EFFECTS OF DDT AND OTHER INSECTICIDES ON FISH AND WILDLIFE

SUMMARY OF INVESTIGATIONS DURING 1947

CIRCULAR 15

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

FOREWORD

During the war and postwar period many new poisons have been and are being developed which, because of their effectiveness in the control of insect, rodent, or plant pests, are likely to be distributed widely over the lands and waters of the United States. DDT is the best known, but several others are being introduced that have similar potentialities for harm. The Fish and Wildlife Service is gravely concerned over the effects on beneficial fishes and wildlife of such widespread use of toxic agents, and has conducted a variety of investigations during the past 3 years to measure the harmful effects and, when possible, to determine procedures or levels of treatment that will reduce them. This circular summarizes the important results to date and contains recommendations that will be of interest and value to individuals and agencies concerned with control of insects and other pests by chemical means.

ALBERT M. DAY, *Director.*

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Effects of DDT and Other Insecticides on Fish and Wildlife Summary of Investigations during 1947[1]

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INTRODUCTION

Since 1945 the Fish and Wildlife Service, in cooperation with other agencies, has been conducting investigations to determine the effects of some of the new insecticides on fishes and wildlife. In order that control workers and others interested in this growing problem may have current information, the results of these investigations have been summarized periodically. This, the third[2] such summary report, presents the findings of work done in 1947, when major attention again was given to evaluations of DDT (dichlorodiphenyltrichloroethane).

It has become increasingly apparent from these studies that, aside from the dosage of DDT ap-

[1] This circular presents the results of field work conducted during 1947 by Stanley P. Rhoades, of the Forest Service, and Dr. Clarence H. Hoffman, of the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture; and the following members and collaborators of the Fish and Wildlife Service: Joseph P. Linduska, Eugene W. Surber, David W. Johnston, Lowell Adams, Mitchell G. Hanavan, Dr. N. W. Hosley, Johnson A. Neff, Robert E. Stewart, Dr. Eugene P. Odum, Robert A. Norris, William Stickel, Lucille Stickel, John L. George, Chandler S. Robbins, E. Ediger, Dr. V. L. Loosanoff, C. A. Nomejko, F. D. Tommers, and Allan J. Duvall.

[2] The findings of the 1945 and the 1946 investigations on the effects of DDT on fishes and wildlife were published in Fish and Wildlife Service Circular 11, DDT: Its effect on fish and wildlife, by Clarence Cottam and Elmer Higgins, 1946; and Fish and Wildlife Service Special Scientific Report 41, DDT investigations by the Fish and Wildlife Service in 1946, by Arnold L. Nelson and Eugene W. Surber, May 1947 [processed].

plied, many factors are involved in determining its ultimate effects on fishes and wildlife.

The type of formulation, size of the area, and the method, frequency, and time (season) of application are some of the highly important variables. Many combinations of these are to be found in the numerous methods of control, and for this reason it is difficult to make specific recommendations that will apply to the use of DDT generally.

Because of the intricate relationships existing between many forms of wildlife and their invertebrate food species, there are definite limitations to what can be accomplished in the laboratory by way of evaluating effects of control agents on wildlife. The fact that a product is of high toxicity to vertebrates in the laboratory may not in itself be a valid basis for judging its full effects under conditions of field use. The summary removal of a basic food supply by a control operation may prove critical to fishes and wildlife even though the direct kill by poisoning is nominal. Consequently, in the continuing studies of economic poisons and wildlife, emphasis is being placed on evaluations under conditions of actual use.

During 1947 studies were conducted in several western forest areas during which DDT in quantities of 1 to 10 pounds to an acre and the gamma isomer of benzene hexachloride in quantities of 1 and 2 pounds to an acre were applied by airplane. The size of treated areas varied from small experimental plots of 25 acres to one that included more than 400,000 acres. An experimental aerial treatment of a forest area near Beltsville, Md., was made, using a dosage of 5 pounds of DDT to an acre; and a 1-mile section of a West Virginia bass stream was treated experimentally with a dosage of 1 pound of DDT to an acre.

Other studies in 1947 included follow-ups of the effect of apple-orchard spraying in Maryland and pecan-weevil control in Georgia. Detailed studies were made of the effects on wildlife of an experimental attempt at tick control in Texas. Laboratory tests also were made at Leetown, W. Va., to determine the acute toxic levels for fishes of several new insecticides; and at the Patuxent Research Refuge, Laurel, Md., the chronic poisoning effects of several new materials on quail were measured. At Milford, Conn., DDT, as it is used in certain insect-control practices, was evaluated for its possible effects on oyster management.

FOREST INSECT CONTROL

MOSCOW, IDAHO

In May and June 1947 about 400,000 acres of forest land near Moscow in northern Idaho were treated for control of the Douglas fir tussock moth. DDT in oil, in a dosage of 1 pound of the toxicant to an acre, was applied by airplane. Follow-up studies were made of the effects on fishes, birds, and mammals.

This project offered an unusual opportunity for evaluating on a large operational scale some of the findings on relationships between wildlife and insecticides that have been obtained on much smaller experimental plots. Unfortunately, however, the control phases of the project were divorced from the investigational work, so planned studies could not be made. The spraying schedule, for instance, was highly flexible, and spray dates for specific areas could not be determined in advance. Without this information it was impossible to time "before" and "after" studies to the best advantage.

Mammals

An attempt was made through live-trapping in two plots to determine the possible effects of the spraying on small mammals. A 40-acre study unit area was located near the center of a treated area of 50 square miles. Live-traps were placed grid fashion at 4-chain intervals. A second study unit, 1½ acres in size, was near the edge of a large treated block. Traps in this case were set at 2-chain intervals. In both units 76 traps were operated for 428 trap-nights, and 67 individual mammals were taken a total of 147 times. The species taken by live-trapping included the red-backed mouse, white-footed mouse, jumping mouse, and two species of chipmunks. These limited samples of the population revealed no marked effects of the spraying. Aside from the mammals taken in trapping, others were under observation. In all, 16 species or subspecies were seen before, during, and after the period of spraying.

Birds

Populations of birds were studied intensively on two 20-acre plots, one located within a large sprayed block and another in an untreated check area. Censusing of the plots began June 2 and was continued until July 11. Spray was applied to the study area on June 21. Six censuses were taken in the treated area before, and five after, the treatment. The check plot was censused five times before, and five times after, the study area was sprayed.

The spraying had no apparent effect on the populations of 44 species of birds in the area concerned. Prior to spraying, the treated area had a density of 435.5 pairs of birds per 100 acres. An average of counts taken after spraying showed a density of

394.0 pairs per 100 acres, a decline of 9.5 percent. In the check area, populations during this same interval declined 10.6 percent, from 376.5 to 336.5 pairs per 100 acres. The slight drop in numbers in both areas was believed due to completion of nesting. Territorial maps accounted for practically all the original individuals throughout the study, and numerous nests and family groups appeared unaffected.

A possible effect of the spray on bird behavior was noted in Townsend's warbler. This species, normally a canopy feeder, was commonly seen feeding at or near the ground level after the spray application. This unusual habit was not noted prior to treatment of the area. A careful check of nests and young of the species showed no measurable effect on either the young or the adults.

Fishes

Of the more than 50 streams in the treated area, 40 were known to contain trout and 18 were listed as fair to excellent fishing streams. Rainbow, eastern brook, and cutthroat trout were not affected by the insecticide during the 5-week period of observation. Large populations of speckled dace and redsided bream were also unaffected by the poison but cottoids, mountain suckers, and black catfish suffered heavy losses in rather limited areas.

Seventy-two trout stomachs were examined, of which 35 were from trout taken from stream sections treated with DDT. Volumetric comparison indicated a 50-percent reduction in available food, largely in aerial insects and riffle forms. Ants and worms were important items of diet both before and after treatment. Crayfish, paralyzed by DDT, comprised 99.2 percent of the contents of the stomachs of 21 brook trout taken in one treated locality, whereas no crayfish were found in stomachs of fish taken in untreated areas. All specimens were caught by rod-and-line fishing, and there was no evidence that the vitality of the fish declined after treatment.

The ecology of stream sections that received a heavy deposit of spray was considerably altered. Annelids and molluscs were not affected, but insect larvae and nymphs were virtually eliminated from the riffle fauna. Even in fast-moving streams, lethal quantities of DDT were not transmitted far beyond the areas of direct application. Such limits were definitely less than 3 miles, probably not more than 1 mile, considering the possible drift of airborne spray.

Stream sections in which a severe kill of invertebrate life had occurred were soon marked by a luxuriant growth of algae, which completely blanketed many of the riffles. The earliest replacement of riffle organisms was a hatch of mayflies noted 2 months after the area had been treated.

Although there was no evidence of immediate damage to game-fish

populations, the importance of the wholesale decline of food organisms could not be determined on the basis of the single season of study.

TETON NATIONAL FOREST, WYO.

During July and August 1947, the Bureau of Entomology and Plant Quarantine, in cooperation with the Forest Service, both of the United States Department of Agriculture, made an experimental attempt to control the mountain pine beetle in the Teton National Forest, Wyo. Four plots, totaling 480 acres, were treated. On three of these (288 acres), the dosage applied was 5 pounds of DDT to an acre, and on the fourth (192 acres) the dosage was 7½ pounds of DDT to an acre. In each case two treatments, using one-half the total quantity for each, were made with an 8-day interval between them. A careful check of results showed that control of this pine beetle was not gained. The lack of success was attributed chiefly to the inadequate deposit of DDT on the boles of the trees by aerial application.

Studies of the effects on wildlife of this control attempt were made by members of the Fish and Wildlife Service and of the Bureau of Entomology and Plant Quarantine.

Mammals

Plots for studying the effect on small mammals were selected, one in an area that received an application of 5 pounds of DDT to an acre, one in an area that received an application of 7½ pounds to an acre, and another in an untreated check area. In all of these an index to the population level was obtained by live-trapping both before and after each of the two applications. The methods and intensity of the study were such that only marked population changes were likely to be noted.

From the trapping returns there was no indication of a marked effect on any of the following species: red-backed mouse (*Clethrionomys gapperi saturatus*), field mouse (*Microtus longicaudus*), white-footed mouse (*Peromyscus maniculatus artemisiae*), jumping mouse (*Zapus princeps princeps*), chipmunk (*Eutamias amoenus luteiventris*), and pine squirrel (*Tamiasciurus douglasii*). There were some indications from field observations, however, that the heavy dosages may have caused abnormal behavior and possible mortality. On August 31, the day following the second application on one of the areas treated with a dosage of 5 pounds to an acre, Stanley Rhoades, of the United States Forest Service, reported an unusual condition among trapped chipmunks. Practically all animals handled at that time were alternately sluggish and in a state of muscular tremors. Similar symptoms were noted in at least one free chipmunk, which would indicate that confinement was not the cause of the atypical condition noted among trapped individuals.

In another of the areas receiving a dosage of 5 pounds of DDT to an acre, Dr. Clarence Hoffman, of the Bureau of Entomology and Plant Quarantine, noted a shrew in a condition of extreme excitability. It died a few minutes after it was observed. Although it was not definitely established that the shrew died as a result of DDT poisoning, the symptoms were highly suggestive.

Birds

Observations were made on birds from July 19 to August 4. Since nesting by most species was completed at that time, a census could not be obtained. A record, however, was kept of individuals seen while the investigator was traversing marked paths through the study plots, and this modified "strip-count" provided a rough index to numbers and species in the areas both before and after spraying. There was considerable movement of birds in the study areas. Each of the treated blocks, however, was an isolated unit, all of which was completely treated, so that the birds in a given unit were subjected to the same conditions of spraying. In all, 33 species were under observation.

In the area that received 7½ pounds of DDT to an acre, the average daily number of birds seen prior to spraying was 69. After the first application of spray (3¾ pounds to an acre) the same working procedure resulted in a count of 51 birds, a decline of 26 percent. After the second treatment the average daily count dropped to 21 birds, a decline from the prespray counts of 69.5 percent.

In the area treated with 5 pounds of DDT to an acre a 42-percent increase in counts of birds occurred after the first application, and after the second spraying 22 percent more sight records were recorded than in the period before treatment. Counts taken in a check area showed marked increases during the same period.

As was to be expected, the greatest numbers of dead and dying birds were found in the area that received 7½ pounds of DDT to an acre. Of the five victims found in this unit, three were pink-sided juncos. Five species of woodpeckers were not observed to be affected by the heavy dosage, and two families of grouse, one with five young and the other with three, survived the 5-pound treatment.

Although the population studies were inadequate to determine the true effects, the complete absence of some species following treatment and the numbers of affected individuals seen were indicative of substantial kills in both the area treated with the 5-pound dosage and the one treated with the 7½-pound dosage.

Fishes

Three of the four plots selected for treatment were so situated that aquatic life was little affected. The fourth plot was bor-

dered by a small creek, Rock Creek, for a distance of ⅜ mile. The creek, which had a flow of only 0.7 cubic foot a second, contained 34 beaver ponds in the section studied and supported a large population of cutthroat trout (*Salmo clarkii lewisi*). The area was sprayed by airplane with DDT in the proportion of 5 pounds of the insecticide to an acre applied in two equal treatments. The first spraying of 2.5 pounds of DDT to an acre was done on July 22, and a thorough coverage of the stream resulted. The second treatment was applied to the area on July 30, at which time almost none of the poison fell on Rock Creek, except for a light drift deposited on some parts of it.

After the first spraying only 11 dead fish were found. This kill was much lighter than was expected considering the dosage, and actually was not as great as has occurred with DDT dosages of less than half the quantity used in this test. Certain conditions of the stream may have greatly minimized the loss: a nearly continuous chain of beaver dams slowed the flow of water so that little mixing of the spray with the water of the creek occurred, and most of the DDT remained suspended at the surface; also, the stream contained much organic debris and was very muddy as a result of activity by the beavers. Studies have shown that the toxic action of DDT may be reduced under such conditions. Another factor would involve the susceptibility of the cutthroat trout to this poison. Although toxic levels are not known for this species, trout in general have been found less susceptible to DDT poisoning than are a number of other freshwater species.

In conformity with the increased feeding activities of fishes observed after DDT has been applied to a stream, the average stomach contents of 11 trout taken at this time were four times as great as those of 32 fish taken before spraying. The riffle organisms were greatly reduced in numbers but were not entirely wiped out, there being some survivors among all susceptible insect larvae and nymphs.

BLACK HILLS NATIONAL FOREST, WYO.

The Bureau of Entomology and Plant Quarantine and the United States Forest Service cooperated in experimental attempts to control the Black Hills beetle in the Black Hills National Forest, near Sundance, Wyo. Each of five plots varying in size from about 15 to 90 acres was sprayed aerially with one of the following toxicants: 10 pounds of DDT to an acre, 7½ pounds of DDT to an acre, 5 pounds of DDT to an acre, 1 pound of gamma isomer of benzene hexachloride to an acre, and 2 pounds of gamma isomer of benzene hexachloride to an acre. The Fish and Wildlife Service investigated the effects of these experiments on wildlife.

An index to the small mammal

populations was obtained by live-trapping both before and after spraying, and an intensive search was made for mortalities. No evidence was found that any of the five species of small mammals taken by trapping was measurably reduced by any of the spray applications.

A systematic coverage of plots also showed little effect on the varied bird population. The small size of the plots, however, several of which were also long and narrow, and the fact that few individuals were restricted to territories by nesting activities, undoubtedly minimized the effects of the treatment. Arctic three-toed woodpeckers in a nest near the center of the plot that received the application of 7½ pounds of DDT to an acre were unaffected by the spraying and developed normally.

ORCHARD INSECT CONTROL

ALLEGANY COUNTY, MD.

A rather cursory survey of bird populations in an orchard area in Allegany County, Md., indicated that DDT as used for codling moth control may have pronounced effects on the bird populations. Late in July, a bird census was taken on a 22½-acre plot in an orchard that had been sprayed with DDT, and four species were found present in the ratio of 31 pairs to 100 acres. A similar plot in a nearby orchard, unsprayed because of early frost damage, had a population of 89 pairs to 100 acres and represented by nine species.

The spray schedule followed in the treated orchard called for the deposition of an equivalent of 15 to 22.5 pounds of DDT to an acre for each application. At the time of the study two applications had been made; hence 30 to 45 pounds of DDT to an acre had been distributed on the area. Additional cover sprays brought the total quantity of DDT applied to the orchard during the season to 60 to 70 pounds or more to an acre.

ALBANY, GA.

Between July 30 and August 28, 1947, Dr. Eugene P. Odum and Robert A. Norris, collaborators of the Fish and Wildlife Service, conducted studies on the effect on birds of DDT used in pecan weevil control near Albany, Ga. Ten pecan groves were under observation. Four of these received one application of DDT, three received two applications (about 2 weeks apart), and three unsprayed groves were used as check areas.

The spray formulation was 6 pounds of 50-percent wettable DDT powder (3 pounds of DDT) to each 100 gallons of water. The quantities of the mixture applied by individual owners contained DDT in amounts ranging from 0.18 to 0.43 pound to a tree or from 2.0 to 6.5 pounds to an acre

(the average being 4.3 pounds to an acre). The spray was confined mostly to the trees and little reached the ground level between or under the trees.

By the time spraying was begun most birds had completed nesting. Nevertheless, without considering juvenile and transient birds, a reasonably stable population was worked with, the birds numbering 50 to 104 individuals to 100 acres in different orchards.

Population counts indicated little effect of the DDT spraying. A decline in numbers of birds in treated areas was noted, but this was about comparable with the decreases observed in check orchards. No dead birds or birds showing symptoms of DDT poisoning were seen. Of four nests under observation, both before and after spraying, the birds in three progressed normally but the fourth nest was deserted after the second spraying. The cause of desertion could not be definitely determined.

For a day or more after the spraying operations numerous dead and dying insects, representing many species, were conspicuous on the sparsely covered ground. With minor exceptions, the birds were not attracted to this ready source of food but continued to forage in their normal niches.

The dosages of DDT used in pecan weevil control are known to be critical for birds when used under other conditions. Factors that might mitigate the effects on birds in the type of operation conducted at Albany, Ga., would probably include: (1) the limited size of the orchards, the birds not being confined to the treated area, and their summer feeding range extending beyond the orchard limits; (2) the period of spraying was later than the peak nesting period, and only a few late-nesting individuals were concerned with the nearly continual job of food-gathering required of birds with nestling young; and (3) except for a few ground-feeding species, the birds appeared not to be attracted to the abundant ground supply of fallen, contaminated insects.

TICK CONTROL

CAMP BULLIS, TEX.

During the summer of 1947, the value of DDT dust for tick control was investigated in a large-scale field experiment by the United States Army and the United States Department of Agriculture. The treated area was a 206-acre plot at Camp Bullis, Tex., within the Leon Springs Military Reservation, about 18 miles northwest of San Antonio. A mixture of 10-percent DDT in pyrophyllite was applied to the ground and vegetation by means of two dry-fog orchard dusters. The rate of application was 43.56 pounds of the dust mixture, or 4.36 pounds of DDT, to an acre. The effects of the experiment on wildlife were studied by members of the Fish and Wildlife Service.

Mammals

Small mammals were too few in numbers to carry on intensive population studies by live-trapping methods. Other larger, wider-ranging species, although plentiful, were not limited by normal range to the 206-acre treated plot, and so were not well suited for study subjects. Nevertheless, intensive studies prior to and after treatment showed that the following species apparently were unaffected or only slightly affected by the DDT operations: white-tailed deer, raccoon, striped skunk, armadillo, jack rabbit, and cottontail rabbit.

Birds

An abundant bird population was studied by comparing population trends in a 40-acre study plot in the treated area with those in a check area of similar size. An intensive search was made for mortalities. In all, 86 pairs of adult birds, representing 33 species, were recorded on the study area. A comparable predusting population of 90 pairs was found on the check area.

The first evidence of bird kill was noted on the day after application of the dust. From all indications deaths continued through the fifth day. Fifteen dead birds were found — 9 cardinals, 2 painted buntings, 2 lark sparrows, 1 yellow-breasted chat, and 1 white-eyed vireo. Because dense ground cover in many places made the recovery of poisoned birds difficult, the true extent of the kill is better indicated by the decline in the census counts from 86 pairs before, to 39 pairs after, dusting. The population in the check plot dropped from 90 to 78 pairs during the same period. The individuals found dead indicated that the species primarily affected were the ground and low-strata feeders. Population records for the 9 species of birds that appeared to be most seriously affected by application of DDT dust are given in table 1.

TABLE 1.—*Population records for 9 species of birds that appeared to be most seriously affected by application of DDT dust*

Species	Number of pairs counted before dusting	Number of pairs counted during the first 6 days after dusting					
		1st day	2d day	3d day	4th day	5th day	6th day
Texas wren	3	2	2	1	0	0	0
Carolina wren	5	1	0	0	0	0	0
Kentucky warbler	1	0	0	0	0	0	0
Yellow-breasted chat	3	0	0	0	0	0	0
Cardinal	10	8	6	5	2	1	1
Blue grosbeak	2	0	0	0	0	0	0
Painted bunting	4	4	3	2	2	0	0
Lark sparrow	8	2	2	2	2	1	1
Field sparrow	5	4	4	4	3	3	1
Total	41	21	17	14	9	5	3

Other Species of Wildlife

Four insectivorous rough green snakes (*Opheodrys aestivus*) and one large spiny lizard (*Sceloporus olivaceous*) were found dead in the study area after the dusting operations. It is believed that mortality among these forms of wildlife was heavy, although because of their secretive habits and the heavy ground cover comparatively few victims were found.

FIELD TESTS

AGRICULTURAL RESEARCH CENTER, BELTSVILLE, MD.

At the Agricultural Research Center, Beltsville, Md., a 90-acre tract covered with a 5-year-old growth of scrub and saplings was sprayed experimentally with DDT in the proportion of 5 pounds to an acre, and a detailed study was made of the effects on the bird population.

Prior to spraying, repeated censuses determined the nesting-bird population on a 30-acre plot at the center of the test area and also in a comparable check plot situated half a mile away. The area was sprayed on the morning of July 3, 1947, and the effects on the birds were noticeable within 24 hours. Although the extremely dense undergrowth impeded the search for sick or dead birds, seven individuals with typical DDT symptoms were seen on the day after the spray application. Census counts revealed a rapid decline in populations. The number of Maryland yellowthroats decreased 63 percent in the first 24 hours, and the total decrease for the species during the period of the study was 79 percent. Prairie warblers declined 64 percent in numbers during the first day and at the end of 48 hours they were down to 7 percent of their prespray population. A slight increase in the numbers of this species was noted a week later, however, which may have been due to movement of individuals into the plot from surrounding areas. House wrens de-

creased 59 percent in numbers during the first 24-hour period and continued to decrease during the six succeeding days. Red-eyed towhees showed a drop of 35 percent in numbers, which may have been a reflection of their habit of feeding in duff and litter. Of the five commonest species in the area, three—the Maryland yellowthroat, prairie warbler, and house wren—were reduced 80 percent. The total decrease in numbers of the five most abundant species, which comprised 77 percent of the original population, was 65 percent.

The populations of the small mammals in the area were too low for detailed studies of effects to be made. One dead meadow vole was found, however, and DDT was recovered from the tissues.

PATUXENT RESEARCH REFUGE, LAUREL, MD.

Late in May 1947 a 117-acre tract of bottom-land woods on the Patuxent Research Refuge, Laurel, Md., was sprayed with DDT by airplane for the third successive year. For that application the DDT was used at the rate of 2 pounds to an acre. A casual check of bird residents revealed no effects on the group. No attempt was made to get detailed evaluations of the spraying, since the primary objective of this particular investigation is to determine any cumulative effects from repeated yearly treatments. Exhaustive studies of both the insect and the vertebrate life will be made after the fourth or fifth annual treatment of the area, and the findings compared with the detailed information obtained prior to the first spraying.

BACK CREEK, W. VA.

A one-mile section of Back Creek, W. Va., was sprayed in 1946 with DDT in suspension at the rate of 1 pound to an acre. The results of this experimental treatment were given in the summary of DDT investigations for that year. During 1947, additional studies of the bottom fauna were made to determine the extent of recovery. Although bottom organisms were reduced 70 percent in numbers at some stations after the spraying in 1946, investigations a year later showed that recovery was practically complete.

On July 23, 1947, a 1-mile section of Back Creek was again sprayed with DDT in the same proportion as in 1946, but mixed with oil instead of held in suspension. The average quantity of DDT deposited at water level was 0.27 pound to an acre, whereas in the tests the year before a somewhat greater quantity of 0.39 pound to an acre was deposited. Some differences in effect were noted between the two types of formulations. The DDT in suspension used in 1946 did not materially reduce the numbers of the surface Coleoptera and Hemiptera. These same groups, however, were immediately and markedly affected by the lasting

surface film of the DDT in oil used in 1947. The reduction of bottom fauna in 1947, as in 1946, was very heavy and amounted to 90 percent at two of the lower stations. The bottom species affected by the oil spray were about the same as those hardest hit by the suspension. The kill of fish, also, was somewhat heavier with the oil formulation, and in contrast to the results with the DDT in suspension, a number of adult fish were among those killed.

LABORATORY TESTS

TOXICITY TO FISHES OF NEW INSECTICIDES

Tests were made at the experiment station of the Fish and Wildlife Service at Leetown, W. Va., to determine the toxicity to fishes of some of the new insecticides. Although these studies have not as yet been completed, pond and aquarium tests have shown the relative toxicities of several compounds to be about as follows:

Chlorinated camphene is considerably more toxic to fishes than is DDT and is lethal to silverling minnows, spotfin shiners, creek chubs, fallfish, and black-nosed dace in concentrations of less than 0.04 p. p. m. (parts per million). In outdoor ponds an application of 0.125 pound to an acre (0.02 p. p. m.) killed all these species, but goldfish survived.

Repeated tests on bluegill sunfish and young rainbow and brown trout indicated that bluegills were less sensitive than trout, which were killed even at concentrations of 0.005 p. p. m. (one part in 200,000,000). The threshold limit for bluegills was 0.01 p. p. m.

Benzene hexachloride is less toxic to fishes than is DDT. Application of 1 pound to an acre (0.18 p. p. m.) in a field formulation [3] on daphnia ponds did not kill bluegill sunfish, goldfish, creek chubs, black-nosed dace, common shiners, fallfish, blunt-nosed minnows, sculpins, golden shiners, and darters. In aquaria, inch-long bluegills tolerated concentrations of 0.45 p. p. m.

A comparison of the beta, delta, and gamma isomers and their effects on rainbow and brown trout at 0.05, 0.2, and 0.5 p. p. m. in acetone solutions of the pure chemicals showed a marked difference in toxicity to the fish. Gamma isomer killed all fish exposed at these rates; beta isomer showed no effect; and delta at the two higher levels produced symptoms of toxicity (pectoral fins forward, locomotion affected), but the fish recovered. Rainbow trout were more susceptible to the gamma isomer than were brown trout.

[3] Field formulation:
1 lb. tech. benzene hexachloride (12 percent gamma isomer)
2,846 ml. aux. solvent (PD–544–B)
Fuel oil No. 2 to make 1 gallon.

Chlordan is less toxic to fishes than is DDT but more toxic than benzene hexachloride. Applications of 1 pound to an acre to outdoor ponds killed 87 percent of the bluegill sunfish. With applications of 0.5 pound to an acre most of the bluegills as well as other species survived, and with those of 0.25 pound to an acre practically all fishes survived. A 12-percent chlordan solution (wt/vol) in fuel oil was used in all applications.

TEPP (Tetraethyl-pyrophosphate). Tests with TEPP indicate its toxicity to fishes is comparable with that of DDT. Concentrations of 0.25 p. p. m. or more were found to be lethal in aquarium tests.

Parathion. In the purest form available parathion did not kill one-inch rainbow and brown trout at 0.063, 0.189, and 0.378 p. p. m. Experimental work on the effects of this insecticide has not been completed. The observation, however, that 0.2 p. p. m. is near the threshold point for bluegills was confirmed. Preliminary experiments with 25-percent emulsifiable parathion powder on bluegill sunfish showed scattered mortality at 0.1 and 0.2 p. p. m., and approximately 50 percent mortality at 0.3 p. p. m.

Bis (p-chlorophenoxy) methane was tested only with bluegill sunfish approximately 1 inch long. There was no mortality at 0.05 p. p. m., and very low mortality at 0.10 p. p. m. All fish treated died when the concentration reached 0.2 p. p. m.

EFFECTS OF DDT ON OYSTERS

DDT is being widely used for mosquito control in many salt-water areas and for control of flies in fish-packing areas. The spraying of piles of oyster shells with DDT to eliminate fly nuisance is a rather common practice. As these same shells may be used as cultch for a new generation of oysters, it is important to know whether spraying them with DDT will inhibit their later use for collecting young oysters.

To determine some of the relationships between insect control through the use of DDT and oyster management, a number of studies were carried on at the Milford Biological Laboratory, Milford, Conn. The results of these investigations have been reported in a manuscript [4] prepared for publication by V. L. Loosanoff, C. A. Nomejko, and F. D. Tommers, from which the following summary is taken:

Neither DDT nor kerosene alone substantially depressed the rate of setting of oysters, but the combined effects of DDT and kerosene reduced the setting on shells dipped for 30 seconds in a 5-percent solution of DDT in kerosene.

The effect of the DDT solution was not noticeably diminished even when shells were dipped in the solution several weeks before planting them.

[4] Effects of DDT on oysters, by V. L. Loosanoff, C. A. Nomejko, and F. D. Tommers. [Unpublished.]

DDT in emulsion appeared to be more toxic than in a solution of the same concentration in kerosene.

The spraying of oyster shells with a 5-percent solution of DDT in kerosene at the rate of 1 pound to an acre did not interfere with the setting of oysters. Spraying the same solution at the rate of 3 or 5 pounds of DDT to an acre, however, may somewhat affect the intensity of setting, although this was not clearly shown in the experiments.

The spraying of oyster beds with DDT solution or emulsion at the rate of 1½ pounds of DDT to an acre caused no unusual mortality among adult or young oysters. Beds sprayed with DDT emulsion usually showed a lighter set than did the untreated control beds or beds sprayed with a 5-percent DDT solution in kerosene.

DDT-painted vertical concrete collectors had somewhat fewer oysters than the kerosene-painted collectors or those in the untreated control beds. Untreated controls collected the largest number of spat.

No significant difference was found in the average size of oysters on the untreated and the DDT-treated collectors.

The dipping of adult oysters in a 5-percent solution of DDT and kerosene resulted in the same rate of mortality as that of oysters dipped in kerosene without DDT. It did not significantly affect their rate of growth or increase in weight.

The shell movement of oysters kept in aquaria to which a 5-percent solution of DDT was added in quantities of approximately 5 pounds of DDT to an acre was not different from that of control oysters. No mortality was observed during exposure ranging from about 5 to 8 days and for 6 weeks after exposure.

Oysters kept in a concentration of one or two parts of DDT in emulsion per million parts of water, although showing abnormal shell movements, survived periods of exposure ranging from about 5 to 8½ days. It is doubtful, therefore, that sufficient concentrations created under natural conditions for comparatively short periods would seriously affect adult oysters.

The treatment of oyster shells with a solution or emulsion of DDT virtually prevented the setting of barnacles.

CHRONIC TOXICITY TO QUAIL OF NEW INSECTICIDES

Several new insecticides were tested at the Patuxent Research Refuge for their chronic effect on quail. For these tests, four floorless brooder coops each having a base area of 46.7 square feet were used to confine groups of 20 quail (10 males and 10 females). In the first test, the effects of spraying the habitat were studied. Wettable mixtures of DDT, DDD (dichlorodiphenyldichloroethane), benzene hexachloride, and chlorinated camphene were applied to the vegetation in the pens, one mixture to

a pen, at the rate of 5 pounds of the toxicant to an acre. Water and a full diet of untreated food were provided the birds. All vegetation in the pens was consumed by the quail within two to three days, and the birds showed no ill effects or loss in weight when the test terminated on the 10th day.

These quail were then placed on a diet that included 0.025 percent of the same toxicant previously sprayed in their respective holding pens. The 0.025 percent represented the quantity of DDT in the diet that had previously been found lethal for 50 percent of young quail over a period of 2 months. All the feed mixtures were readily accepted.

The first signs of abnormal behavior (extreme excitability) among these quail were noted among the DDT-fed birds on the 8th day. The first mortalities occurred in the same group, when 3 individuals died on the 11th day. On the 14th day a female on the DDD diet was found dead, and a second female from the same group found moribund in the morning of that day died during the day without showing unusual symptoms. No other mortalities occurred among any of the test groups until the 32d day, when a female on the chlorinated camphene diet died. This quail at the beginning of the test period was lighter in weight than the average weight of the birds and may have had more than an average susceptibility to the poison. On the 34th day a male on the benzene hexachloride diet died. No other losses were recorded up to the 44th day when tests were terminated. The total losses attributed to poisoning by the insecticides were: DDT-fed birds, 3 deaths; DDD-fed birds, 2 deaths; benzene-hexachloride-fed birds, 1 death; and chlorinated-camphene-fed birds, 1 death (questionable). Weight records for the quail in these tests showed no marked differences, although DDT-fed birds, which suffered the highest mortality, also showed the least gain in weight.

Some of the toxicants used in these tests may be stored in body tissue, and so animals held on a sublethal diet may accumulate considerable quantities of the poison. Other studies have shown that acute toxic symptoms may appear when partial starvation causes a utilization of fat reserves and a release of the stored toxicant. An attempt was made to determine this point for the quail given the diets just described. At the conclusion of the feeding tests all food was withheld for an interval of two days. A quantity of feed adequate for one day of feeding was then provided each group, and a second 2-day period of starvation was imposed. This treatment had no apparent effect on any of the test groups.

SUMMARY

Investigations during 1947 of insecticide-wildlife relationships included field and laboratory tests, and evaluations of actual operations.

In one area of more than 400,000 acres of forest land in Idaho, DDT in oil was applied by airplane at the rate of 1 pound to an acre for control of the Douglas fir tussock moth. Studies near the center of a large, continuously treated block indicated about the same wildlife effects as had previously been found in smaller units. Birds and mammals were unaffected. Fishes were affected but slightly in the area as a whole, but rather heavy losses of some species were noted in limited regions. Uneven spray distribution or unintentional retreatment may have been the cause for the heavy fish kill in some parts of the area.

In two forest areas in Wyoming aerial applications were made of DDT in quantities of 5 to 10 pounds to an acre and of the gamma isomer of benzene hexachloride in quantities of 1 and 2 pounds to an acre. In the tests on the Teton National Forest, treatments of 5 and 7½ pounds to an acre caused heavy bird damage, and there were indications that mammals were also affected by the heavier application. The destruction of fishes was not so heavy as has been found elsewhere with much lighter dosages. A continuous chain of beaver dams, which retarded the flow of the stream and reduced the mixing of the DDT-oil solution with the muddy, debris-filled water, probably minimized the effects of the spray.

None of the experimental applications of DDT and benzene hexachloride in tests in the Black Hills produced measurable effects on birds or on five species of live-trapped mammals. The small size of the plots and the fact that the birds were through nesting and so not restricted to territories probably lessened the possibilities of poisoning.

Evidence that the size of the treated area and the time of spraying with reference to seasonal bird activity may strongly modify spraying effects was also found in studies made near Albany, Ga., where DDT at the rate of 2 to 6.5 pounds to an acre was applied to an area in pecan weevil control operations.

Indications of a heavy song-bird mortality were found in preliminary studies in a Maryland apple-orchard district where seasonal totals of more than 50 pounds of DDT to an acre had been used.

In an experimental program of tick control in Texas in which DDT dust in the quantity of 4.36 pounds to an acre was used, there was a 50-percent reduction in the bird population. Mammals were slightly affected, if at all, and some kill of amphibians and reptiles was observed.

In a Maryland woodland the experimental aerial treatment of

scrub and sapling growth with 5 pounds of DDT to an acre caused a heavy bird mortality. Three of the commonest species were reduced 80 percent in numbers, and the total reduction for the 5 commonest species was 65 percent.

The aerial application of DDT in oil at a rate of 1 pound to an acre to a 1-mile section of Back Creek, W. Va., caused a nominal kill of fishes but a heavy kill of bottom fauna. At the lower end of the 1-mile section more than 90 percent of the aquatic organisms were killed.

Laboratory tests of several new insecticides showed that chlorinated camphene was considerably more toxic to fishes than was DDT; TEPP (tetraethyl-pyrophosphate), parathion, and bis (p-chlorophenoxy) methane were about of the same toxicity as DDT; and chlordan and benzene hexachloride were slightly less toxic in field formulations. In chronic toxicity tests with quail, DDT appeared to be slightly more toxic than were DDD, benzene hexachloride, and chlorinated camphene. The last named was apparently the least toxic of the group.

Detailed studies of the effects of DDT on oysters indicated that these shellfish are fairly resistant. Spraying of oyster beds at the rate of 1½ pounds of DDT to an acre, applied either as an emulsion or in an oil solution, caused no mortality among adults or young. Application rates up to 5 pounds to an acre showed no evidence that spraying shell piles for fly control appreciably reduced the value of the shells for collecting set. In fact, spraying the shells with DDT appeared to have a positive value in that it prevented the attachment of barnacles.

RECOMMENDATIONS FOR MINIMIZING DANGER TO WILDLIFE

Additional investigations have shown no cause for modifying appreciably the recommendations given first in Fish and Wildlife Circular 11, DDT: Its Effect on Fish and Wildlife, and restated in the summary of the 1946 studies. With minor revisions these are given again herein:

Use DDT for the control of an insect pest only after weighing the value of such control against the harm that will be done to beneficial forms of life. Wherever more than a small area is involved, consult county agricultural agents, State or Federal entomologists, wildlife and fishery biologists, and United States Public Health Service officials.

Use DDT only where it is needed, and in all cases use only the minimum quantity necessary for control. Wherever it is applied by airplane, provide careful plane-to-ground control to insure

even coverage and to prevent local overdosage.

Because of the sensitivity of fishes and crabs to DDT, avoid, as far as possible, direct applications to streams, lakes, and coastal bays.

In aerial applications over aquatic areas, use one-fifth pound or less of DDT to an acre in oil solution to avoid damage to fishes, crabs, or crayfishes. If treatment is repeated several times in a season, use one-tenth pound to an acre or less. As a greater percentage of the applied dosage is deposited at the water surface by most ground methods of application, these dosages should be reduced by 50 percent when ground spray equipment is used.

In forest areas use less than 2 pounds of DDT to an acre to avoid damage to birds, amphibians, and mammals. Because of its great toxicity to many aquatic forms, use smaller quantities of DDT in emulsions.

Wherever DDT is used, make careful before and after observations of mammals, birds, fishes, and other wildlife.

In the control of early appearing insect pests, apply DDT, if possible, just before the emergence of leaves and the main spring migration of birds; for late appearing pests, delay applications, whenever practicable, past the nesting period of birds. Adjust crop applications and mosquito-control applications so far as possible to avoid the nesting period.

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