Cah. O.R.S.T.O.M., sér. Ent. méd. et Parasitol., vol. VII, n° 1, 1969

Insecticide resistance in non-target aquatic organisms *

by

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The effect of pesticides on non-target aquatic organisms has been a subject of increasing concern in recent years. This concern was awakened by such books as *Silent Spring* by Rachel CARSON (1962) and *Pesticides and the Living Landscape* by Robert RUDD (1964). A number of papers have since appeared discussing the effects of pesticides on the ecosystem following their application (NIERING, 1968). However, little research has been carried out on the effect of pesticides and the development of resistance on aquatic organisms and the ecological balance of the aquatic environment. Most of the research concerned with the development of insecticide resistance by aquatic organisms has been directed to insects classed as noxious Diptera by BROWN (1964).

Much of the early work on non-target aquatic organisms centered on the effect of pesticides on the fauna present in ponds following an application of persistant insecticides for mosquito control. The results of such insecticide treatments have shown that only certain species are adversely affected. Often following such an insecticide treatment, an increase in abundance of a particular species has been noted. One example has been described by MOYE and LUCKMANN (1964), who reported that tricoptera and chironomid populations doubled those of controls following an aldrin application. This is typical of resurgences often observed in pest species following insecticide treatment. One reason for resurgences may be the loss of natural controls such as predators or a decrease in competition.

Another type of effect observed in aquatic populations following an insecticide treatment is a change in the types of species present. HOFFMAN and DROOY (1953) reported finding eleven species of three genera in a prespray count of a stream. Following the application of DDT, the fauna changed to six species of five genera. Most of the effects reported by these early authors have been transitory. This is due primarily to the rapidity of reestablishment, which may not occur as readily where large areas are treated or isolated conditions exists.

The potential for the development of pesticide resistance by non-target organisms, as with pest species, probably exists in most populations. An unique opportunity to study the effect of a number of persistant insecticides applied over a span of several years to non-target aquatic organisms exists in Mississipi. More insecticides have been applied to the delta region of Mississippi for the production of cotton over the last 20 years than most other areas of the world. There are many small ponds and drainage canals which consist of slow moving water present throughout the year distributed within this large agricultural area. Insecticides are applied by air from

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* Communication présentée au Congrès de Téhéran (7-15 septembre 1968) - section B. 2.4.

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late June through September and the aquatic communities receive these pesticides from both drift and run off.

In similar areas located some distance from active agriculture where accidental contamination has occurred from such sources as the use of insecticide cans for floats, heavy tolls of many aquatic organisms have been observed. For example, heavy tolls of the southern cricket frog (*Acris gryllis*), Mosquito fish (*Gambusia affinis*), snakes and turtles along with many other species has been noted (BOYD *et al.*, 1963). However, in almost all cases a small number of living individuals of these species were present. These observations clearly show that if genes and physiological mechanisms for resistance exist in aquatic populations, a sufficient selective force could be present to increase their frequency. This sort of selective pressure may exist where repeated contamination occures such as in many agricultural areas or where the population is more isolated from other gene pools and is routinely although less intensively treated. Some examples of the latter are small ponds and marshes treated with larvicides for mosquito control.

The development of resistance to pesticides by aquatic invertebrates, although not documented except for a few diptera, has not been seriously questioned. This was not true of natural populations of vertebrates, which were believed by some to be unable to develop resistance to pesticides due to their low reproductive potential along with their non-target status. Miss CARSON (1962) states in her book, *Silent Spring*, that vertebrate animals are being placed in great jeopardy since they possess no capacity similar to invertebrates for becoming resistant to pesticides. She further states that if such capacities do exist they will require measurement on a geological scale. This concept was fostered by the fact that vertebrate evolution is discussed primarily from paleontological evidence.

Anyone knowing of the long history of insecticide use in the delta region of Mississippi and seeing the area teaming with wild life, such as small fish and frogs, would question how these organisms survive. The survival of mosquito fish in these contaminated environments strongly suggested possible resistance to pesticides. In 1962, Dr. Claude BOYD and I initiated a study to compare the toxicity of DDT to mosquito fish located in the delta with fish located near State College, Mississippi, where little or no insecticide contamination had occurred. The results of this first study (figure 1) show a difference in toxicity of populations from areas having a history of exposure when compared to populations from uncontaminated areas. These results suggested resistance to DDT.

Similar results to those reported for mosquito fish were found for the southern cricket frog to DDT and later aldrin (VINSON et al., 1963 b). Since aldrin was not a pesticide used in the area, these results suggested cross-resistance. Following these early studies, Dr. Denzel FERGUSON and his associates (1964) at Mississippi State University have reported several fish with high degrees of resistance to a number of pesticides (table 1).

These studies have been extended to some of the non-target invertebrates which serve as food for fish and other top carnivors. Mr. Syed NAQVI (pers. comm. 1968) has studied the toxicity of several insecticides to cyclopoid copepods ; a clam, *Eupera singley* and a snail, *Physa gyrina*. He found that these delta invertebrates were highly tolerant to both endrin and toxaphene when compared to those collected at State College. Dr. Howard CHAMBERS and I have recently run dosage-mortality curves on corixids collected from the delta and compared to uncontaminated populations from State College. The delta corixids showed a 10-fold resistance to endrin and toxaphene and revealed a much flatter dosage-mortality curve. Their results indicate the development of resistance in several of the delta invertebrate populations.

The significance of these findings has been difficult to evaluate. Many biologists welcomed the news of resistant non-target organisms and it has reduced fears that non-target organisms, particularly lower vertebrates, face extinction in a pesticide contaminated environment. However, these resistant organisms may be a serious potential hazard rather than a blessing. RUDD (1964) in his book, *Pesticides and the Living*

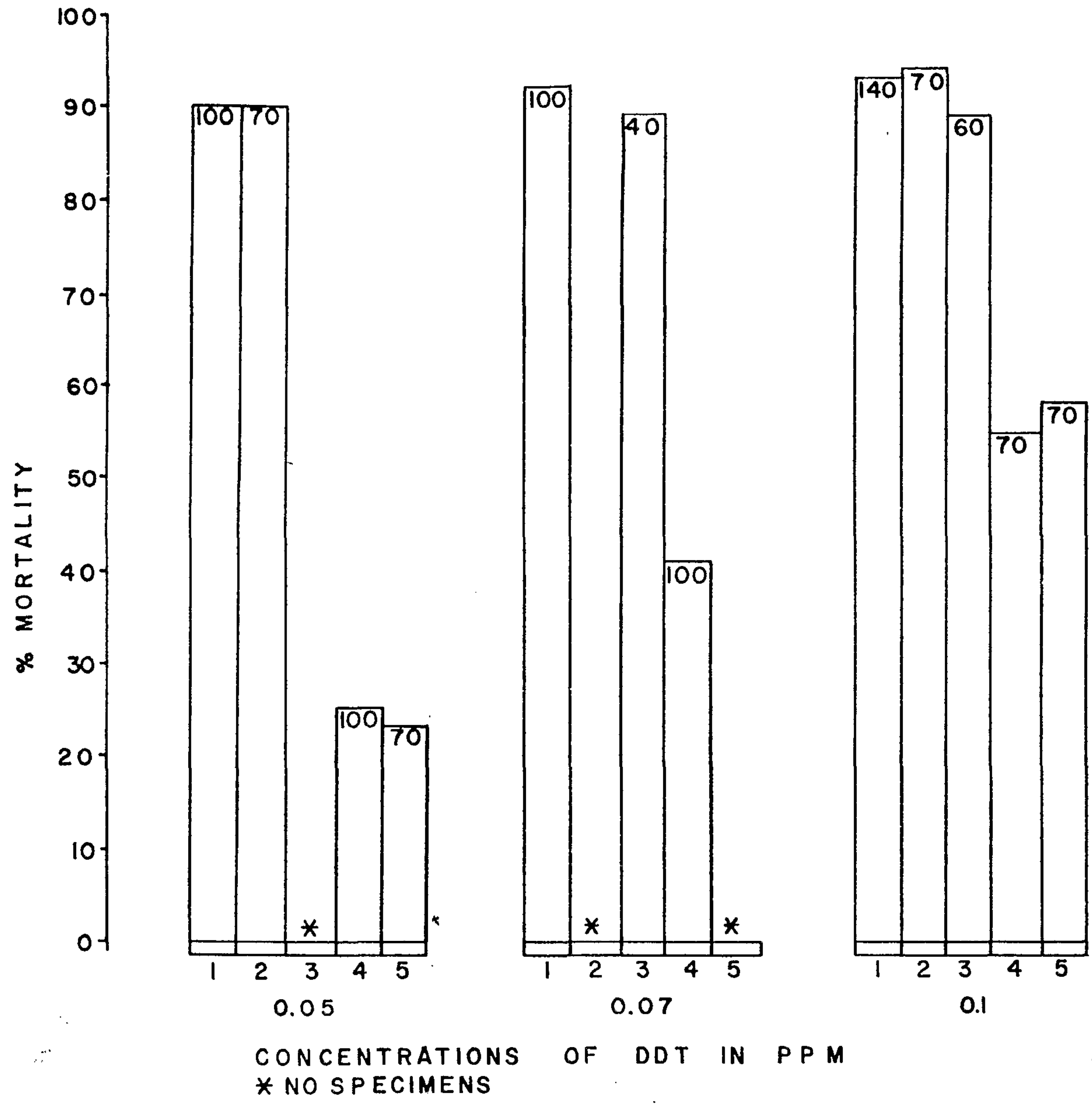

FIG. 1. — Mortality of mosquito fish maintained 72 hrs. in 3 DDT concentrations. Bars 1, 2, and 3 represent fish from untreated areas ; bars 4 and 5 denote fish collected near treated cotton fields. Sample size for each test is indicated by a number near the top of each bar. VINSON et al., 1963 *a*

Landscape, cites several examples of the transferral and biological magnification of pesticides in food chains. This problem is magnified intensely if the organisms lower in the food chain are resistant and harbour high levels of pesticides in their tissues. FERGUSON et al. (1966) reported that resistant mosquito fish tolerate as much as 214 ppm endrin in their tissues following 2 weeks exposure to 500 ppb and one such fish is able to release enough endrin in 10 liters of water to kill five susceptible mosquito fish and survive. ROSATO and FERGUSON (1968) studied the toxicity of endrin resistant mosquito fish to eleven species of vertebrates and reported that the resistant mosquito fish tolerated endrin residues sufficiently to kill potential predators several hundred times their own weight. Similar instances may occur in insect populations. At State College, Mississippi, the corixid population is low and a notonectid population is present which feed heavily on the corixids. Preliminary observations have revealed very high populations of corixids but few notonectids in the delta. The absence of notonectids from the insecticide contaminated delta streams may be due to the presence of resistant corixids concentrating toxic residues.

TABLE 1

The maximum fold difference between susceptible and resistant populations of several species of fish to several insecticides

N.d. = No Data.

Insecticide	Species of Fish			
	Gambusia affinis	*Lepomis macrochirus*	*Lepomis cyanellus*	*Notemigonus cryaolucas*
D.D.T.	11	5	5	5
Endrin	1.500	200	75	333
Dieldrin	31	36	38	38
Toxaphene	250	69	39	40
Methyl parathion	30	N.d.	N.d.	N.d.

from FERGUSON, D.E. (1968, person. com.).

Finally I would like to spend a few minutes discussing areas that need investigation. In a recent review on the consequences of insecticidal use on non-target organisms by NEWSOM (1967), few references were made to resistance in non-target organisms except for the work reported here on fish and several beneficial insects of agricultural importance. Thus information as to which aquatic invertebrates are potentially capable of developing resistance, those that are naturally tolerant, and those which have already developed resistance, is needed, particularly since these organisms are a vital link in the aquatic food chain. There is also a need for information concerning species displacement due to prolonged insecticide contamination.

Further information as to the route whereby a pesticide is able to exert an effective selective pressure upon non-target aquatic organisms is needed. There are several possible routes. One is through biconcentration and transferral up the aquatic chain resulting in a greater selective pressure on those organisms higher in the food chain. Information is needed as to which organisms are more important as bioconcentrators or vehicles for the transferral of pesticides. How the development of resistance by the different members of the aquatic food chain can effect the movement of pesticides would be of particular significance.

A second way a pesticide may exert a selective pressure upon the aquatic environment is through direct environmental contamination. We need to know more about what part of the environment is being contaminated by the various pesticides and how it is affected by pesticide use and formulation. There are several ways in which a pesticide may enter the aquatic environment : — 1. The pesticide can move into the stream or pond bound to soil particles and become rapidly incorporated into the mud. — 2. The pesticide may be dissolved or suspended in the water or on detritus present in the water. — 3. It could be present as a surface film since many pesticides are formulated in oil. Which one of these routes of pesticide movement is correct might be indicated by which insects are resistant. For example, if bottom dwelling organisms were resistant or contained high residues of a particular pesticide, it would suggest this route of entry into the aquatic environment for that pesticide.

Small ponds and streams which have received pesticides over the last decade for mosquito control may offer an ideal study location. An example is reported by RATHBURN and BOIKE (1967) who reported malathion resistance in a population of *Aedes* in Florida. This population was somewhat isolated and concentrated and was the subject of an intensive controle operation. Since many mosquitoes have developed resistance it would certainly be surprising if some of the other aquatic organisms in the same environment had not.

When more data is collected on the effects of pesticides on the non-target environment it may well point to the fact that insecticides are adversely upsetting the ecological balance in the environment and ultimately effecting the health of man. Partly due to the fears of some workers concerning environmental contamination and to the realization of others that pesticides may fail to control resistant vector populations, a shift towards biological control measures such as genetic incompatibility, sterile male techniques and the use of pathogenic agents is and should further be explored and emphasized. It should also be noted here that one using these biological control agents must consider the pesticide contamination of the environment into which they are being placed.

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