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It is apparent to one who has been brought up on a farm and who has worked in the fields of mosquito control, fisheries management, and water pollution abatement, that there are some conflicts of interest and methods used in these fields. There are, however, many common interests and areas in which the aims and objectives coincide. All too often in the past, there has been a failure to explore and stress common interests and a tendency to emphasize conflicting interests. Our present age of specialization in training and interest is in part responsible for this situation. In order to advance in a field we must devote almost our full time to that field with the result that we know little of the problems, interests, and values of the other sciences. In this atmosphere we become wrapped up in our own endeavors and we strive for the ultimate in control, production, or yield by all means at hand without due regard to the whole system of values and the general well-being of man now and in the future. Sometimes wildlife interests have placed recreational values above other necessities of life. Agricultural workers have on occasion made yield a fetish and have striven for an ever-increasing yield by all possible means,even though some of them may be harmful to other values and in spite of the fact our problem is now one of over-production. Mosquito control workers have at times used what appeared to be the most effective control method, regardless of its effects on other elements in the biota and without a clear concept of the long range effects of their activities on the environment or the biological balance. In addition, some of those working for the abatement of pollution have striven for goals which are not attainable under our present conditions.

To be really successful in the solution of our control problems we must realize that many of them are really problems of applied ecology. For the most effective control we must work with nature; not against her. Chemical control is a reoccurring process and , in time, it becomes very costly. Control procedures which do not work with nature are always abandoned sooner or later. Biological control is best in the long run and it should be used whenever possible,alone or in combination with chemical control. A knowledge of the life history and the environmental requirements of the organism to be controlled, plus the ecological approach, is basic and essential in any control program . Experience has shown that the surest way, to eliminate a species from an area, is to destroy its habitat. Manipulation of the environment or habitat can be effectively used for the control of mosquito populations. Such biological approaches are often not harmful to other desired organisms, and sometime they may be beneficial.

If chemical control methods are used over a period of time, they may become very detrimental to other members of the biota. In the use of any chemicals, it must be remembered that it is the extremes which are limiting, even if they are of short duration. Conditions must not be unfavorable for survival for even short periods. Since a fish can be killed only once, lethal conditions over a short period can be as effective in destroying a population as such conditions extending over a longer period. In approaching this problem, it must be remembered that conditions, which the individual may survive for considerable periods, may be entirely unsatisfactory for the survival of the species. For example, while certain individuals survived conditions in Nazi Concentration Camps, such conditions were not satisfactory for the survival of the species. For the perpetuation of the species, conditions must be conducive for growth, reproduction, and survival.

The value of the biological approach to control problems has been demonstrated by the TVA experience. After a period of very costly control by chemical methods alone, the approach was changed to naturalistic or environmental control with only emergency chemical control. This resulted in a great reduction in costs and improvement in results. For a number of years the most widely used mosquito larvicide was oil applied at a rate of 15 gallons per acre. When treatment was from a boat a certain percentage of black oil was often used as a marker. Field studies indicated that this method of mosquito control could be quite harmful to water fowl and often resulted in unsightly conditions. Investigations carried out in the TVA area in 1939 and 1940, demonstrated that oiling resulted in a great reduction of fish food organisms, especially those inhabiting marginal aquatic vegetation.

After successful methods were developed for the application of Paris green dusts by means of airplanes, this material was widely used. While there were some indications that this material was harmful to the aquatic biota, no definite conclusions resulted from the TVA investigations of this material. Early in the 1940's the toxicity of these materials when used as mosquito larvicides became largely an academic question as they were displaced by the new chlorinated hydrocarbon, DDT. In 1944, this material began to be widely used as a larvicide and adulticide. Its immediate effectiveness led to its widespread use for many purposes and set the stage for the development of many other synthetic organic insecticides. Previous to 1943, the greatest threat to aquatic life from pesticides was their use for the control of insect vectors of disease, chiefly the malaria mosquito. The advent of DDT, however, was the beginning of a drastic change in the character and scope of the problem of pollution by pesticides. This contact insecticide, with its great toxicity to a wide variety of organisms and its residual properties, completely changed many of the approaches to insect control and the effects of larviciding on the aquatic biota. Chemical control was given a great impetus and many came to believe that the organic insecticides were the answer to all control problems and that basic principles of insect control developed over the years could be forgotten. In many areas the doctrine, "that if a little is good, more is better," was followed and DDT was used for the control of both larvae and adults. As resistance developed in certain forms there was a continual striving for new, more toxic, broad spectrum insecticides. Development of these be true. It has also been found that some of the materials which are generally very toxic to fish are relatively non-toxic to certain of the microcrustacae, whereas, materials which are generally toxic to the latter may be relatively non-toxic to fishes.

As indicated in Table 1, the new organic insecticides are more toxic to bluegills than they are to fathead minnows. This does not hold true for goldfish and guppies as they are usually more resistant to the chlorinated hydrocarbon insecticides. Inter specific differences in toxicity are especially marked among the organic phosphorus compounds. This is especially true for Malathion, which is over 130 times more toxic to bluegills and over 500 times more toxic to Chinook Salmon than it is to fathead minnows. These results indicate that with the new organic insecticides toxicity to fish and safe concentrations for use in water areas cannot be determined simply by carrying out bioassay studies with one species of fish. The toxicity of these materials to all important aquatic organisms must be known before safe dosages for water areas can be established.

Studies made to date indicate that many of the new organic pesticides are extremely toxic to fishes. Guthion, Dieldrin, Toxaphene, and Endrin are especially toxic. Endrin is more toxic to fish than any other substance which has been tested to date in the Public Health Service Laboratory at Cincinnati. It is toxic to bluegills at a fraction of a part per billion. Laboratory bioassay data now available on the toxicity of the new organic pesticides to fishes indicate that, when all fish species tested are considered 96 hour TL<u>m</u> values are below 0.1 ppm for the following materials: Endrin, Toxaphene, Dieldrin, DDT, Aldrin, Chlordane, Lindane, Methoxychlor, Heptachlor, Guthion, Di-syston, Malathion, and Diazinon (6) (9). On the basis of the same laboratory studies, 50 per cent or more of certain fishes will be killed in 96 hours in water areas three feet deep which receive a direct application of 0.5 pound per acre of the following materials: Endrin, Toxaphene, Dieldrin, Aldrin, DDT, Heptachlor, Chlordane, Lindane, Methoxychlor, Heptachlor, Guthion, Malathion, and Diazinon (7) (9) and (unpublished data of FHS). It should be pointed out that laboratory results often cannot be directly applied to field conditions. Further it has been found that DDT is sometimes tied up with soil particles or organic materials and partially inactivated. However, it must be realized that the 96 hour TL<u>m</u> value is the amount which kills half the fish in that stated time. Such concentrations will generally be far from satisfactory for use in actual field operations. Even DDT which appears to be most susceptible to inactivation will kill fish at dosages of 0.1 pound per acre when routinely applied. Further while some of the above listed materials hydrolyze to a certain extent, others will, according to laboratory findings, kill 50 percent of the bluegills present at a very small fraction of a pound per surface acre (Table 2). It is believed that in field operations only a fraction of the amounts here listed can be routinely used with safety to aquatic life.

These findings indicate that, when the organic pesticides are applied to land areas at dosages usually used, great care should be exercised to insure that they do not drift onto water areas. Further when they are applied directly to water areas dosages must be very small. In mosquito control operations it appears desirable to give preference to those materials which are not so toxic to aquatic life. In the future it would seem desirable to direct our research efforts toward the development of specific toxicants which can be used to control a pest species without significant harm to other members of the biota.

In many instances biological methods can be used effectively for the control of mosquitoes. These methods are usually compatible with wildlife management and some of them are distinctly beneficial. Diked and dewatered areas which are subject to reflooding in the fall can be effectively managed for water fowl feeding areas without decreasing their effectiveness for mosquito control. Controlled burning for the elimination of coppice and floatage in the fluctuation zone of reservoirs is effective, not only for mosquito control but, also, for the production of duck food plants. When coppice is not controlled duck food plants are largely eliminated from fluctuation zones. The maintaining of high constant pool levels in spring and early summer is beneficial to the fish spawning and the survival of fry especially of black bass and other Centrarchids. It also benefits mosquito control by preventing the growth of unwanted semi-aquatic and marsh vegetation. Shore line clearing and maintenance for mosquito control is also a benefit to boating, swimming, and water skiing. The drainage of pot holes and low areas in the fluctuation zone promotes fish migration and prevents the stranding of fish at low water periods. The control of lotus, water hyacinth, alligator weed, and certain other plants in connection with mosquito control operations is also beneficial for fish production as the yield of fish food organisms is limited in such areas and fishing is difficult. From these few examples of common interest, it is apparent that wildlife and fisheries managers and mosquito control operators have many common interests and objectives. If this is realized and they work cooperatively in these areas, it will be much easier to resolve areas of conflict for the benefit of all groups.

Summary and Conclusions

Mosquito control by means of chemicals is a repetitive process which in time becomes very costly and may result in great harm to other members of the aquatic biota. For effective control, it is essential to work with nature. Biological control through the manipulation of the environment is the cheapest and best method where it can be effectively used. Often biological and chemical methods can be efficiently combined. Manipulation of the environment by ditching, drainage, dredging, and filling, diking, and dewatering, burning shore line cleaning, coppice and water weed control, and water level management can be effectively used for mosquito control and wildlife and fisheries management.

When chemical control methods are used, the minimum amount essential for adequate control of the mosquito in question should be determined and field applications should be limited to that dosage. If this amount results in significant kills of other important members of the biota, consideration should materials has been phenomenal. In 1943, there was only one synthetic organic insecticide on the market. In 1955, there were over 100 different materials being used commercially, and these were available in thousands of different formulations. From 1940 to 1950 there was a threefold increase in the use of insecticides; from 1950 to 1955, the amount used doubled again; and since that time has almost doubled again.

With exception of DDT, which has been extensively studied, very little is known of the toxicity of these materials to the aquatic biota under a variety of field conditions. Much study is needed in order to determine the minimum amount needed for mosquito control and the effects of this amount on other organisms in the biota. Extensive investigations are also needed to determine materials, formulations, methods, and frequency of treatment which are the least toxic and are not significantly detrimental to other organisms of importance in the biota.

Studies carried on by the Public Health Service at Savannah, Georgia, during the period 1945 to 1949 were designed to determine the effects on aquatic life of routine applications of DDT as used in actual malaria control operations. On the basis of these studies (1) (2) (3), it was recommended that, for malaria control, hand applications of DDT should not exceed 0.05 pound per acre. The latter dosage is larger because in airplane treatment only a fraction of the material released reaches the water surface when limited areas are treated.

It was found that the character of the area treated was of great importance in determining the toxicity of the applied DDT to aquatic life. In a shallow, sand-bottom pond having little organic matter there was a significant kill of aquatic organisms after 2 treatments at 0.05 pound per acre. However, in a pond having clay turbidity, there was no fish kill after 14 treatments at the rate of 0.1 pound per acre. Generally kills were noted after the tenth treatment at 0.1 pound per acre. Analysis of bottom materials from treated ponds indicated that DDT is absorbed or inactivated by soil particles and organic debris. Subsequent studies with Toxaphene and Dieldrin indicate that, either these materials are not inactivated by the soil, or the dosage used was such that the capacity of the soil to absorb and inactivate them was exceeded.

It is unfortunate that extensive field studies, such as were carried out with DDT, have not been made with other organic insecticides which have appeared subsequently. Bioassays of the more important synthetic organic insecticides (4) (5) (6), indicate that several of them are considerably more toxic than DDT to certain fresh water fishes (Table 1). As indicated by $TL_{\underline{m}}$ values reported by the PHS (7) (8) and summarized in Table 1, the organic phosphate compounds are, with a few exceptions, considerably less toxic to fishes than are the chlorinated hydrocarbon insecticides. It has been found, however, that certain species cannot be generally labelled as resistant or sensitive. Resistance and sensitivity varies for the same species with the material under test. For example, a species which is resistant to one material may be very susceptible to another, whereas, with another species the reverse might be given to the use of other materials less toxic to other aquatic organisms even though they may be less effective for the control of the pest species.

Materials to be used for mosquito control should be thoroughly tested to determine the dosage, formulation, method of application, and frequency of treatment which are least harmful to the aquatic biota. Most of the new synthetic organic insecticides are very toxic to aquatic organisms and can be safely used only in very small quantities.

Resistance and sensitivity to the same material varies greatly among the different species of aquatic organisms. Further, because an animal is resistant to one compound, it does not necessarily follow that it will be resistant to another. It may be very sensitive. With another species, the situation may be reversed. Sensitivity among fishes to the same material may vary over 500 times. Bioassays with one species are, therefore, not satisfactory for indicating safe levels of a particular material. The toxicity of the material to all important species must be determined. Safe levels of insecticides for routine field application will generally be only a small fraction of the dosage which will kill half the fish in 96 hours.

Research should be directed toward the development of toxicants specific for mosquitoes so small quantities which are not significantly detrimental to other important members of the biota can be effectively used for mosquito control.

Wildlife and fisheries managers and mosquito control workers have many common interests and objectives. If they work together in a cooperative way and come to understand each other's problems, many control methods can be developed which can be effective and beneficial to both interests. Such understanding and cooperative effort will assist greatly in resolving direct conflicts of interest with great benefit to them and the general public.

Literature Cited

(1) Tarzwell, Clarence M.
1947. Effects of DDT mosquito larviciding on wildlife. Part 1. The effects on surface organism of the routine hand application of DDT larvicides for mosquito control. Pub. Health Reports, 62 (15): 525-554.

(2) 1948. Effects of routine DDT mosquito larviciding on wildlife. Jour. Nat. Malaria Soc. 7 (3):199-206.

(3) 1950. Effects of DDT mosquito larviciding on wildlife. Part 5. Effects on fishes of the routine manual and airplane application of DDT and other mosquito larvicides. Pub. Health Reports, 65 (8):231-255.

(4) 1958. The toxicity of some organic insecticides to fishes. Proc. of the 12th Annual Conf. Southeastern Assn. of Game and Fish Commissioners. pp. 233-239.

(5) 1959. Pollutional Effects of Organic Insecticides. Transactions of the 24th North American Wildlife Conference.

(6) Henderson, C., Q. H. Pickering, and C. M. Tarzwell
The toxicity of organic phosphate and chlorinated hydrocarbon insecticides to fish. Trans. 2nd Sem. on Biol. Prob. in Water Pollution. April 21, 1959.

(7) Henderson, C., Q. H. Pickering, and C. M. Tarzwell
1959. Relative toxicity of ten chlorinated hydrocarbon insecticides to four species of fish. Trans. of the Amer. Fish. Soc., 88: 23-32.

(8) Henderson, C., and Q. H. Pickering
1958. Toxicity of organic phosphate insecticides to fish. Trans. of the Amer. Fish Soc., 87:39-51 (1957).

(9) Kimura, S. with Yoshihiro Matida
1958. Study on the toxicity of agricultural control chemicals in relation to freshwater fisheries management No. 1. General summary of the studies on the toxicity of agricultural insecticides for freshwater fishes by means of the bioassay method (Part 1). Bull. Freshwater Fish. Res. Lab., 7:2:51-53.

Table 1 /1 - The toxicity of some organic insecticides to fathead minnows and bluegills as indicated by 96-hour median tolerance limits expressed in parts per million /2.

Organic Phosphates	Fathead Minnows	Bluegills	Chlorinated Hydrocarbons	Fathead Minnows	Bluegills
Guthion	0.093	0.0052	Endrin	0.0010	0.0006
EPN	0.20		Toxaphene	0.0075	0.0035
Para-oxon	0.33		Dieldrin	0.016	0.0079
TEPP	1.7	0.840	DDT	0.032	0.016
Parathion	1.4	0.700	Aldrin	0.033	0.013
Chlorthion	3.2		Chlordane	0.052	0.022
Systox	3.6		Lindane	0.062	0.077
Di-syston	3.7	0.064	Methoxychlor	0.064	0.062
Methyl parathion	8.3		Heptachlor	0.094	0.019
Malathion	12.5	0.095	BHC	2.3	0.790
Co-ral	18	0.18	Sevin /3	12.0	5.3
OMPA	121				
Dipterex	180				

Sevin - carbamate bluegills 5.3 ppm 96 hr. TLm (50 %)

/1 Data from Henderson, Pickering, and Tarzwell (1959).

/2 All tests made in soft water at 25° C.

/3 This material is a carbamate and not a chlorinated hydrocarbon.

Table 2

Amount of Chlorinated Hydrocarbon Insecticide When Applied To Water Surface That May Produce Fifty Percent Fish Mortality

Insecticide	96 Hour TL_m P.P.B. (Micrograms/Liter) Active Agent*	ppm	Pounds Per Acre Applied to the Surface of Water 3 Feet Deep to Reach the TL_m Concentration
Endrin	0.60	.0006	0.005
Toxaphene	3.5	.0035	0.03
Dieldrin	7.9	.0079	0.07
Aldrin	13	.013	0.11
DDT	16	.016	0.13
Heptachlor	19	.019	0.16
Chlordane	22	.022	0.18
Methoxychlor	62	.062	0.51
Lindane	77	.077	0.63
BHC	790	.790	6.4

*Under standardized conditions--bluegills in soft water. Temperature 25°C.

REFERENCES CITED

Bourn, Warren S. and Clarence Cottam. 1950. Some biological effects of ditching tidewater marshes. U. S. Fish and Wildl. Serv. Research Rept. 19. 30 pp.

Bradbury, Harold M. 1938. Mosquito control operations on tide marshes in Massachusetts and their effect on shore birds and waterfowl. Jour. Wildl. Mgt. 2(2):49-52.

Bureau of Sport Fisheries and Wildlife. 1957. Field manual - Branch of Wildlife Refuges.

Clarke, J. Lyell. 1938. Mosquito control as related to marsh conservation. Proc. 25th Ann. Mtg. New Jersey Mosq. Exterm. Assoc.:139-146.

Darsie, Richard F., Jr., and Paul F. Springer. 1957. Three-year investigation of mosquito breeding in natural and impounded tidal marshes in Delaware. Univ. of Del. Agr. Expt. Sta., Bull. 320(Tech). 65 pp.

Gerberich, John B. 1946. An annotated bibliography of papers relating to the control of mosquitoes by the use of fish. Amer. Midl. Nat. 36(1):87-131.

Gerhardt, Richard W. 1956. Present knowledge concerning the relationship of blue-green algae and mosquitoes in California rice fields. Proc. and Papers 24th Ann. Conf. Calif. Mosq. Control Assoc.:47-50.

Herms, William B. and Harold F. Gray. 1944. Mosquito control. Commonwealth Fund, N. Y. 419 p.

Hess, A.D. and T.F. Hall. 1945. The relation of plants to malaria control on impounded waters with a suggested classification. Jour. Nat. Malaria Soc. 4(1):20-46.

Hinman, E. Harold. 1934. The predators of the Culicidae (Mosquitoes). I - The predators of larvae and pupae, exclusive of fish. Jour. Trop. Med. and Hyg. 37(9):129-134.

Ingram, William M. and G.W. Prescott. 1954. Toxic fresh-water algae. Amer. Midland Naturalist. 52(1):75-87.

Martin, A.C. and F.M. Uhler. 1951. Food of game ducks in the United States and Canada. U. S. Fish and Wildl. Serv. Research Rept. 30. 308 pp. (U.S.D.A. Tech. Bull. 634. 1939).

Martin, A.C., Ray C. Erickson and John H. Steenis. 1957. Improving duck marshes by weed control. U.S. Fish and Wildl. Serv., Circ. 19 (Rev.). 60 pp.

Price, Milton H. 1938. New developments in mosquito control in Rhode Island. Proc. 25th Ann. Mtg. New Jersey Mosq. Exterm. Assoc.:111-114.

Rozeboom, L.E. and A.D. Hess. 1944. The relation of the intersection line to the production of Anopheles quadrimaculatus. Jour. Nat. Malaria Soc. 3(3):169-179.

Stearns, L.A., Donald MacCreary, and F.C. Daigh. 1940. Effect of ditching for mosquito control on the muskrat population of a Delaware tidewater marsh. Univ. of Del. Agr. Expt. Sta., Bull. 225 (Tech. 26). 55p.

Steenis, John H. 1950. Waterfowl habitat management in the Tennessee Valley. U.S. Fish and Wildl. Serv., Spec. Sci. Rept. - Wildl. No. 7. 14 pp.

Steenis, John H., Norman G. Wilder, Henry P. Cofer and Robert A. Beck. 1954. The marshes of Delaware, their improvement and preservation. Delaware Board of Game and Fish Comm. Pittman Robertson Bull. 2. 42 pp.

Tarzwell Clarence M. 1950. Effects of DDT mosquito larviciding on wildlife. V. Effects on fishes of the routine manual and airplane application of DDT and other mosquito larvicides. Publ. Hlth. Repts. 65(8):231-255.

Travis, B.T. 1957. Present status and future possibilities of biological control of mosquitoes. Mosq. News 17(3):143-147.

United States Public Health Service and Tennessee Valley Authority. 1947. Malaria control on impounded water. U.S. Govt. Print. Off. 422 p.

Whitlaw, J.T., William E. Bickley and Ernest N. Cory. 1956. Mosquitoes in farm ponds in Maryland. Jour. Econ. Ent. 49(2):273.

Wiebe, A.H. and A.D. Hess. 1944. Mutual interests of wildlife conservation and malaria control on impounded waters. Jour. Wildl. Mgt. 8(4):275-283.

Provost: Thank you, Dr. Tarzwell.

Loosanoff: May I ask you a question, Dr. Tarzwell, about some of the insecticides you discussed? You compare TEPP and parathion. TEPP is an organic phosphate. It disintegrates entirely in 12 hours. How can you compare it on a basis of 96 hours?

Tarzwell: Most of the fish died in the first little while, but we were running the other tests for 96 hours and so we ran this one for that period. TEPP does hydrolyze quite rapidly.

Loosanoff: Yes, in ten hours.

Tarzwell: It depends on the temperature, of course. In 45 hours a good deal of it is gone. Parathion, of course, has a much longer half-life.

Provost: Now we will have a discussion on the "Relationship of Larvicides and Adulticides used in Mosquito Control to Wildlife" by Dr. John L. George of Laurel, Maryland. Dr. George.

George: I'm going to be talking to you this morning primarily as a wildlife biologist. However, in addition to that I hope it's clear that I'm speaking also as a conservationist, that is I'm presenting one segment in a rather large field and my responsibility is in that field. As a conservationist I'm particularly happy to be talking to a group that is made up of diverse elements. Very often when you get into a problem that is controversial, you do a great deal of talking to your own group and you find that they tend to agree with your thinking and that reinforces your thinking. But when you do have a problem, I think the very best thing you can do is meet with all the other parties concerned, find out what their thinking is, what their problems are and very often you find there are elements of agreement.