EFFECTS OF FEEDING DDT-SPRAYED INSECTS TO FRESH-WATER FISH

SPECIAL SCIENTIFIC REPORT: FISHERIES No. 3

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

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Washington, D. C.
October 1949

United States Department of the Interior
J. A. Krug, Secretary
Fish and Wildlife Service
Albert M. Day, Director

Special Scientific Report - Fisheries
No. 3

EFFECTS OF FEEDING DDT-SPRAYED INSECTS TO FRESH-WATER FISH

By

C. H. Hoffmann

Bureau of Entomology and Plant Quarantine, Agricultural Research Administration
U. S. Department of Agriculture, Beltsville, Maryland

and

E. W. Surber

Fish and Wildlife Service, United States Department of the Interior

Kearneysville, West Virginia

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INTRODUCTION

Field observations along streams have shown that large numbers of terrestrial and aquatic insects are killed when forested areas are sprayed by airplane with DDT at the rate of 1 pound per acre. The immediate loss in bottom organisms ordinarily amounts to about 90 percent (Hoffmann and Merkel 1948). As the affected insects alight on the water or come to the surface, fish gorge on them. Observations (Surber 1946) made shortly after the spraying of a trout stream in Pennsylvania showed that 30 brook trout in a livebox made 54 rises for insects in a 5-minute period.

As a result of these field observations, questions arose as to whether the consumption of poisoned insects might not kill fish directly, or whether the insects and a dearth of food after the gorging affected the fish. Information on this general problem was obtained through controlled outdoor and laboratory tests. Ginsburg (1947) found that mosquito larvae killed by DDT at concentrations from 1 to 0.05 p.p.m., and subsequently fed to goldfish at the average daily rate of approximately 25 larvae per fish over a 4-day period, did not poison the goldfish (Carassius auratus). As our preliminary work indicated that the condition of the fish at the time of treatment greatly influences susceptibility to poisoning, some experiments were conducted along this line. Typical symptoms of DDT poisoning are nervousness exhibited by the quivering of the body and rapid movement of the fins, and, in the later stages, by wild aimless dashing about. Fish often succumb with their gill-flaps extended as in suffocation; occasionally they have been observed to exhibit the nervous symptoms and recover.

Methods

Laboratory-reared adults and larvae of the housefly (Musca domestica Linnalus) and field-collected tendipedid (midge-fly) larvae were sprayed with a DDT suspension or a DDT-oil solution at a rate equivalent to 1 pound of DDT per acre. These insects were then fed to smallmouth black bass (Micropterus dolomieu), largemouth black bass (Micropterus salmoides), bluegill (Lepomis macrochirus), and black crappie (Pomoxis nigro-maculatus). The adult flies were anaesthetized with carbon tetrachloride and scattered on paper in the bottom of a 0.1-milliacre chamber into which the insecticide was applied

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Note—The authors are indebted to D. D. Friddle, Fish and Wildlife Service, and to E. P. Merkel, Bureau of Entomology and Plant Quarantine, for technical assistance. The Division of Control Investigations, Bureau of Entomology and Plant Quarantine, furnished cultures of houseflies.

immediately with a small atomizer; the housefly maggots and tendipedid larvae, on the other hand, were not anaesthetized before being sprayed. The treated insects were fed alive to fish conditioned in daphnia ponds, aquaria, or battery jars containing hard water. The small, medium, and large aquaria used contained 25, 27, and 44 liters of water, respectively. The sprayed insects were fed individually to the fish and were usually devoured immediately. Water temperature readings were taken daily at about 8:00 a.m., and 4:30 p.m.

The following spray formulations were used in these experiments:

Formula 1: 2 pounds of 50 percent wettable DDT powder and water to make 1 gallon.

Formula 2: 1 pound of DDT, 2 pints of xylene, and fuel oil No. 2 to make 1 gallon.

Formula 3: 1 pound of DDT, 3180 ml. of a napthenic solvent (PD-544-B), and fuel oil No. 2 to make 1 gallon.

Consumption by the Bluegill of Insects Sprayed with DDT in Oil

The following experiment was set up to ascertain whether fish gorging on poisoned insects for one day and receiving untreated food on succeeding days were affected by the poison. On June 18, 1947, 20 bluegills in excellent condition and averaging 82 mm., in length were isolated in each of three concrete daphnia ponds (25 by 8 by 3 feet). The fish in two ponds were fed all the adult houseflies sprayed with formula 3 that they would eat in a day. After fasting for 3 days, the fish in one pond devoured an average of 13 treated flies per day compared with 16 in the other pond, and the fish in the control pond took an average of 12 untreated flies each. Later the fish in all ponds were fed untreated food periodically. The temperature of the water during the experiment averaged 71° F. No mortality resulted in any of the ponds by the end of 14 days, when the experiment was concluded. In a previous experiment (Surber 1946) 25 fingerling and 25 adult bluegills in each of two ponds devoured 3,988 and 4,037 sprayed flies, respectively, over a period of three days, and all the fish survived, as did those in the control pond.

A second experiment was aimed to determine the immediate effect on fish after devouring treated insects, and the ultimate effect on fish when some of them subsequently were fasted and others well fed. Each of 12 aquaria was stocked with three bluegills averaging 78 mm., in length. In eight of these, fish were given all the houseflies treated with DDT in oil (formula 3) that they would devour in one day. The fish in the other four aquaria were fed untreated flies. The

average number of flies consumed in both controls and experimental aquaria was 11 per fish. Subsequently, the fish in 4 aquaria receiving treated flies and 2 in control aquaria were fasted; those fish in the remaining 6 aquaria were fed untreated adult houseflies.

The water temperature averaged 73° F., for the two-week period. The fish ate approximately 10 unsprayed flies each day throughout the course of the experiment. No fish were observed to have DDT tremors, or to have died from the effects of DDT. This experiment indicated that (1) gorging on insects treated at a rate equivalent to 1 pound of DDT per acre for 1 day was not lethal, and (2) that delayed mortality did not result from these feedings if the fish were deprived of food for two weeks after consuming the sprayed insects.

A similar experiment was conducted with bluegills ranging from 50 to 64 mm., in length, with the exception that the fish were given all the treated adult flies they would eat over a 3-day period. The test fish each devoured an average of 12 sprayed flies per day, as compared with 11 flies each for the control fish. During the 9-day test, the temperature of the water in the aquaria averaged 72° F. One-third of those that ate sprayed flies developed symptoms typical of DDT poisoning either on the last day of feeding or the following day. However, only 1 fish died in the experiment, and it had not previously exhibited symptoms of DDT poisoning.

Consumption by Bluegills and Crappies of Insects Sprayed with a DDT Suspension

Four bluegills (43 to 56 mm., in length) that were individually given midge larvae treated with wettable DDT (formula 1) devoured 11, 11, 22, and 41 larvae, respectively. Those eating 11 larvae each died in less than 16 hours, whereas the other fish lived for 12 days, when the experiment was concluded.

In another experiment, six bluegills (31 to 41 mm., in length) were fed 9 to 13 housefly larvae treated with wettable DDT. The three fish eating the largest number of insects died within 12 days; the others survived.

Each of 16 bluegills averaging 55 mm., in length were fed suspension-treated (wettable DDT formula 1) houseflies for 3 days. The average water temperature was 69° F. Most of the fish devouring 8 to 10 sprayed flies were alive 10 days later, when the first part of the experiment was concluded. Those surviving were fed all of the sprayed housefly larvae that they would devour in one feeding. Many

of the bluegills ate from 8 to 11 larvae in addition to the poisoned adult flies, and survived an additional 7 days, when the experiment was concluded. Some of the fish showed definite DDT tremors, but later recovered.

Six bluegills and six black crappies averaging 31 mm., in length were placed together in each of four aquaria. The fish in two aquaria devoured midge larvae, treated with wettable DDT, in fairly constant numbers for the first 3 of 4 feeding days, and the fish in two control aquaria received untreated larvae. The water temperature averaged 72° F. Altogether 278 treated larvae were fed one group and 637 to another, whereas the two control groups each took 425 untreated larvae. The fish consuming the least number of treated larvae died first. Eleven fish in one aquarium succumbed three to four days after the first feeding. Seven in the second aquarium died 4 to 5 days after the first day of feeding; in addition, four died 7 to 8 days later. All of the control fish were alive at the end of the 12-day experiment. Since about equal numbers of bluegills and crappies died, there was no noticeable difference in susceptibility to DDT between the two species.

Consumption by Largemouth Black Bass of DDT-Sprayed Insects

Four largemouth black bass, 83 mm., in length, were placed in 8 inches of water in each of three Fearnow pails. The fish in two pails were fed 241 and 271 housefly maggots treated with wettable DDT (formula 1) over a period of 7 days, while the control fish consumed 200 untreated maggots. The temperature of the water during this experiment averaged 68° F. Of the bass receiving treated larvae all died 2 to 4 days after the cessation of feeding, whereas all of the control fish survived.

In another experiment four largemouth bass 52 mm., in length were placed in each of eight aquaria. The fish in six aquaria were fed all the treated housefly larvae (sprayed with wettable DDT, formula 1) that they would eat on two successive days (table 1). Two controls were fed untreated larvae. After the second feeding, those aquaria in which the fish ate approximately the same number of larvae were grouped in pairs. The fish in one aquarium in each group were fed untreated larvae during the next 12 days while the fish in the other aquarium of each group were fasted. The two controls were fed untreated housefly larvae throughout the feeding period. Water temperatures in the aquaria averaged 70° F. Eight of 24 bass fed the treated larvae at the beginning of the experiment died. Five of these deaths occurred in those aquaria where the fish were fasted.

Mature housefly larvae sprayed with wettable DDT were fed to largemouth black bass averaging 45 mm., in length that were isolated individually in 5-by 11-inch round battery jars containing 4 inches of water. Some of the bass refused the sprayed insects and were eliminated from the test. Eleven bass devoured three or more treated larvae (enough to cause marked distension of the stomach) in 2 days. These fish were used in the test. The average temperature of the water in the jars was 69° F. Five bass that ate 4, 4, 5, 7, and 9 treated larvae died 5, 10, 9, 10, 13, and 9 days, respectively, after feeding; only two fish exhibited symptoms typical of DDT poisoning. Six bass that took 3, 3, 5, 5, 6, and 7 treated larvae, respectively, survived. Of five control fish that consumed an average of 21 untreated maggots over a period of 16 days, one died. Although the fish were proffered all the larvae they would eat, those given untreated larvae ate by far the most. Fish eating poisoned insects were variously affected but significant numbers survived the test.

Nine largemouth black bass of the same size as those in the preceding experiment were fed maggots sprayed with wettable DDT. Those fed 3, 5, 6, and 7 sprayed larvae, respectively, died within 18 hours, and two eating 8 larvae each died before the end of the second day; others eating 8, 8, and 9 treated larvae survived the 10-day test, as did the control bass that consumed 13 untreated larvae each.

Twenty-six largemouth black bass averaging 50 mm., in length were isolated individually in battery jars. One-half of them were fed mature housefly larvae sprayed with wettable DDT, and one-half were fed larvae sprayed with DDT in oil (formula 2). Five bass were placed in individual jars as controls. The water temperature averaged 71° F. The experiment was terminated after 7 days. Twenty of the 26 fish receiving sprayed larvae died. Of the 20, 9 had eaten larvae sprayed with the DDT suspension and 11 had eaten larvae sprayed with the DDT solution. The fish in the controls ate an average of 7 larvae each in a single feeding as compared with an average of 9 each for the bass receiving the suspension-treated larvae and 4.5 each for the oil-treated larvae. Great variation occurred when the numbers of treated larvae eaten were compared with survival time in days. Bass that had eaten 9 to 14 suspension-treated larvae survived, while others that had consumed fewer larvae died within 1 to 7 days. Of the four bass that ate 4 larvae each treated with DDT oil spray, two were living 7 days later. Most of those that ate from 5 to 8 treated larvae died within 12 hours. The fish in the controls survived.

Table 1.--The influence of fasting on survival of largemouth black bass fed housefly larvae sprayed with wettable DDT at a rate equivalent to one pound per acre.

Aquarium No.	Treated larvae eaten in 2 days	Untreated larvae eaten the next 12 days	Fish[1] killed
	Number	Number	Number
2	40	115	2
4	35	fasted	1
6	46	fasted	3
7	32	124	1
5	41	fasted	1
3	43	150	0
1	53[2]	150	0
8	40[2]	144	0

1/ Original number: four bass per aquarium.

2/ Untreated (control).

Four bass averaging 76 mm., in length were kept in each of three aquaria, the water temperature averaging 64° F. The two experimental groups receiving maggots treated with DDT in oil (formula 2) ate 42 and 75 in one day, while the control fish devoured 50 untreated larvae. All fish appeared normal six days later. This experiment suggests that larger fish of this species are less susceptible to DDT poisoning than smaller ones.

Consumption by Smallmouth Black Bass of DDT-Sprayed Insects

In a preliminary experiment, three aquaria were each stocked with four smallmouth black bass (49 to 69 mm., in length). The average temperature of the water in the aquaria was 70° F. In one aquarium, the fish were fed midge larvae sprayed with wettable DDT (formula 1). One bass ate 20 larvae and died 16 hours later; another consumed 15, and died 2 days later, at which time, another died that had not fed; while the largest fish (69 mm.,) consumed 90 larvae and was alive 12 days afterwards when the experiment was concluded.

Two bass (each 54 mm., in length) in separate jars were fed midge larvae sprayed with wettable DDT. The fish were then fasted. One devoured 45 larvae in one afternoon and died about 6 days later; the other took 73 larvae in 10 minutes. This fish was active for the following 6 days, then became sluggish for several days, and died 11 days after the large feeding.

In another experiment, three smallmouth bass (70 to 79 mm.,) were fed 5, 9, and 10 adult houseflies sprayed with wettable DDT, and a control was fed 11 untreated flies. The average temperature of the water in the aquarium jars was 70° F. The bass that ate five flies died in 5 days, whereas the others were healthy 10 days after feeding. The fish that ate 9 treated adult flies was fed 14 untreated housefly larvae; it died 5 days later. The bass originally given 11 untreated adult flies was fed 20 sprayed larvae, and was alive 7 days later, when this experiment was discontinued. The other bass originally fed 10 treated adult flies was fed 14 larvae treated with DDT in oil (formula 2) at the same dosage, and died 6 days later.

These experiments indicate that smallmouth black bass sometimes die from feeding on sprayed insects. It also showed that they could gorge themselves on poisoned insects without dying. Observations combined with the erratic results obtained in this and in certain other experiments suggested that fish in poor condition were the most susceptible to DDT poisoning.

Results of the Direct Feeding of Wettable DDT in Gelatin Capsules

Eight smallmouth black bass, ranging in weight from 5.5 to 8 grams each, were placed in individual aquaria. These fish were taught to consume a trout diet contained in gelatin capsules. After 2 weeks of the training they were fasted for 3 days to make them hungry enough to eat the capsules. Two of the fish (controls) were given capsules with meat only. Wettable DDT powder in gelatin capsules was given two of the fish at the rate of 50 milligrams per kilogram of body weight, two were given 100 milligrams per kilogram, and two were given 200 milligrams per kilogram.

Before feeding, a small amount of the meat diet was placed inside each capsule with the powder without mixing, so as to add weight and cause the capsules to sink into the water. The capsules were also coated with the meat before introduction into the aquaria. The fish were fed the capsules containing DDT between 8:25 and 8:30 a.m., November 15, 1946. They showed symptoms characteristic of DDT poisoning by afternoon of the first day. By 9:00 a.m., the following day, five of the six fish fed DDT were dead. Two leaped from the aquaria during the night, probably as a result of their violent reactions to DDT. The only live fish (one of the two receiving 50 milligrams per kilogram) remaining, other than the controls, was lying on its side and exhibiting convulsions on the morning of November 16. Death occurred at 1 p.m.

This experiment indicated that DDT given intragastrically, even without solvents, was more toxic to smallmouth black bass than to goldfish (Ellis, Westfall, and Ellis, 1944).

Effect of Condition on the Ability of Rainbow Trout to Withstand DDT

Six daphnia ponds (450 cubic feet of water each) were stocked with fifty 3.7-inch rainbow trout each on November 15, 1946. These were well-fed hatchery trout. In three of the ponds the trout were fed a regular hatchery diet, and in the remaining three ponds the fish were fasted. On November 26, four ponds (two containing fed and two with unfed trout) were sprayed with wettable DDT (formula 1) at the rate of one pound of DDT per acre. Two other ponds (1 with fed and 1 with unfed trout) served as controls. The average water temperature during the period November 26 to December 8 was 43° F.

There was no mortality in the control ponds. In the ponds which were sprayed and the trout fed, the mortalities were 4 and 10 percent. The sprayed ponds in which the fish were not fed suffered losses of 70 and 60 percent, respectively. This experiment indicates that fish weakened by the lack of food are more susceptible to DDT poisoning than well-fed fish.

Summary and Conclusions

Experiments in which midge larvae, housefly larvae, and adult flies, sprayed with a DDT suspension or an oil solution at a rate equivalent to 1 pound of DDT per acre, were fed to fingerling bluegills, smallmouth black bass, and largemouth black bass, gave erratic results. Some fish apparently were killed by devouring relatively small numbers of sprayed insects; others gorged without effect. Sometimes the fish became sick and exhibited DDT tremors but recovered later. Deaths attributable to DDT occurred after variable periods.

Fish devouring the DDT-oil sprayed insects were usually more easily killed and died earlier than those devouring insects sprayed with a DDT suspension.

Large fish appeared less sensitive than small fish to DDT-sprayed insects.

Fish recently removed from nursery ponds where they were well fed invariably survived the effects of DDT better than did those kept in holding ponds without natural or artificial food. Well-fed fish that gorged upon insects sprayed with DDT survived in large numbers even though they were fasted after the test feeding. Several laboratory and outdoor experiments indicated that the condition of fish is a very important factor in their susceptibility to DDT poisoning.

When fingerling smallmouth black bass were fed wettable DDT in gelatin capsules at 50, 100, and 200 milligrams per kilogram of body weight, all fish were killed, indicating that smallmouth black bass are more sensitive to DDT than are goldfish.

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