the relation of plants to mosquito production. The presence of suitable host plants for the larvae to use for attachment and for their oxygen supply are necessary for such mosquitoes.

A few years ago many articles appeared on plants that capture and kill mosquito larvae. Only one of these plants, the bladderwort, *Utricularia,* has received a great deal of attention. The bladderwort is an aquatic plant that has small bladders on the leaves in which mosquito larvae are entrapped and digested. No one has presented satisfactory evidence that these plants can control enough mosquitoes to be of any great value.

A great many people think that there are plants that are toxic or that produce substances that make the water toxic to mosquito larvae. There is a considerable amount of literature concerning the plant *Chara* which is said by some to produce a water environment unfavorable for mosquito larvae. Some claim that it produces so much oxygen that the larvae are killed. There is no uniform agreement among the specialists that this is actually so. In fact, one may find large mosquito populations growing in ponds containing a considerable amount of *Chara.*

There may be at least one exception. As you have heard for the past several years, some of the workers in California have been investigating the use of blue-green algae for the control of mosquitoes in rice fields. Their studies are as yet incomplete, but they seem to have considerable evidence that blue-green algae in some way, and they think in a toxic way, render the water unsuitable for the mosquito larvae.

What seems to be a constantly reoccuring folktale is that some plants are repellent to adult mosquitoes. In every community there is at least one plant said, by some local inhabitant, to repel mosquitoes. For instance in Florida, a number of years ago an investigation indicated that there were no mosquitoes on one of the Keys. The reason given was that the dodder or lovevine which was very abundant there was repelling the mosquitoes. Unfortunately, it was later noted that the other Keys also had dodder *and* mosquitoes. It has been found in all similar cases that there were factors other than the plants themselves responsible for the absence of mosquitoes.

PREDATORS. Many members of the animal groups are predaceous on mosquitoes' eggs, larvae, pupae and adults. Hinman (1934, 1934a) surveyed the literature very completely and published a list of the various predators of mosquitoes, and included a large bibliography. If one would look into the literature during the period 1900 to 1934 he would find not only numerous titles regarding the use of predators for mosquito control, but he would also find sizable bulletins and published papers in the scientific journals telling of the merits of predators for mosquito control, and particularly on the use of fish. Of the predators, only fish are being used by man for mosquito control, but their use has been greatly reduced since the introduction of DDT.

PARASITES. Parasites have been investigated to a less degree than have the predators. In 1927 Speer published an extensive list of the parasites of mosquitoes. There have been no promising additions since that time with the exception possibly in the protozoa.

The various parasitic organisms that we might be concerned with in mosquito control would be fungi, bacteria, viruses, protozoans and helminths.

Of the microorganisms, fungi, bacteria and protozoa reported from mosquitoes, probably only the protozoa belonging to the microsporidia are actually killing any appreciable amount of mosquitoes. There are a few records of parasitic helminths or worms, but the only ones of any interest at all are nematodes.

THE FUTURE OF BIOLOGICAL CONTROL. The title of this discussion is also concerned with the future possibilities of biological control of mosquitoes. Some comments and predictions will be made concerning the various biological control categories previously mentioned.

Some of the newer aspects of biological control may indeed be found useful. Certainly there is no known single cure-all for mosquitoes. Thus the mosquito control supervisors must use all the methods that will fit their particular circumstances.

Environmental Control.—It is expected that even greater use will be made of water level fluctuations and wave actions for mosquito control.

Altering the salinity or pollution of water will certainly receive continued use in the situations where the methods are applicable. I would consider the possibilities quite limited. In the water areas that are large in size such as large marshes, one could hardly expect to control the pollution of the water sufficiently to give satisfactory mosquito control to a community. That is, of course, assuming that the species are susceptible to the water pollution method. The same is true of altering salinity.

The use of plants for shade along stream margins can have some bearing on the control of populations of mosquitoes. Although not a means of reducing the production of mosquitoes, it is going to prove worthwhile to plan the landscaping around homes to reduce the harborages of mosquitoes. Except, perhaps, where the breeding area is limited, mosquito control cannot be materially affected by plants. Another exception may also prove to be in the use of blue-green algae which may prove practical at least in rice fields.

Predators.—Of all the predators, perhaps only fish will continue to be most useful, largely because their populations can be maneuvered by man, they are quite tolerant of a variety of water conditions, and they can be moved to water areas where they are needed. Fish probably cannot be useful in controlling mosquito populations in natural producing areas such as salt marshes or wide marshy areas unless there is some vegetation control. Certainly fish are useful in controlling mosquitoes in small situations like cisterns, barrels, ornamental ponds, small lakes and small ponds. The increased use of fish should be considered for future control although they seldom are the complete answer to mosquito control.

We do of course wait with great interest, the result of the introduction of *Toxorhynchites* into Samoa to control the *Aedes* vectors of elephantiasis (Peterson, 1956).

Parasites.—Probably the most likely place for investigators to concentrate their attention would be on parasites. Everyone is well aware of the microorganisms, the bacteria, the fungi, and the protozoa that do destroy mosquito larvae. These organisms have been found in routine examinations for parasites, but only in rare instances have people investigated the possibility of using the organisms for control. Many similar organisms can now be cultured; and in the future we would expect many more to be cultured. Today, with the big advancements in tissue culture it seems that there is an added possibility that some of the parasitic microorganisms could be cultivated and distributed in mass. Almost everyone is aware of the recent advances in the use of the bacterium causing milky disease for the control of grubs of the Japanese beetles. Likewise, the very spectacular spraying of viruses to control plant feeding insects (Bird, 1954; Dowden and Girth, 1953; Steinhaus, 1949; and Thompson and Steinhaus, 1950).

New experiments with microorganisms are showing us some of the most promising biological control of all times. There

is no reason why some of the micro-organisms may not have an application in mosquito control. At least for the time being, use must be made of all the known methods for control.

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