EFFECTS OF PESTICIDES ON FISH AND WILDLIFE IN 1960

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF SPORT FISHERIES AND WILDLIFE
Circular 143

United States Department of the Interior...Stewart L. Udall, Secretary
Frank P. Briggs, Assistant Secretary
Fish and Wildlife Service...........Clarence F. Pautzke, Commissioner
Bureau of Sport Fisheries and Wildlife......Daniel H. Janzen, Director
Bureau of Commercial Fisheries...........Donald L. McKernan, Director

EFFECTS OF PESTICIDES ON FISH AND WILDLIFE:

A REVIEW OF INVESTIGATIONS DURING 1960

Fish and Wildlife Service
Circular No. 143

Washington : 1962

FOREWORD

The Fish and Wildlife Service is the agency of the Federal government responsible for conservation of wildlife in the United States. In Public Law 85-582, the Service was specifically directed to evaluate the effects of pesticides on wildlife, to assist in the development of chemicals and techniques to minimize losses, and to inform the public of its findings and recommendations.

This report summarizes research findings for 1960, and also some earlier work of the Bureau of Commercial Fisheries. Reports published by Service personnel in 1960 are reviewed, and progress is reported for research studies underway. Certain publications appearing in 1960 that were prepared by other scientists are reviewed also. Separate accounts summarize the studies of the Branch of Fisheries Research and the Branch of Wildlife Research, both in the Bureau of Sport Fisheries and Wildlife, and the Branch of Shellfisheries of the Division of Biological Research in the Bureau of Commercial Fisheries. Recommendations are made for the use of pesticides that will cause minimum damage to wildlife; and additional research needs are outlined.

CONTENTS

Page

GENERAL INTRODUCTION 1

EFFECTS ON WILDLIFE, by James B. DeWitt, D. Glen Crabtree, Robert B. Finley, and John L. George 4

Laboratory Studies and Toxicology 4

Enclosure Studies 6

Effects of Field Treatments 7

Forest Insect Control 7

Spruce Budworm 7
Gypsy Moth 7

Protection of Yards, Gardens, and Ornamental Trees 8

Dutch Elm Disease 8
Crab Grass 8

Agricultural Pest Control 8

Imported Fire Ant 8
Japanese Beetle 11
Crop Insects in the Klamath Basin 11
Seed Protectants 11

Orchard Pest Control 12

Range Pest Control 12

Aquatic Pest Control 12

Mosquitoes and Other Insects 12
Aquatic Plants 13
Clear Lake Gnat 13
Fish Population Control 13

Miscellaneous Control Measures 14

DDT and Malathion Applications to Scout Jamboree Site 14
Aldrin Contamination of Lakes at the Rocky Mountain Arsenal 14

EFFECTS ON SPORT FISHERIES, by Oliver B. Cope.................... 16

Laboratory Studies and Toxicology.................... 16

Imported Fire Ant.................... 16
Chronic Effects of DDT and Heptachlor.................... 16
Toxicant Tolerance Tests.................... 17
Residue Analyses.................... 17

Effects on Field Populations.................... 17

Forest Insect Control.................... 17

Spruce Budworm.................... 17
Elm Spanworm.................... 18
Antibiotics and White Pine Blister Rust.................... 18

Agricultural Pest Control.................... 18

Imported Fire Ant.................... 18
Alfalfa Weevil.................... 18
Beet Insects.................... 19

EFFECTS ON COMMERCIAL FISHERIES, by Philip A. Butler.................... 20

Toxicity Studies.................... 21

Phytoplankton.................... 21
Crustacea.................... 21
Mollusks.................... 22
Eggs and Larvae.................... 22
Mature Oysters.................... 22
Fish.................... 23

General Considerations.................... 23

Studies Reported During 1960.................... 24

ADDITIONAL WILDLIFE RESEARCH NEEDED, by Daniel L. Leedy.................... 25

ADDITIONAL SPORT FISHERIES RESEARCH NEEDED, by Oliver B. Cope.................... 27

ADDITIONAL COMMERCIAL FISHERIES RESEARCH NEEDED, by Philip A. Butler...... 28

RECOMMENDATIONS FOR MINIMIZING DANGERS OF PESTICIDES TO FISH AND WILDLIFE. 29

TABLE 1. Quantities of pesticides causing 50 percent mortality of quail and pheasants: Summary of feeding tests at Patuxent Wildlife Research Center during 1960.................... 31

2. Quantities of pesticides causing 50 percent mortality of mallard ducks: Summary of feeding tests at Patuxent Wildlife Research Center during 1960.................... 34

3. Heptachlor epoxide content of tissues of birds from areas treated with 2 pounds of heptachlor per acre.................. 35

4. Heptachlor epoxide content of tissues of mammals, reptiles, amphibians, fish, and crustaceans from areas treated with 2 pounds of heptachlor per acre.................................. 37

5. Heptachlor epoxide content of individual tissues of mammals and reptiles from areas treated with 2 pounds of heptachlor per acre.. 38

6. Heptachlor residues in woodcock................................ 39

7. Mortality of bobwhite quail kept in enclosures where the ground was treated with heptachlor............................ 40

8. Summary of quail populations as indicated by dog censuses on treated and untreated areas.................................. 41

9. Pesticide residues in fish-eating birds from Tule Lake and Lower Klamath Refuges, 1960.................................. 42

10. The highest concentration of a selected series of pesticides tolerated by 5 kinds of phytoplankton utilized by molluscan larvae as food.. 42

11. Preliminary data on the concentration of certain pesticides required to cause paralysis in small, 25 mm, stone crabs within 24 hours.. 43

12. Preliminary data on the toxicity of a selected series of pesticides to medium size brown and white shrimp. Values shown are 48-hour median tolerance limit in parts per billion... 43

13. Preliminary data on the effects of selected pesticides on mollusks at a concentration of 1.0 ppm. Figures represent approximate percentages of development or growth as compared with untreated control cultures................................ 44

14. Percentage decrease in growth of mature oysters compared with control animals after 7 days exposure to a concentration of 0.1 ppm of the indicated pesticide........................... 44

15. Toxicity of 55 commonly used pesticides (the approximate lethal dose or levels in diet reducing reproduction 25 percent or more) to bobwhite, ring-necked pheasant, and mallard........... 45

FIGURE 1. Effects of toxaphene on 1½-inch oysters....................... 48

REFERENCES.. 49

EFFECTS OF PESTICIDES ON FISH AND WILDLIFE:

A REVIEW OF INVESTIGATIONS DURING 1960

GENERAL INTRODUCTION

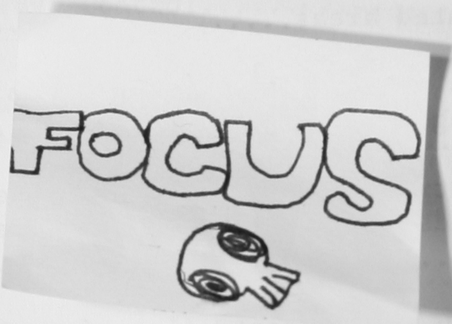
Pesticide use in 1960, as indicated by total sales volume, increased only slightly over 1959. Total sales volume in the United States, as reported by the National Agricultural Chemicals Association, was $285 million at the manufacturer's level, an increase of 3 percent (Agricultural Chemicals, 1961a). Production volume increased for certain important chemicals. DDT production was greater than ever before for the third successive year, and both 2,4-D and 2,4,5-T were produced in larger quantities than in any previous years. Total volume of synthetic organic pesticidal chemicals produced, rose 9.2 percent over 1959 to 638 million pounds (Shepard, et al., 1961). The number of products listed in the 1960 Pesticide Handbook (Frear, 1960) was 7,851 compared with 7,041 in the 1959 edition. Total production of all pesticidal chemicals, including inorganic compounds, is approximately 1 billion pounds (Shepard, et al., 1960).

Forest area treatments for spruce budworm control covered about 360,000 acres in 1960, considerably less than in 1959. Compilations by the U. S. Department of Agriculture (Hall, unpubl.) indicate that during the past several years an average of about 1.8 million acres of forests have been treated with insecticides each year, but this is still only a fraction of 1 percent of the total forest area of 640 million acres in the United States.

Insecticidal treatments of rangelands are also limited. Compilations by the U. S. Department of Agriculture (Hall, unpubl.) indicate these treatments have averaged about 1.6 million acres per year during the past several years, and this is a fraction of 1 percent of the 630 million acres of permanent range and pasture land in the United States. Herbicidal treatment of rangeland is growing in importance (George, 1960d).

Most pesticides are applied as a part of various agricultural pest control activities. It is estimated by agricultural experts of the U. S. Department of Agriculture that almost 69 million acres, or about 15 percent of the 465 million acres of cropland, are treated each year with insecticides (Hall, unpubl.; Wooten and Anderson, 1958). Herbicidal treatment is growing in importance as annual treatments total about 50 million acres today (Ennis, 1960).

The program for control of the imported fire ant continued in the South, with extensive treatments of pastures and agricultural land. Toward the end of the year, however, recommended treatment levels were reduced. Consequently, new agricultural areas received two applications of ¼ pound heptachlor per acre rather than a single treatment of 1¼ or 2 pounds per acre. Studies to find other chemicals suitable for fire ant control also were underway in 1960.


FOCUS

EFFECTS OF PESTICIDES ON FISH AND WILDLIFE:

A REVIEW OF INVESTIGATIONS DURING 1960

GENERAL INTRODUCTION

Pesticide use in 1960, as indicated by total sales volume, increased only slightly over 1959. Total sales volume in the United States, as reported by the National Agricultural Chemicals Association, was $285 million at the manufacturer's level, an increase of 3 percent (Agricultural Chemicals, 1961a). Production volume increased for certain important chemicals. DDT production was greater than ever before for the third successive year, and both 2,4-D and 2,4,5-T were produced in larger quantities than in any previous years. Total volume of synthetic organic pesticidal chemicals produced, rose 9.2 percent over 1959 to 638 million pounds (Shepard, et al., 1961). The number of products listed in the 1960 Pesticide Handbook (Frear, 1960) was 7,851 compared with 7,041 in the 1959 edition. Total production of all pesticidal chemicals, including inorganic compounds, is approximately 1 billion pounds (Shepard, et al., 1960).

Forest area treatments for spruce budworm control covered about 360,000 acres in 1960, considerably less than in 1959. Compilations by the U. S. Department of Agriculture (Hall, unpubl.) indicate that during the past several years an average of about 1.8 million acres of forests have been treated with insecticides each year, but this is still only a fraction of 1 percent of the total forest area of 640 million acres in the United States.

Insecticidal treatments of rangelands are also limited. Compilations by the U. S. Department of Agriculture (Hall, unpubl.) indicate these treatments have averaged about 1.6 million acres per year during the past several years, and this is a fraction of 1 percent of the 630 million acres of permanent range and pasture land in the United States. Herbicidal treatment of rangeland is growing in importance (George, 1960d).

Most pesticides are applied as a part of various agricultural pest control activities. It is estimated by agricultural experts of the U. S. Department of Agriculture that almost 69 million acres, or about 15 percent of the 465 million acres of cropland, are treated each year with insecticides (Hall, unpubl.; Wooten and Anderson, 1958). Herbicidal treatment is growing in importance as annual treatments total about 50 million acres today (Ennis, 1960).

The program for control of the imported fire ant continued in the South, with extensive treatments of pastures and agricultural land. Toward the end of the year, however, recommended treatment levels were reduced. Consequently, new agricultural areas received two applications of ¼ pound heptachlor per acre rather than a single treatment of 1¼ or 2 pounds per acre. Studies to find other chemicals suitable for fire ant control also were underway in 1960.

Bureau personnel were able to make wildlife observations as part of certain preliminary trials of kepone. Wildlife observations also were made on areas in Montana where experimental studies of grasshopper control were being conducted.

Field studies of wildlife effects were made in 1960 in connection with a relatively small number of pest control programs in forests and on agricultural lands. No studies at all were made of the effects of certain other treatments. The program for control of the white-fringed beetle is one of the most extensive; 139,000 acres were treated in 1960. Recommendations call for treatment of non-tilled lands with 3 pounds of dieldrin per acre and for treatment of farmlands with 2 pounds of heptachlor, 5 pounds of chlordane, 10 pounds of DDT, or 1½ pounds of dieldrin per acre (U. S. Department of Agriculture, unpubl.). Chemical treatments of yards, gardens, and ornamental trees are made privately by enough different people to warrant serious consideration, since 18.6 million acres are devoted to non-farm residences (Barlowe, 1958).

Agricultural experts indicate over 28 percent of the 53 million acres in urban, industrial, and other built-up areas are treated with insecticides, and dosage is heavy; yards and gardens are among the lands most heavily treated with insecticides (Hall, unpubl.).

Treatment for crab grass control requires very heavy dosages of such chemicals as chlordane and arsenic. About 10 million pounds of organic arsenicals were used for crab grass control in 1959 (Shepard, et al., 1961).

Orchards totaled about 3 million acres; dosages are heavy and about 80 percent of the area has been treated (Hall, unpubl.). Treatments have affected wildlife populations to an unknown degree. Mosquito control is a continuing program in many areas; there is a nationwide group of full-time professional workers organized into local abatement districts for this sole purpose. Applications to saltmarsh areas alone are estimated to exceed 2 million acres (Hall, unpubl.). Plant control by chemicals is increasing rapidly. Efforts include large-scale programs to change habitats from brush or woodland to rangeland, as well as to change plant composition in forest stands. Herbicides also are being used to remove plants from waterways, lakes, and irrigation ditches. About 50 million acres of agricultural land are treated with herbicides (Ennis, 1960). Chemicals have been used to control fish of unwanted kinds, and can be expected to be used further. A fish control laboratory is under construction at LaCrosse, Wisconsin, and will be completed in March 1961 (U. S. D. I., 1960).

Many important research facts concerning pesticides were summarized in 1960 at a symposium sponsored by the Agricultural Research Service (A. R. S., 1960). The symposium, entitled "The Nature and Fate of Chemicals Applied to Soils, Plants, and Animals," included 22 separate reports. In one of these reports, Westlake and San Antonio (1960) stated that recent observations by entomologists showed that insecticidally effective compounds were present in the aerial parts of plants grown in soil treated with heptachlor. These observations were not in agreement with the general assumption that compounds having very low solubility in water are not translocated to any appreciable degree.

The same authors showed the persistence of certain chemicals in soils on Plant Industry Station test plots. Chlordane, for example, diminished from somewhat more than 80 ppm in 1952 to somewhat less than 60 ppm in 1954, but still was above 50 ppm in 1958.

The importance of the physical condition of the animal to its susceptibility to poisoning was discussed by Radeleff and Bushland (1960), who found that "emaciation and lactation, singly or in combination, predisposed sheep . . . and probably cattle to poisoning by certain of the chlorinated hydrocarbons . . ." In contrast, in an experiment with Dipterex, ". . . when the rabbits were under stress, struggling against restraint, neither stableflies nor screwworms were destroyed. When doses ordinarily toxic for the rabbit were given, no symptoms appeared." These authors also discussed the symptoms and lesions of poisoning by several compounds, the difficulties of diagnosis, and, in particular, the problems of interpreting residues in diagnosis.

Entomological research needs listed by E. F. Knipling, Director, Entomology Research Division, Agricultural Research Service, U. S. Department of Agriculture, in his symposium report (Knipling, 1960) include studies of methods of insect control that would increase specificity and reduce hazards. Types of studies listed included development of insect attractants, study of insect diseases and parasites as control agents, search for insect-resistant varieties of plants, and development of control methods by introduction of sterile males in the population.

Dr. A. Perry, of the U. S. Public Health Service, stated that pesticides should be developed that could be prescribed for a particular need without risking the hazards of present insecticides (Agricultural Chemicals, 1961b).

The magnitude of the pesticide-wildlife research program depends partly on funds allotted to it. As recently as 1958, the annual amount available for research on this problem was $56,000 or less. In 1958, Public Law 85-582 expressed the interest of Congress in this problem and authorized $280,000 per year to be spent on research. Appropriations were raised to $181,000 in 1959 and $280,000 in 1960. Public Law 86-279, passed in 1959, increased the authorized amount to $2,565,000, and $615,000 was appropriated in 1961, and $684,000 in fiscal year 1962 (beginning July 1, 1961).

While expenditures for research in pesticide-wildlife relations were increasing, the demand for wildlife resources also was increasing. Hunting and fishing visits on the national forests increased 18 percent in 1959 over 1958, from 17 million to 20 million visits (U. S. D. A. 541-60). The Fish and Wildlife Service has contracted with the Bureau of the Census to determine the value of expenditures in fishing and hunting in 1960 (U. S. D. I., 1960). In 1955, a similar survey indicated about $3 billion were spent by 24 million licensed sportsmen. The esthetic appeal of wildlife, although more difficult to measure, is considered invaluable by the Service. Most visitors to wildlife refuges come to enjoy the living natural resources.

EFFECTS ON WILDLIFE

by

James B. DeWitt, D. Glen Crabtree,
Robert B. Finley, and John L. George
Branch of Wildlife Research
Bureau of Sport Fisheries and Wildlife

The effects of pesticides on wildlife are discussed in three sections of this report: Laboratory Studies and Toxicology, Enclosure Studies, and Effects on Field Populations.

Reports of Bureau work in progress or not yet prepared for publication have not been credited to individual workers. Biologists and chemists responsible for these studies at the Patuxent Wildlife Research Center, Laurel, Maryland, include James B. DeWitt, John L. George, Calvin M. Menzie, Vyto A. Adomaitis, William L. Reichel, Walter Rosene, Jr., Paul A. Stewart, and William H. Stickel; at the Denver Wildlife Research Center, D. Glen Crabtree, Robert B. Finley, Vernon A. Perry, James E. Peterson, Richard E. Pillmore, William H. Robison, and James R. Tigner; and at the Alabama Cooperative Wildlife Research Unit, Maurice F. Baker. Other staff members who participated in the studies include Clyde Vance, James W. Spann, Charles V. Beth, Malcolm M. Exedine, Steve Leskosky, and Donald Landon.

Suggestions and comments concerning the preparation of the report were made by Daniel H. Janzen, Director of the Bureau of Sport Fisheries and Wildlife and Lansing A. Parker, Assistant Director. The following persons reviewed the manuscript: Daniel L. Leedy, C. Edward Carlson, Eugene H. Dustman, and Walter W. Dykstra, in the office of the Branch of Wildlife Research; Cecil S. Williams at the Denver Wildlife Research Center; John L. Buckley, Don W. Hayne, Paul F. Springer, William H. Stickel, and Lucille F. Stickel, at the Patuxent Wildlife Research Center. Mrs. Frances Fochler aided in assembling reference materials and in preparing copy.

Laboratory Studies and Toxicology

Quail, Pheasants, and Mallards: Feeding Tests

More than 400 toxicological tests involving 27 pesticides were conducted at the Patuxent Wildlife Research Center during 1960. Tests with herbicides were initiated as part of a plan to maintain several generations of quail, pheasants, and ducks on diets containing sublethal amounts of these compounds. Preliminary results indicated that the amide of 2,4-D was the most toxic derivative tested, but all phenoxy herbicides tested appeared to act as cumulative poisons.

Results of the feeding tests in 1960 are summarized in table 1.

Dibrom and Sevin, which are being tested for the control of mosquitoes and forest insects, showed relatively low toxicities in feeding tests. Dibrom was tested on quail chicks, and Sevin was tested on young and adult quail and pheasants. Phosphamidon, another compound proposed for use in forest insect control, was found to be very toxic to young quail (table 1).

Effects of kepone, Sevin, methoxychlor, and heptachlor on reproduction were studied in chronic feeding tests. Kepone, which is moderately toxic (table 1), completely inhibited reproduction of quail when it was included in winter and spring diets at the rate of 50 ppm. Pheasant reproduction was almost completely inhibited at both 25 ppm and 50 ppm (0.7 and 0.5 viable chicks per hen as compared with 13.3 for controls). Reproduction of quail was sharply reduced when the diet contained 1, 5, 10, or 25 ppm of kepone in both winter and reproductive periods. Many of the chicks were crippled or defective at hatching. Pheasants fed diets containing 5 or 10 ppm of kepone produced less than 50 percent of the number of viable chicks produced by the controls. Male pheasants reared on diets containing 50, 100, or 150 ppm of kepone did not develop characteristic coloration; their plumage resembled that of adult females. Histopathological examinations of these birds revealed marked abnormalities of testicular tissue and the presence of numbers of malformed sperm.

Pheasants whose winter and spring diets contained 5,000 ppm of Sevin, 2,500 ppm of methoxychlor, or 25 ppm of heptachlor produced no viable chicks. Reproduction of pheasants fed at these levels during the winter, but given insecticide-free food from the beginning of the reproductive period also was affected. Results of these tests and of studies with other compounds (table 15) indicated that the effects of insecticides on pheasant reproduction were roughly proportional to the percentage of the lethal dose that had been ingested.

Woodcock

Methods for keeping woodcock in relatively small cages were developed at Patuxent to facilitate toxicological studies. Woodcock from Massachusetts supplied by Dr. W. G. Sheldon were given capsules containing heptachlor in widely varying amounts and in several different formulations. Healthy, cage-hardened woodcock eliminated the chemical so rapidly through the intestines that no acute oral toxicity figures were obtained. Methods were developed experimentally for producing groups of earthworms carrying different amounts of heptachlor and heptachlor epoxide, and future tests will present heptachlor in living food.

Ducks Fed Contaminated Snails

At the Denver Wildlife Research Center, a mallard and a pintail were fed living aquatic snails containing aldrin and dieldrin acquired from a lake at the Rocky Mountain Arsenal. Both ducks, still apparently healthy, were killed and analyzed after 6 weeks. Whereas a random sample of snails contained 7 ppm of dieldrin, the whole-body analyses of the mallard and pintail revealed only

6 ppm and 5 ppm. If all the insecticide contained in snails had been retained in the ducks, their tissues would have contained 40-45 ppm of the chemicals.

Pesticidal Residues in Animals Collected in the Field

Chemical analyses at the Patuxent laboratory showed pesticidal residues in the majority of animals either shot or found dead on areas treated with heptachlor. The levels of chemical content are shown in tables 2-5. Eighty percent of the 41 bobwhite quail, 90 percent of the 20 mourning doves, and all 5 of the rails from areas treated for fire ant control contained heptachlor epoxide in edible tissues.

Woodcock from both northern and southern areas were analyzed for heptachlor content, with results as shown in table 5. Portions of the woodcock wintering range in Louisiana are adjacent to, or are included in, lands that have been treated with heptachlor for control of imported fire ants. Only minute traces of heptachlor residues were found in woodcock collected shortly after arrival on the winter range in 1958, but subsequent collections and analyses showed progressive increases in the percentage of birds containing heptachlor epoxide, and in the concentrations of the toxicant in body tissues. Heptachlor residues were found in immature birds collected in New Brunswick in 1959, but have not been detected in immature birds from other northern areas.

Enclosure Studies

Bobwhite quail were kept in outdoor pens, on ground treated with heptachlor, in a series of experiments at the Patuxent Center. In breeder pens (3 x 10 feet), heptachlor was applied as 10 percent granules at seven different rates from 0.25 to 2.00 pounds of heptachlor per acre. For each of the seven treatment rates, there were five different combinations of methods of presenting food and water as shown in table 7. Thus there were 35 different treatment combinations. Each of the 35 treatment combinations was tested twice, using groups of two quail in each experiment. These tests were continued for 14 days unless the birds died sooner. Results are given in table 7.

In a 1/200-acre cage (10 x 22 feet), there were additional tests of the 2-pound per acre treatments. These were made with groups of 6 or 20 birds, and the tests were continued for 30 days, unless the birds died sooner.

Results for both series are shown in table 7. A greater proportion of the birds died when food was scattered on the ground than when it was kept clean in containers, and a greater proportion died when heptachlor was applied at the higher rates; but further experiments are necessary before the effect of such treatments can be predicted fully.

Effects of Field Treatments

Forest Insect Control

Almost one-third of our land area is in forest (Wooten and Anderson, 1958). During 1960, there were only a few Federal and State cooperative pest control programs involving more than 100,000 acres each. Both were spruce budworm control programs, one in Maine (217,000 acres) and one in Montana (118,000 acres). The total acreage treated was 376,000 acres. This acreage is considerably less than that treated in past years.

The acreage of private applications is not known. It is known that many private timber companies use herbicides in maintaining their forests. In the South, chemical company experts estimate this has amounted to less than 2 percent of the private acreage. A general summary of the effects on wildlife of chemicals used in forests was prepared by Service personnel (George, 1960a).

Spruce Budworm.--An area of 217,000 acres in Aroostook County, Maine, was treated in June at the rate of 1 pound of DDT per acre. Treatments made in this same county in 1958 resulted in considerable fish mortality and reduction of aquatic invertebrates (Warner and Fenderson, 1960). In 1960, observations by biologists of the Maine Department of Inland Fisheries and Game indicated effects similar to those reported for 1958.

In Montana, in 1960, 60,000 acres in the Gallatin National Forest were treated for spruce budworm control. The rate was 1 pound of DDT per acre except near streams, where the rate was 0.5 pound per acre. The Montana State Fish and Game Commission submitted deer specimens collected from this area before and after treatment and also from an area in the Bitterroot National Forest that was treated in 1959. No detectable amount of pesticide was found in deer tissues collected before treatment. Residues were present in the deer from the Bitterroot area; analyses have not been completed for deer from the Gallatin area.

Analyses of vegetation clipped from an area in the Gallatin Forest where deer were known to feed showed significant amounts of pesticide on a dry-weight basis.

The possibility that spruce-budworm control treatments could have deleterious effects on woodcock reproduction was suggested by Wright (1960) as a result of his studies in New Brunswick.

Gypsy Moth.--Sevin and methoxychlor have been suggested as substitutes for DDT in the control of gypsy moths and certain other insect pests because of their lower toxicity to warm-blooded animals. In laboratory tests made at Patuxent, these compounds had relatively low orders of toxicity to quail and pheasants and affected reproduction only when fed at relatively high concentrations. However, exposure to sublethal concentrations of these compounds increased susceptibility to other pesticides. Intermittent exposures to relatively low concentrations of several different chlorinated insecticides over relatively short periods had more pronounced effects than continuous exposure to a greater concentration of a single compound for longer periods.

A field study of the effects of Sevin and DDT on birds was begun in the spring of 1960 by the University of Massachusetts and the Massachusetts Cooperative Wildlife Research Unit. Sevin was applied to a 500-acre area at the rate of 1 pound of chemical per acre. DDT was applied at the same rate to another 500-acre area, and a third area remained untreated as a check. Towhees and other birds were trapped and banded and search was made for nests in the preliminary parts of this study, which is being continued.

Protection of Yards, Gardens, and Ornamental Trees

There were 18,600,000 acres in non-rural homesites in 1954 (Barlowe, 1958). Many species of birds and other desirable forms of wildlife are found in urban areas. There are various treatments of individual yards and gardens and some large-scale urban treatments. The degree of contamination at present is unknown.

Dutch Elm Disease.--The effects on birds of DDT treatments for Dutch elm disease control have been studied in Wisconsin with partial financial support from the Bureau. Published reports appeared in 1960.

Hickey and Hunt (1960) studied bird mortality in two communities in Wisconsin where no elm spraying had been done previously. They estimated that no less than 86 percent of the robins died on one area. In general, there was a 3-week lag between spray treatments and robin deaths. The spraying, which was done in the tree-dormant season, did not noticeably affect May migrants through the area. A brown creeper died the day of spraying; the species besides the robin that were affected the most in the 8 weeks following included the starling, common grackle, cardinal, and yellow-shafted flicker.

In a second Wisconsin study, bird populations were studied in three communities where the trees were sprayed and in three others where they were not (Hunt, 1960). Robin populations in the sprayed communities were 69, 70, and 98 percent below the average for the unsprayed communities. Numbers of other common species censused were moderately to irregularly lower on sprayed than on unsprayed plots.

Crab Grass.--No treatments for crab grass control have been studied intensively to determine their side effects on wildlife. However, some of the treatments involve dosages of arsenic and chlordane sufficiently high to cause damage to birds, mammals, and other desirable forms coming in contact with the poison.

Agricultural Pest Control

The greatest single consumer of insecticides is the agriculturist who uses chemicals to control insect pests of crops. There are 465 million acres of cropland in the United States (Wooten and Anderson, 1958), and agricultural experts estimate about 69 million acres are treated with insecticides (Hall, unpubl.). About 50 million acres are treated with herbicides (Ennis, 1960).

Imported Fire Ant.--Approximately one million acres of farmland in the Southern States were treated with heptachlor or dieldrin during 1960 in an attempt to control this introduced pest. A special effort was made to determine the long-term effects of these treatments on birds, mammals, and important food organisms. The findings from studies made by Bureau biologists and from several conducted by cooperating State agencies provided important new data on the cumulative and residual characteristics of these pesticidal materials. These are summarized below.

1. Bobwhite and Songbirds in Wilcox County, Alabama: Treatment of 2,400 acres with heptachlor (2 lb/a) and 1,200 acres with dieldrin (2 lb/a) in March 1958 was followed by mortality and disappearance of quail and other animals, as has been reported earlier (Clawson and Baker, 1959; Baker, 1958).

A year later, in the spring of 1959, with no further treatment of the area, 33 dead specimens were found on the treated area, and none on the untreated check area. Baker (1960, unpubl.) also reported an overwinter decline of quail that appeared to be greater than normal, as well as a scarcity of meadowlarks and robins.

Earthworms collected from the heptachlor area one year after treatment contained 0.7 ppm of heptachlor epoxide; earthworms collected from the dieldrin area at the same time contained 1.5 ppm of dieldrin.

Quail census results for 1958-60 indicated that the populations returned to normal size during the second year after treatment (table 8).

2. Bobwhite in Decatur County, Georgia: Whistling cock counts and covey counts have been made on two treated study areas in Georgia and on an untreated area in Alabama each year since 1958. Heptachlor (2 lb/a) was used for most applications, dieldrin (2 lb/a) for a smaller number. Censused areas contained approximately 10,000 acres each. Initial results of the study were reported by Rosene (1958). Quail populations were low on treated areas following treatment, but increased each year thereafter. Populations appeared to be approaching a normal level in the third year after treatment.

3. Bobwhite on Experimental Kepone Area, Alabama: Kepone, which has been suggested as a replacement for heptachlor, is less toxic than heptachlor in laboratory tests, but has marked inhibitory effects upon reproduction of quail and pheasants, as discussed earlier in this report.

Field observations of birds in an area treated with kepone were made in Alabama in August. Kepone in peanut butter was applied to 480 acres at the rate of 3.5 grams of chemical per acre. The application was made as a test of the effectiveness of kepone against fire ants. Dr. Maurice Baker reported several observations of quail with tremors; some of these, and others, were subsequently found dead. Meadowlarks that appeared sick were observed also. Chemical analyses of specimens have not been completed.

4. Cotton Rats in Alabama: Cotton rats were studied on an area treated with heptachlor near Gadsden, Alabama, in early spring of 1960. The trapped plot, which contained 6.7 acres, was in the center of a 55-acre treated area. Granular heptachlor was applied March 31 at the rate of 1.25 pounds of chemical per acre. Rats were trapped on a 6.7-acre untreated area for comparison. Repetition of the study is planned for 1961. In preliminary

analysis of the data, the slightly greater decline of rats on the treated area appeared not to be statistically significant.

5. Woodcock: The principal wintering range of the woodcock is in the Gulf States, where the fire-ant control program is underway. Woodcock feed primarily on earthworms, which are known to concentrate certain insecticides in their bodies, and thus become potential sources of serious poisoning.

Several studies of woodcock were made in 1960 in an attempt to determine amounts of heptachlor carried, effects of heptachlor, and current breeding success. Toxicological tests and results of residue analyses are described earlier in this report.

Woodcock wings were solicited from hunters during the 1959-60 season so that age and sex ratios in the kill could be measured. This wing survey was undertaken with the view that similar information in succeeding years might provide a measure of breeding success. Hunters submitted 8,786 wings from 19 States and Provinces. The age ratio shown by the wings was 1.18 juveniles to 1 adult. About 50 percent of the juveniles and 40 percent of the adults were males. Mortality rates were approximated from various long-term banding studies, particularly those made in Louisiana by Leslie L. Glasgow and in Massachusetts by William G. Sheldon. If the wing-survey data are representative of the population, the overall success of reproduction in 1959 was very nearly in balance with the rate of mortality.

An exploratory trial involving measurement of woodcock use of treated and untreated fields was made in central Louisiana in the winter of 1959-60. Night counts were made on about 45 acres of a 140-acre treated area and on two untreated areas. Heptachlor had been applied to the 140-acre area in May of 1959, after woodcock had left for the northern breeding grounds. The rate of application was 2 pounds of chemical per acre. Woodcock counts for the three areas were compared with each other and with counts made in previous years by Dr. Glasgow and his students. Counts on the treated field were relatively low at the beginning of the season and declined more sharply during the season than on the other fields. It seemed likely, however, that dryness and unfavorable cover conditions on the treated field contributed heavily to this decline.

Other animals than woodcock were present on the treated area in 1959-60, but satisfactory comparisons of numbers could not be made with other fields or other years. Doves, meadowlarks, and pipits roosted in large flocks on the treated field, and some individuals of these and other species were seen feeding there by day. At least three armadillos, one skunk, and one or more rabbits fed in the treated field. Leopard frogs, spring peepers, cricket frogs, and toads were fully as common on the treated field as on the other two.

Nine animals were killed for analysis and four others were found dead. A trace of heptachlor epoxide was present in one killdeer and one pipit found dead. A skunk found dead contained 3.7 ppm of heptachlor epoxide in liver tissue. A meadowlark taken alive contained 2 ppm and a woodcock taken alive contained 1.5 ppm. Animals that contained no heptachlor epoxide included one pipit, one meadowlark, one robin, four woodcock collected alive, and one woodcock found dead.

Japanese Beetle.--Chemical applications for control of Japanese beetles are made locally in many areas and there have been some large-area treatments. In the usual control operation, either aldrin or heptachlor is applied at the rate of 2 pounds of chemical per acre. Many airports are treated routinely as part of the effort to prevent introduction and spread of insect pests. The U. S. Department of Agriculture reported (USDA Press Release 1158-61) that "more than 10,000 acres of airport grounds in the northeastern Great Lakes and Middle Atlantic States" have been treated, and "eventually, all major U. S. airports will receive such treatment."

Animal specimens collected by Dr. George J. Wallace in a Michigan area treated in 1959 with 2 pounds per acre of aldrin were analyzed chemically at Patuxent. Five sparrows contained 7.7 to 15.4 ppm of dieldrin (the epoxide of aldrin, produced by metabolic processes). Seven other specimens (four blue jays, one mourning dove, and one titmouse) contained from 0.5 to 12.1 ppm of dieldrin.

The Michigan Department of Conservation conducted a planned search of aldrin-treated areas after the 1959 applications and saved the specimens for analysis. They also collected specimens in other treated areas and received specimens from the public. Analyses have not been completed.

Crop Insects in the Klamath Basin.--Between May 22 and June 2, 1960, 307 fish-eating birds were found dead on Tule Lake and the Lower Klamath Refuges in California. Water on these refuges comes from agricultural lands in surrounding areas, both on and off the refuges, in an essentially closed system of irrigation and drainage. Personnel of the Denver Wildlife Research Center and the California Department of Fish and Game participated in the investigation to find the cause of bird mortality. Chemical analyses of tissues of birds showed toxaphene content within the range of concentrations found in cases of fatal toxaphene poisoning (table 9). Birds in the field also were observed to exhibit symptoms of poisoning, which included loss of muscular coordination and convulsive extension and flexing of limbs. The California Fish and Game Laboratory found no disease organisms in birds they examined.

Toxaphene poisoning therefore was considered the probable cause of mortality. The most likely source of toxaphene was an application of 2 pounds per acre made on a 1500-acre unit of the Lower Klamath Refuge in 1958. Levels of pesticides in tissues of fish and invertebrates collected from Tule Lake did not indicate that the general irrigation system was currently contributing any great amount of pesticide. Continued sampling of water in Tule Lake was considered desirable for further information on possible future sources of pesticide contamination of refuge water areas.

Seed Protectants.--Fulvous tree duck populations are believed to be in serious danger if the practice of treating rice seed with aldrin and other toxic chemicals is continued generally within the bird's limited range in the United States. The seeds are treated as a protection against seedling blight, seed rot, birds, insects, and other possible sources of loss. Heavy mortality of birds occurred in Brazoria County, Texas, during a short period when rice was first flooded (J. R. Singleton, unpubl. report). Reports of heavy losses and greatly reduced numbers of birds also were received from Gust J. Nun, U. S. Game Management Agent, Beaumont, Texas.

Several reports indicate seed treatments have caused great damage to birds in England.

Orchard Pest Control

Most of the approximately 3 million acres of commercial orchards are heavily treated with insecticides and other chemicals (Hall, unpubl.). Although many of these areas are no longer important wildlife producing lands, some serve as sustaining areas for wildlife during the non-growing season. The use of chemicals, such as endrin, for rodenticides will affect these sustaining values of orchard land; but studies are not complete, and the full effects of orchard treatment are unknown.

Range Pest Control

The Agricultural Research Service's 1960 tests for grasshopper control in Montana included application of Sevin (8 and 4 oz/a), dimethoate (4 and 2 oz/a), and aldrin (2 oz/a) to 320-acre test plots. Biologists from the Denver Research Center made strip counts of birds and ran live-trap lines for small mammals before and after treatment on the treated plots and on a check plot. No dead animals were found and the counts showed no significant effects, but the conditions of the tests were too unfavorable to permit a judgment of whether these formulations are safe for wildlife.

A few captive animals were placed in exposure cages on a plot sprayed with dimethoate at 4 ounces per acre in an attempt to observe any direct dermal or respiratory effect of this new organophosphate insecticide. The live animals exposed to spray (one bushy-tailed wood rat, eight deer mice, two prairie rattlesnakes, and one garter snake) were kept alive at Denver for several weeks without showing symptoms of illness.

Aquatic Pest Control

Mosquitoes and other Insects.--There has been no overall survey to determine the amount of toxicants used or to map the areas and tabulate the acreages treated in mosquito control programs or programs directed against other aquatic insect pests; but there is a nationwide group of full-time professional workers organized into local abatement districts for the purpose of controlling the pests. Although dosages and amounts of chemicals often are very low, treatments of certain marsh areas before mosquito emergence now may involve dosages of 2 or more pounds of DDT per acre, and in some programs, parathion and dieldrin have been used. Although no field studies of the effects of this program on wildlife have been conducted during the past year, a summary of the effects of chemical treatments of water areas has been published (George, 1960c). A committee composed of research biologists, research entomologists, and control workers has been organized to help coordinate mosquito control and wildlife management programs without loss of wildlife. A Service representative is a member of the committee.

Aquatic Plants.--Man's growing desire to have clean canals for navigation, clean lakes and streams for swimming and boating, and irrigation ditches for agriculture, has resulted in more and more herbicidal treatments of our nation's waterways for aquatic weed control. Service investigations include a study of methods to utilize chemicals to improve wildlife habitat. There has been no overall appraisal of the effects of herbicidal treatment of waterways on wild animals, nor has there been any detailed survey of the magnitude of this problem. Available information has been summarized by Service personnel (George, 1960d).

Clear Lake Gnat.--Many western grebes were found dead on Clear Lake after DDD (also called TDE) treatments in 1954 and 1957. Nesting populations of grebes on the lake were much lower in 1958 and 1959 than in earlier years. A complete report of the Clear Lake studies of the effects on wildlife of DDD applications was published (Hunt and Bischoff, 1960). Hunt and Bischoff give strong circumstantial evidence that grebe losses occurring after DDD treatments were caused by chronic poisoning from DDD. The grebes apparently absorbed toxic materials from contaminated fish and insects. ". . . the following items indicate poisoning rather than other causes of mortality: (1) the decline in the grebe population corresponded with the period in which pesticide applications were made, (2) the absence of any known infectious disease in autopsied grebes picked up after two of the chemical treatments of the lake, (3) clinical symptoms common to poison victims were exhibited by some grebes from the lake, and (4) an abnormally high concentration of DDD was found in fatty tissue of dead grebes. Observations of dead grebes were made following each DDD application. These die-offs began one or two months after pesticide application and usually lasted several weeks. The fact that die-offs were noted during these periods only, indicates the possibility of chronic poisoning of grebes." "Differences in DDD concentrations in the fat from fish and grebes may also be interpreted to suggest that grebes show a higher susceptibility to DDD than do many fishes." Analysis of visceral fat from apparently healthy largemouth bass and white catfish indicated accumulation of DDD at levels as high as 2,275 ppm and 1,700 ppm. The highest concentration in grebe tissue was 1,600 ppm, in birds believed killed by chronic poisoning.

Chemical analyses of fish showed that "All fish . . . samples analyzed contained DDD . . . The amount of DDD found in all flesh samples exceeded the specified rate of dilution of active insecticide in the lake water on a p.p.m. basis . . . Flesh samples of largemouth bass and Sacramento blackfish hatched between seven and nine months after the last DDD application contained 22 to 25 p.p.m. and 7 to 9 p.p.m. of DDD, respectively." Plankton-eating fish accumulated less of the toxic material than carnivorous fish species of the same size. Plankton samples were taken, but they were too small to indicate DDD concentration, so data concerning chemical buildup through the entire food chain were incomplete.

Fish Population Control.--Fish populations will be subject to greater and greater control as sport fishing and recreational pressures encourage more intensive management of water resources. A fish control laboratory of the Bureau of Sport Fisheries and Wildlife is under construction at LaCrosse, Wisconsin.

Certain chemicals such as toxaphene, which have been used to kill fish, have caused damage to fish-eating birds of several types. Other chemicals are available that are toxic to fish and relatively non-toxic to warm-blooded animals.

Miscellaneous Control Measures

DDT and Malathion Applications to Scout Jamboree Site.--A 2,300-acre area near Colorado Springs was dusted with DDT (3 lb/a) and malathion (0.5 lb/a) on June 15, 1960, before the Fifth National Boy Scout Jamboree. The treatment was made for reduction of fleas and other arthropods that might carry certain diseases. During the following 2 months, 45 fish, 27 frogs, 1 snake, and 2 birds were found dead and submitted to the Denver Wildlife Research Center for analysis. Mud, upland soil, water, and vegetation samples were collected over a period of 6 months. Varying amounts of DDT and DDD residues have been found in many of these samples, but interpretation of the data will require completion of additional chemical analyses.

Aldrin Contamination of Lakes at the Rocky Mountain Arsenal.--Three small industrial lakes northeast of Denver have been polluted with aldrin that has escaped from an insecticide plant. Each winter and early spring large numbers of ducks die there when the lakes are at low water level. Losses have been estimated at 2,000 ducks per year.

Investigation of the problem by personnel of the Denver Wildlife Research Center showed that mud from the lakes and inlet canal contained aldrin and dieldrin ranging as high as 480 ppm. Living algae contained up to 79 ppm of dieldrin and living snails up to 88 ppm. Dead ducks found around the lakes contained from 30 to 64 ppm of dieldrin.

Waterfowl killed or crippled by duck hunters in late October 1960 were obtained from lakes at the Rocky Mountain Arsenal. These birds were analyzed for pesticide content with the following results:

Kind	Insecticide Content
Redhead	12 ppm dieldrin and 1 ppm aldrin
Redhead	10 ppm dieldrin
Coot	19 ppm dieldrin
Coot	5 ppm dieldrin
Blue-winged teal	39 ppm dieldrin
Ring-necked duck	4 ppm dieldrin

Since all these birds were shot by hunters during the hunting season, it is presumed that they contained insecticide residues in amounts similar to those of birds taken and eaten by hunters of the Rocky Mountain Arsenal Rod and Gun Club. The species represented may not be typical, however, because redheads and coots probably were abandoned intentionally. The dieldrin residues average somewhat lower than the amounts found in ducks picked up dead by the lakes at other times. The pesticide tolerance for dieldrin in poultry going to interstate markets has been set at zero by the U. S. Food and Drug Administration. It is probable that thousands of ducks used these lakes

Certain chemicals such as toxaphene, which have been used to kill fish, have caused damage to fish-eating birds of several types. Other chemicals are available that are toxic to fish and relatively non-toxic to warm-blooded animals.

Miscellaneous Control Measures

DDT and Malathion Applications to Scout Jamboree Site.--A 2,300-acre area near Colorado Springs was dusted with DDT (3 lb/a) and malathion (0.5 lb/a) on June 15, 1960, before the Fifth National Boy Scout Jamboree. The treatment was made for reduction of fleas and other arthropods that might carry certain diseases. During the following 2 months, 45 fish, 27 frogs, 1 snake, and 2 birds were found dead and submitted to the Denver Wildlife Research Center for analysis. Mud, upland soil, water, and vegetation samples were collected over a period of 6 months. Varying amounts of DDT and DDD residues have been found in many of these samples, but interpretation of the data will require completion of additional chemical analyses.

Aldrin Contamination of Lakes at the Rocky Mountain Arsenal.--Three small industrial lakes northeast of Denver have been polluted with aldrin that has escaped from an insecticide plant. Each winter and early spring large numbers of ducks die there when the lakes are at low water level. Losses have been estimated at 2,000 ducks per year.

Investigation of the problem by personnel of the Denver Wildlife Research Center showed that mud from the lakes and inlet canal contained aldrin and dieldrin ranging as high as 480 ppm. Living algae contained up to 79 ppm of dieldrin and living snails up to 88 ppm. Dead ducks found around the lakes contained from 30 to 64 ppm of dieldrin.

Waterfowl killed or crippled by duck hunters in late October 1960 were obtained from lakes at the Rocky Mountain Arsenal. These birds were analyzed for pesticide content with the following results:

Kind	Insecticide Content
Redhead	12 ppm dieldrin and 1 ppm aldrin
Redhead	10 ppm dieldrin
Coot	19 ppm dieldrin
Coot	5 ppm dieldrin
Blue-winged teal	39 ppm dieldrin
Ring-necked duck	4 ppm dieldrin

Since all these birds were shot by hunters during the hunting season, it is presumed that they contained insecticide residues in amounts similar to those of birds taken and eaten by hunters of the Rocky Mountain Arsenal Rod and Gun Club. The species represented may not be typical, however, because redheads and coots probably were abandoned intentionally. The dieldrin residues average somewhat lower than the amounts found in ducks picked up dead by the lakes at other times. The pesticide tolerance for dieldrin in poultry going to interstate markets has been set at zero by the U. S. Food and Drug Administration. It is probable that thousands of ducks used these lakes without immediate acute intoxication, acquired sublethal doses of dieldrin, and flew on to their nesting grounds in other parts of the midcontinental region. Efforts are being made to initiate corrective action.

EFFECTS ON SPORT FISHERIES

by

Oliver B. Cope
Branch of Fishery Research
Bureau of Sport Fisheries and Wildlife

The Fish-Pesticide Research Laboratory at Denver, Colorado, in approaching its objective of understanding the interrelationships among fish, water, chemical control agents, and fish foods, has formed a balanced program and staff. After the laboratory was established in 1959, some projects were immediately launched and are now operating smoothly; others were started but have been beset with annoying technical problems that have resisted immediate resolution; other projects have been purposely delayed because they logically follow the building of foundations by other projects.

During 1960, a great array of determinations from chemical analyses, biological assays, and field measurements and observations was amassed. Many of these were routine, and are not mentioned in this report. The facts reported here are considered to be the most significant findings of the year in the Fish-Pesticide Research Laboratory.

Laboratory Studies and Toxicology

Imported Fire Ant

Attention was given to reports broadcast throughout the Southeastern States on mortality to fish from the ingestion of fire ants. The press in Mississippi publicized statements to the effect that great numbers of fire ants had been found in the stomachs of fish found dead, and that the ants had killed the fish. Mr. Paul Frey at Gulf Breeze, Florida, after interviewing interested persons, established laboratory feeding tests to attempt the induction of morbidity or mortality. His bluegill were not killed.

Neither the sting of the fire ant nor the absorption of poison in the digestive tract caused any noticeable effects on his fish.

Chronic Effects of DDT and Heptachlor

An experiment was begun by the Fish-Pesticide Research Laboratory on chronic effects of DDT on cutthroat trout under controlled conditions at the National Fish Hatchery at Jackson, Wyoming. Fish in lots and sublots are being given DDT at 5 levels in their pelleted diet and at 5 levels in bath form. Samples are being analyzed by chemists for residues of DDT and others are being examined histologically. Effects on growth, blood morphology, other tissue changes, reproduction, and quality of offspring are being measured in this program. Experiments on chronic effects of heptachlor on guppies in the laboratory at Denver are being conducted for the measurement of effects on reproduction.

Toxicant Tolerance Tests

Preliminary testing of pesticides was performed in the Fish-Pesticide Research Laboratory at Denver. The phytoactin antibiotic, Phyto-Pabst AL 319, when tested against rainbow trout, showed a 24-hour LD50 of 1.9 ± 0.2 ppm. The microbial insecticide, Thuricide, produced no effects on rainbow trout when tested at 200 times the amounts to be expected in field applications. Two possible fish toxicants were tested against rainbow trout. Copper methanearsonate killed 20 percent of the fish at 0.5 ppm in 48 hours and 100 percent at 1.0 ppm in 24 hours. Silver methanearsonate killed 30 percent of the fish at 0.1 ppm in 48 hours and 100 percent at 0.15 ppm in 24 hours. Antibiotic sprays, two derivatives of cyclohexamide, were tested against rainbow trout at 400 to 1,600 times the amounts expected in the field, and no acute toxicity resulted.

Residue Analyses

Fish analyzed chemically after exposure to DDT were found to have DDD as one component. Analysis of a sample of the stock of DDT in the warehouse showed only the presence of p,p'-DDT and o,p-DDT.

Cholinesterase determinations have been performed on bluegill. The method used is colorimetric and measures the amount of unhydrolyzed acetylcholine remaining after incubation. In the course of studying the effect of malathion in the *in vitro* reaction, it was observed that malathion itself gives a color in the reaction mixture. This color formation follows Beer's Law and may produce a sensitive colorimetric method for malathion determination.

Effects on Field Populations

Forest Insect Control

Spruce Budworm.--The U. S. Forest Service sprayed DDT on 60,000 acres of budworm-infested forest in the Gallatin National Forest in Montana in 1960. The operation featured the dispersal of 0.5 pound per acre to within ½ mile of the streams, and the remaining portion of the area received 1 pound per acre. Biologists of the Fish-Pesticide Research Laboratory worked in Swan Creek to measure effects. Samples of water collected periodically from 6 minutes to 24 hours after the application of the spray contained less than 0.002 ppm at 6 minutes, 0.01 ppm at ½ hour, 0.002 ppm at 1 hour, and up to a trace thereafter. Samples of insects drifting in the stream showed dead and dying organisms to be present in greatest numbers 1 hour after the spray was applied. Stoneflies were at their peak in numbers ½ hour after the spray, mayflies 1 hour after, caddis and beetle larvae 1½ hours after, and dipterans 3 hours after. Trout in live-cars in the stream suffered no mortality up to 96 hours after the spray. Trout from live-cars contained traces of DDT in their bodies after 6 hours exposure, and 0.1 ppm was found in fish exposed

12, 24, 48, 72, and 96 hours. Insects taken in drift samples were analyzed and found to have a trace of DDT at ½ hour, 3.4 ppm at 1 hour, and 11.0 ppm and 14.2 ppm of DDE at 3 hours. Insects exposed 3 to 6 hours in the stream were fed to trout. The fish had 0.1 ppm of DDT 20 hours after feeding began.

A report on this study was prepared for publication (Bridges and Andrews, 1961).

Elm Spanworm.--The U. S. Forest Service sprayed DDT in northern Georgia in 1959 and 1960. The program was directed against the elm spanworm, and the DDT was applied at the rate of 0.5 pound per acre. The 1959 treatment resulted in substantial reductions in aquatic insect populations in one area, but the 1960 work produced no effects on fish or invertebrates in a similar situation (Frey, 1961).

Antibiotics and White Pine Blister Rust.--The U. S. Forest Service experimented with aerial treatments with several antibiotics for the control of white pine blister rust in the Couer d'Alene National Forest in 1960. Personnel of the Fish-Pesticide Research Laboratory studied effects on stream life when some sprays were applied. The chemicals used were methylhydrazone, cyclohexamide semicarbazone, special semicarbazone, phytoactin in 20 percent oil, and phytoactin with additives and 20 percent oil. Only the plot receiving cyclohexamide semicarbazone, at 7 grams of active ingredient per acre, contained enough water for study. Samples of drifting aquatic insects indicated that no acute effects occurred, and there was no evidence of morbidity or mortality of fish.

Agricultural Pest Control

Imported Fire Ant.--Treatment of Florida ponds with 0.25 pound per acre of heptachlor granules in December 1959, and again in June 1960, resulted in some bluegill mortality, but mortality did not occur in all ponds. Analysis of bluegill, largemouth bass, redear sunfish, and golden shiners collected from these waters over a period of time suggested an increase in heptachlor in fish tissues to the 57-day sample. All fish taken in the 8-month sample contained less toxicant than those collected at 57 days. All fish had heptachlor and heptachlor epoxide in their bodies; one sample of golden shiners had 8.3 ppm of heptachlor and 1.7 ppm of heptachlor epoxide.

Alfalfa Weevil.--Personnel of the Fish-Pesticide Research Laboratory assisted in the planning and evaluation of a malathion emulsion treatment at Jackson, Wyoming. The spray was applied at the rate of 1 pound per acre for the control of alfalfa weevil. Measurement of actual spray deposit showed that 0.53 to 0.73 ppm reached the ground. Pilots avoided the direct spraying of the larger waterways in the area, but some drifting was noted, and analysis showed that up to 0.04 ppm of malathion was in the water. A partially dewatered canal in the center of the sprayed area contained 0.20 ppm of malathion 30 minutes after the spray. Rainbow trout in the laboratory have been killed by 0.20 ppm of malathion. Small sculpins, cyprinids, and suckers were killed in the canal, as were various kinds of aquatic invertebrates. Protection of aquatic animals in the larger canals and downstream in the Snake River was considered to be good.

Beet Insects.--A 5-acre pond near Mead, Colorado, received endrin during a beet-insect spray program in the summer of 1959. Samples of water, aquatic vegetation, fish, and mud were periodically collected by the Fish-Pesticide Research Laboratory and analyzed for residues of endrin. Only 6 ounces of emulsifiable endrin per acre were sprayed, but large numbers of dead yellow perch, pumpkinseed, bluegill, black crappie, largemouth bass, and carp were washed up on the shores after the spray. Up to 1.00 ppm of endrin was contained in fish surviving the exposure. Samples of water had up to 0.04 ppm; of mud, 0.80 ppm; and of vegetation, 0.55 ppm. Endrin disappeared from the pond water in about 4 weeks, from the vegetation after about 6 weeks, from the bottom mud after about 8 weeks, and from the fish after about 16 weeks (Bridges, 1961).

EFFECTS ON COMMERCIAL FISHERIES

by

Philip A. Butler
Division of Biological Research
Bureau of Commercial Fisheries

In 1946, the peace-time uses for the "miracle" insecticide DDT were being greatly expanded. At that time, scientists at the Fish and Wildlife Shellfishery laboratories in Maryland and Connecticut discovered that the spraying of shucking house shell piles with DDT emulsions to eliminate the fly nuisance rendered the oyster shells more suitable as cultch. The setting of barnacles and bryozoa was inhibited on sprayed shells, and this apparently provided additional space for the setting of oysters.

These observations passed almost unnoticed, and until recently there have been relatively few investigations of the effects of pesticides on commercial species in the marine environment. In the past few years, however, the accumulation of data showing adverse indirect effects of pesticides on freshwater fish and wildlife has focused attention on our lack of information on related problems in the estuarine environment.

There have been accidental but drastic instances of mass mortalities of marine forms resulting from the chemical control of saltwater marsh insects. For the most part, however, our concern is based on the assumption that, sooner or later, significant amounts of these chemicals may be carried from forest and farmland into the estuaries along the coast, either as particulate matter, adsorbed on silts and detritus, or perhaps in some new chemical relationship.

Our concern is heightened by the fact that estuaries provide the temporary or permanent habitat for a majority of the most valuable commercial species of fish and shellfish. Both shrimp and menhaden whose annual harvests are, respectively, the highest in dollar value and poundage, accomplish much of their early growth in brackish estuarine waters. Most of our commercial shellfish are predominantly estuarine animals, and much of the nutrition of the seas is affected to some extent by this important ecological zone.

The need for a thorough understanding of the indirect results of pest control on the biota in the marine environment resulted in the allocation of funds for this specific purpose in 1958. Fact-finding projects were initiated at three Bureau of Commercial Fisheries biological laboratories in Connecticut, Florida, and Texas. Their objectives were to explore the extent of the problem, determine the kind of information needed, and the type of program required to obtain this information.

Preliminary screening tests have been conducted at these laboratories because of their unique facilities in terms of either trained personnel or availability of the test animals and equipment. The work to date has stressed methods for evaluating the toxicity of the most widely used pesticides to a few of the most important species.

Toxicity Studies

Phytoplankton

Microscopic plants, suspended in the water, make up the broad basis of the food chain in the sea. The productivity of coastal waters and the harvest of all our marine species are directly dependent on the amount and quality of phytoplankton available. Since the herbicides have been developed for their specific toxicity to higher plant life, they might be expected to be toxic to these one-cell plants as well.

It is difficult to evaluate in nature the effects of pesticides on the micro-flora of the marine environment. The rapid recovery of such populations from natural disasters and their normally fluctuating concentrations make field evaluations almost impossible. In laboratory cultures, however, their extraordinary sensitivity to commercial herbicides is readily apparent. Since these forms are the basis of the food supply of all other animals in the environment, their continued destruction by pesticides could have drastic results.

Tabulated in table 10 are data showing the toxicity of herbicides to pure cultures of 5 kinds of microscopic plants grown in the laboratory as food for larval mollusks. For comparison, their relative tolerance to some insecticides is also shown.

Crustacea

Perhaps half of the many pesticidal chemicals in use today are designated as insecticides and have been developed for their selective toxicity to terrestrial arthropods. Unfortunately, several of our most important marine food species including the lobster, crab, and shrimp are also arthropods. It might be expected, then, that these animals would be particularly vulnerable to the effects of agricultural insecticides.

Research projects to determine the tolerance of marine arthropods have been complicated by difficulty in the interpretation of results. Ordinarily, toxicity is evaluated in terms of mortality rates. In both crabs and shrimp, however, toxicity is manifested first by increased irritability and then by loss of equilibrium. In laboratory experiments, the animal lies on its back and may be paralyzed for days or weeks before it succumbs. In nature, the paralyzed animal would fall an early prey to predators.

Only a limited series of experiments have been completed that indicate the extent to which marine crustacea are affected by insecticides.

Stone, mud, and blue crabs show a differential susceptibility to such control agents as Sevin, endrin, dieldrin, DDT, and lindane. Mortalities are observed in both stone and mud crabs at concentrations of 1 ppm (Sevin, endrin), but in most cases higher concentrations are required to cause more than a paralyzing effect (table 11).

Mud crabs, perhaps because of their small size, appear to be particularly sensitive to the herbicide 2,4-D and show irritation at a concentration of only 1.0 ppb.

Post-larval and small shrimp are far less resistant than crabs and, in general, these smaller and younger stages are more sensitive than larger specimens of the same kind. The younger stages usually grow in the upper reaches of estuaries nearest the source of pollution, and hence are doubly vulnerable.

Larger shrimp may also show a consistent species differential in their reactions to pesticides. In general, brown shrimp are more hardy than white under laboratory conditions and this is indicated by their greater tolerance to some of the pesticides (table 12).

Mollusks

Oysters and clams present problems of particular concern in consideration of pesticide toxicity. Their larval stages, suspended in estuarine waters, are especially vulnerable to any chemical changes in the fluid environment surrounding them. The adults are immobile on the bottom and unable to move away from polluted water.

In addition, these mollusks have the ability to store within their tissues concentrations of chemicals thousands of times greater than the amounts present in the environment. It is not known whether gradual storage of these chemicals interferes with the growth, reproduction, and quality of the oyster meats as human food. If pesticide chemicals are stored to any extent, the oysters would no longer be suitable as food.

Eggs and Larvae.--Observation of the effects of more than 30 pesticides on clam or oyster eggs and larvae (table 13) has revealed considerable diversity in response. DDT, for example, causes more than a 90 percent mortality and almost completely stops growth of oyster larvae at a concentration of 0.05 ppm. Lindane, however, at a concentration 100 times greater, appears to enable clam larvae to grow faster than untreated controls.

Some of the compounds screened, when tested at very low concentrations, appeared to improve larval growth rates, possibly because of their inhibition of toxic bacteria in the culture. With almost every compound tested, slowing of the rate of growth was the first evidence of toxicity. Appreciable mortality usually occurred only when concentrations were high enough to reduce growth rates by 50 percent or more. In nature, slower growth rate could be disastrous since it would expose the larvae to natural hazards for a much longer period.

Mature Oysters.--The reaction of adult oysters to pesticides must be observed at low concentrations, since, if sufficiently irritated, the oyster closes its shell and avoids the chemical. Chemical toxicity in larger oysters is first revealed by a decrease in growth rate just as it is with larvae. Consequently, growth measurements are a convenient way of evaluating the different pesticides (table 14).

Decreases in growth rate may be detected in as little as 24 hours, but changes in activity as indicated by shell movement are much slower to appear. Following prolonged exposure, 1-4 weeks, and depending on the concentration of the toxicant, shell growth may cease entirely (figure 1).

In such instances, there will be significant mortalities. Exposure to toxaphene for example, at a concentration of 0.1 ppm for 3 weeks, will cause a 50 percent mortality. If the surviving oysters are transferred to unpolluted water, there is a fairly rapid recovery. This suggests that there is no permanent storage of the chemical, but the data are as yet insufficient.

Fish

The limited research completed on the effects of agricultural chemicals indicates that although marine fish are more resistant generally than the crustacea, they are still sensitive to exceedingly small concentrations of the common insecticides.

Small, non-commercial "minnows", including Fundulus, Cyprinodon, and Mollienisia, show considerable diversity in tolerance. Forty-eight hour median tolerance limits, for example, may vary as follows (parts per billion): Endrin, 4-35; dieldrin, 47-220; and DDT, 400-3,000. Only endrin has been tested on juvenile mullet of about 35 mm length. Toxic concentrations varied tenfold depending on the test conditions. In circulating water, however, 24-hour median tolerance limits were approximately 2-3 parts per billion.

Similar variations in toxicity are expected under field conditions. For this reason, although much data are available relating to the effects of DDT in salmon streams, a new program is now underway to examine this relationship in Alaska. It is quite possible that the heavy rainfall and rapid run-off there will necessitate a revision in methods for controlling spruce budworm with DDT in order to avoid damage to salmon spawning grounds.

General Considerations

All of the pesticides tested so far have been found toxic to marine animals at levels far below recommended application rates. It should be recognized, however, that the experimental testing has been done under laboratory conditions. There are no data to demonstrate that pesticidal chemicals do collect in estuaries following their proper use, except in those relatively rare situations in which they are intentionally applied directly to brackish waters.

Laboratory testing shows that toxicity levels may vary depending on the age and species of animal, the formulation of the product, and the test conditions. This indicates that similar variability is to be expected unier field conditions, and that generalized regulations for pesticide use may be either dangerous or inapplicable.

There is evidence that some pesticides may have useful applications in the management of commercial fisheries. The specificity of others indicates the possibility of developing chemicals that will affect only noxious pests. There is reason to believe that with sufficient research data available, the proper use of chemical controls will not be incompatible with the efficient management of our commercial marine resources.

Studies Reported During 1960

Personnel of the Bureau of Commercial Fisheries completed and published a general paper (Butler, 1960) on the effects of pesticides on commercial fisheries. In addition, specific effects of pesticides on oysters were reported by Butler, et al. (1960); Davis (1960), and Loosanoff (1960). Other studies had been published by Loosanoff (1947) on the effects of pesticides on oysters; and by Chin and Allen (1957) on the effects of pesticides on shrimp.

Effects of chemicals on zooplankton were reported by Loosanoff, et al. (1957) and Ukeles (1960).

ADDITIONAL WILDLIFE RESEARCH NEEDED

by

Daniel L. Leedy, Chief
Branch of Wildlife Research
Bureau of Sport Fisheries and Wildlife

The amount and importance of wildlife mortality resulting from pesticide treatments has been measured for several species and chemicals. A single measurement is a major undertaking, yet many measurements would be needed to understand even the immediate effects of the major pesticide programs now in progress. New chemicals and new techniques still are being developed and additional pest control programs begun. Thus, a principal research need continues to be early appraisal of effects of different chemical treatments. One of the best ways to obtain these early measurements is by working with the research entomologists while their methods still are developing. Certain cooperative studies of this kind have begun, as described earlier.

Laboratory experiments, however, give the quickest reliable information concerning a variety of chemicals. Field results are, in a general way, predictable from laboratory studies. There are conspicuous exceptions, however, and field trials are necessary for proper knowledge of the impact of a control program. Most tests at the Bureau's laboratories have been made with quail and pheasants, both because these birds are valuable game species and because they feed on the ground, where they come in close contact with chemicals. Quail and pheasants also are easily kept and bred. Tests with other kinds of birds and with mammals are needed, for different species react differently. Some tests have been made with mallards and blackbirds, and a few with woodcock. Other migratory birds, such as mourning doves, should be considered. Tests should include long-term feeding of sublethal quantities of chemical, and, where practicable, an evaluation of effects of the chemical on reproduction. Experiments also should be designed to measure the effects of exposure to sublethal amounts of more than one chemical, because migratory birds encounter many areas of diverse chemical history in their annual trips.

Measurement of pesticide residues in laboratory animals known to have died as a result of poisoning is needed for comparison with residues in animals collected in the field or found dead after chemical treatment. Each field study and each laboratory experiment requires residue analyses for interpretation. Present analytical methods are laborious and costly, and most of them permit analysis of a sample for only one chemical. Development of new or improved methods is a principal research need. Gas chromatography has shown promise, but is not yet perfected satisfactorily for this work. Use of radioactive isotopes is another technique that might prove useful in certain studies.

One possible means for partial simulation of field treatments is the use of enclosures. Animals can be penned on ground treated experimentally in different ways. Pens also can be used to hold animals on areas that are to be treated in actual control operations. The simulation is not perfect, for few wild animals confine themselves to areas of sizes that are feasible for enclosures. Research is needed not only in conducting experiments using enclosures, but also in determining how best to use enclosures as an adjunct to field studies.

The major research problems in determining the effects of pesticides on wildlife remain in evaluation of effects in the field. Not only must laboratory results be verified, but certain problems can be solved only by field studies. We know very little about delayed poisoning through concentration of toxicants in food organisms, but there is evidence that it occurs. Fish-eating birds at Clear Lake and at Klamath Refuge were killed as a result of eating contaminated fish, as discussed earlier in this report. The second-year mortality of birds in Wilcox County, Alabama, and some robin mortality in areas treated for Dutch elm disease control, may be from similar causes.

Although we know that concentrations of certain chemicals in soil continue to increase with successive pesticide treatments, we have little knowledge of the effects on soil organisms or on vertebrate animals. Long-term effects of pesticide applications on animal numbers or reproductive potential still are poorly understood. Further, the possibility of pesticide treatments eliminating certain kinds of animals whose geographic range is small is a very real danger that has received little consideration or study.

The difficulty of measuring the effects of chemicals on wildlife populations is a major handicap in making field evaluations. Present methods often require great efforts over long periods to obtain small amounts of reliable information. New, simpler, more sensitive measures are greatly needed. Thus, development of better techniques must be listed as an important research need; it is basic to an increased rate of progress in solving pesticide-wildlife problems.

ADDITIONAL SPORT FISHERIES RESEARCH NEEDED

by

Oliver B. Cope
Branch of Fishery Research
Bureau of Sport Fisheries and Wildlife

The entire area of study on fish and pesticides needs attention if fishery science is to understand enough about the subject to set down principles and details for management use. Out of this requirement for investigation on all aspects of the problem, there appear certain pressing needs on specific topics. These specific topics should receive emphasis in pesticide studies, because the answers to many practical fishery management problems depend upon knowledge in these areas.

One topic needing attention pertains to environmental effects on acute toxicity of pesticides to fish and fish foods. Fishery personnel are accumulating a valuable array of facts on acute toxicities to various species of fish in the laboratory. We require this information, but we must also proceed to the next step, that of measuring influences on these toxicities. We must know the importance of water chemistry, temperature, the biota, and other factors in the environment, as well as the significance of size, age, and condition of fish. Biologists must have this information before they can predict effects.

Another major subject on which little is known deals with chronic effects of pesticides on fish. Low-level, prolonged exposure may have a serious impact on growth rate, on fecundity, on the quality of the offspring, on the genetic character of the stock, or on other vital functions in the fish. Because studies on these effects often require years for completion, it would seem to be imperative that the earliest possible beginning be made.

The complex relationships between fish food, fish, and chemicals should be studied as soon as possible. Since we know that aquatic invertebrates can quickly build up and store insecticides and furnish relatively large quantities of food for fish in short periods of time, it is appropriate to learn about rates of ingestion in both fish and invertebrates and the connection between these rates and morbidity and mortality in fish. Furthermore, studies are needed concerning starvation in fish due to depletion of the food supply by the action of pesticides, and the effect of starvation on susceptibility to poisoning.

A major task in the endeavor to learn about fish and pesticides is the bridging of the gap between laboratory studies and field investigations. Laboratory studies are needed for precise measurements under controlled conditions, and field studies are necessary to learn what happens under operating conditions. We need intermediate studies in ponds and raceways so that we can observe results in situations where the amount of control available to the biologist and chemist is intermediate between that in the laboratory and that in the wild.

ADDITIONAL COMMERCIAL FISHERIES RESEARCH NEEDED

by

Philip A. Butler
Division of Biological Research
Bureau of Commercial Fisheries

The magnitude of the problem of the relation of chemical pesticides to commercial fisheries is still undetermined. The effects of many widely used pesticides on commercial species have not been investigated because of limitations in time and personnel. But more important is the absence of data on what happens to these chemicals once they are applied to field and forests.

We need to know if these pesticides become physiologically inert or if they become more toxic. Are they concentrated or dispersed? Are they immobilized in the soil or do they eventually reach the sea? These questions must be answered. If pesticides do persist and are carried into environments where they pose a threat to marine animals, then much additional knowledge will be necessary to enable us to protect these natural resources.

RECOMMENDATIONS FOR MINIMIZING DANGERS OF PESTICIDES TO FISH AND WILDLIFE

It is best to begin by selecting a chemical that will offer as little danger as possible to animal life. This selection can be guided to some extent by the relative toxicities found in laboratory studies. Results of Patuxent laboratory studies are summarized in table 15 for this purpose. Laboratory appraisals, however, need substantiation in field tests before they can be considered dependable indicators of field hazards, for there are many differences between laboratory and field studies.

The kinds of animals apt to be affected also should be considered, for animals differ greatly in susceptibility to pesticide poisoning. The effects of DDT on different animal groups are shown in the table below; data in this table are generalizations of our best current opinion on the basis of reports in the literature.

Effects on vertebrates and crustaceans of single applications of DDT in oil solution

Pounds DDT per acre	Crustaceans	Fish	Amphibians	Reptiles	Birds	Mammals
0.1	+	+	-	-	-	-
0.2	++	++	+	+	-	-
1.0	+++	+++	++	++	+	-
2.0	+++	+++	++	++	+	-
5.0	+++	+++	+++	+++	+++	+

- No immediate apparent effect
+Some kill
++Moderate kill
+++Heavy kill

Procedures to minimize wildlife damage in pesticide programs have been given in many publications. Some of the more important recommendations are summarized below.

1. Be sure there is a real need for pesticide use.

2. Treat the minimum necessary area.

3. Select the chemical that will be the least dangerous to fish and wildlife but still control the target pest. Judge the danger of a chemical both by its toxicity and by its disappearance rate. Avoid chemicals that tend to accumulate in the soil.

4. Use no more chemical than is absolutely necessary. Be sure no areas receive a double dose.

5. Consider the carrier in which the pesticide is mixed, for some carriers are toxic to wildlife.

6. Plan the time of treatment to reduce hazards. Try to avoid the main spring migration and nesting periods of birds.

Table 1. Quantities of pesticides causing 50 percent mortality of quail and pheasants: Summary of feeding tests at Patuxent Wildlife Research Center during 1960

Compound	Test period (days)	Bobwhite quail				Ring-necked pheasants			
		Young		Adult		Young		Adult	
		ppm in diet	mg/kg eaten	ppm in diet	mg/kg eaten	ppm in diet	mg/kg eaten	ppm in diet	mg/kg eaten
Organophosphates									
Bayer 25141	<10	50	40	25	16	100	180		
	<100	5	40	5	65				
Bayer 29493	<10	50	40			200	20		
	<100	10	30	25	75				
Bayer 22408	<10								
	<100	200	2,000						
Bayer 22684	<10								
	<100	200	2,125						
Dibrom	<10	1,000	2,290					5,000	10,670
	<100	<250	640						
Dimethoate	<10	100	130	250	950				
	<100	25	190					5,000	2,875
DDVP	<10								
	<100	5,000	1,700						
EPN	<10	200	220						
	<100	100	130					>200	>165
Parathion	<10	100	320						
	<100	50	140					>200	>200

(Continued)

Table 1. Quantities of pesticides causing 50 percent mortality of quail and pheasants: Summary of feeding tests at Patuxent Wildlife Research Center during 1960 (continued)

Compound	Test period (days)	Bobwhite quail				Ring-necked pheasants			
		Young		Adult		Young		Adult	
		ppm in diet	mg/kg eaten	ppm in diet	mg/kg eaten	ppm in diet	mg/kg eaten	ppm in diet	mg/kg eaten
Phosphamidon	<10	25	80			500	200		
	<100	1	4					>200	>270
Thimet	<10	200	270			500	350		
	<100								
Chlorinated hydrocarbons									
Heptachlor	<10	100	115			250	290		
	<100	50	165	25	230	50	140	50	180
Heptachlor epoxide	<10	50	60						
	<100	10	90	>10	>85				
Kepone	<10	400	460					500	130
	<100	100	775	100	430	100	420	150	595
Thiodan	<10	400	450			500	620		
	<100	100	375						
Carbamates	<10	>5,000	>14,000						
	<100	250	800	>500	>13,000	5,000	65,000	>5,000	>30,000
Herbicides and fungicides									
Amitrole	<10								
	<100	5,000	26,000	>5,000	>65,000	5,000	35,550	>5,000	>12,000

(Continued)

Table 1. Quantities of pesticides causing 50 percent mortality of quail and pheasants: Summary of feeding tests at Patuxent Wildlife Research Center during 1960 (continued)

Compound	Test period (days)	Bobwhite quail				Ring-necked pheasants			
		Young		Adult		Young		Adult	
		ppm in diet	mg/kg eaten	ppm in diet	mg/kg eaten	ppm in diet	mg/kg eaten	ppm in diet	mg/kg eaten
Amitrole-T	<10								
	<100	>5,000	>78,000	>5,000	>51,500	5,000	16,000		
Dacthal	<10	5,000	5,500						
	<100								
Dalapon	<10								
	<100	>5,000	>56,000	>5,000	>70,000			>5,000	>40,000
Dexon	<10	250	475			2,500	145	2,500	31
	<100			>500	>5,800				
2,4-D acetamide	<10	2,500	1,825						
	<100			>2,500	>38,000			>2,500	>16,500
2,4-D dimethyl amine salt	<10								
	<100	5,000	28,000						
2,4-D butoxy-ethanol ester	<10								
	<100	5,000	38,000	5,000	40,700	5,000	29,500		
2,4,5-TP butoxy-ethanol ester	<10	5,000	9,350						
	<100					5,000	9,240		
Dyrene	<10								
	<100	>5,000	>63,000	>5,000	>83,000				
MCPA	<10								
	<100	5,000	19,000	5,000	47,000			>5,000	>36,000

Table 2. Quantities of pesticides causing 50 percent mortality of mallard ducks: Summary of feeding tests at Patuxent Wildlife Research Center during 1960

Compound	Test period (days)	Young		Adult	
		ppm in diet	mg/kg eaten	ppm in diet	mg/kg eaten
Chlorinated hydrocarbons					
Heptachlor	<10	200	590		
	<100	100	425	>50	470
Herbicides and fungicides					
Amitrole	<10				
	<100	5,000	15,750	>2,500	>16,000
Amitrole-T	<10				
	<100			>2,500	>17,000
Dalapon	<10				
	<100	5,000	15,000	>2,500	>26,000
2,4-D acetamide	<10	2,500	3,400		
	<100			>2,500	>35,000
2,4-D dimethyl amine salt	<10				
	<100	5,000	8,250	>2,500	>34,000
2,4-D butoxyethanol ester	<10				
	<100			5,000	>33,000
2,4,5-TP butoxyethanol ester	<10				
	<100			2,500	33,700
MCPA	<10				
	<100	5,000	10,700		

Table 3. Heptachlor epoxide content of tissues of birds from areas treated with 2 pounds of heptachlor per acre[1/]

Species	Found dead — Time after treatment						Shot — Time after treatment			
	1 Month		1 Year		2 Years		1 Year		2 Years	
	No.	ppm	No.	ppm	No.	ppm	No.	ppm	No.	ppm
Pipit, water	1	38.0					6	7.9		
Sparrow, Le Conte's	2	34.9								
Sparrow, swamp	2	33.9					2	18.0		
Sparrow, savannah	18	29.3	1	6.2			15	2.6	14	0.9
Sparrow, field	5	24.6					1	0		
Oriole, orchard	1	23.7								
Sparrow, chipping	8	22.3	2	1.0						
Warbler, myrtle	3	20.2							1	13.3
Sparrow, white-throated	13	20.0	3	11.5			3	8.9	9	5.2
Mockingbird	8	19.7	1	10.6			1	5.4	1	0
Thrasher, brown	13	16.0					1	5.1	11	4.6
Woodpecker, red-bellied	1	14.9					1	0		
Yellowthroat	1	14.5								
Chat, yellow-breasted	1	14.0								
Meadowlark, western	1	13.4								
Jay, blue	3	12.8	1	14.3			1	5.4	1	2.3
Thrush, hermit	3	12.6								
Blackbird, red-winged	3	12.2					9	3.9		
Shrike, loggerhead	4	12.2								
Sparrow, vesper	8	11.9					3	0		
Robin	7	11.3			6	6.0	8	5.8	14	4.5
Grackle, common	6	10.9								
Sparrow, house	16	10.9								
Kingbird, eastern	1	10.4								
Cardinal	18	10.3	1	4.7	1	Trace	3	4.3	3	1.1
Rail, Sora	1	7.8	1	0.8						
Starling	1	7.4	5	12.1						

(Continued)

1/ Entire carcasses analyzed. Average content is given in parts per million.

Table 3. Heptachlor epoxide content of tissues of birds from areas treated with 2 pounds of heptachlor per acre[1/] (continued)

Species	Found dead, Time after treatment						Shot, Time after treatment			
	1 Month		1 Year		2 Years		1 Year		2 Years	
	No.	ppm	No.	ppm	No.	ppm	No.	ppm	No.	ppm
Rail, Virginia	2	7.2	1	0.8						
Meadowlark, eastern	25	6.8	1	9.6			18	2.0	15	2.3
Wren, carolina	1	6.0	1	0			7	3.6		
Dove, mourning	1	5.8	5	3.3			6	1.8	8	1.2
Bobwhite	21	5.6					11	3.3	9	1.3
Snipe	4	4.5					7	0.6	4	2.9
Heron, green	2	4.3								
Flicker, yellow-shafted	2	3.9								
Bluebird, eastern	1	3.2			2	16.4				
Warbler, yellow-throated	1	Trace								
Gnatcatcher, blue-gray			1	31.0						
Phoebe, eastern			1	28.3						
Heron, little blue			1	7.8						
Plover, upland			1	4.1						
Thrush, Swainson's					1	9.7				
Towhee, rufous-sided							4	8.2		
Blackbird, rusty							3	5.0		
Killdeer							36	2.0		
Goldfinch, American									1	4.5
Waxwing, cedar									2	4.4
Dove, ground									1	2.6
Sparrow, fox									1	1.9
Finch, purple									1	1.8
Sparrow, song									3	Trace
Warbler, Kentucky									1	0

1/ Entire carcasses analyzed. Average content is given in parts per million.

Table 4. Heptachlor epoxide content of tissues of mammals, reptiles, amphibians, fish, and crustaceans from areas treated with 2 pounds of heptachlor per acre

Species	Found dead Time after treatment 1 Month		Shot Time after treatment 1 Year	
	No.	ppm	No.	ppm
Mammals				
Mouse, oldfield	1	33.5	2	4.1
Mouse, white-footed	10	17.4		
Rabbit, cottontail	1	14.2		
Mouse, harvest	13	12.8		
Rat, cotton	14	7.9	14	3.6
Rat, rice	12	3.7	1	6.6
Mice, unidentified	10	3.4		
Rabbit, swamp	1	3.3		
Squirrel			2	0
Reptiles				
Snakes:				
Corn snake			1	12.2
Hognose snake			1	2.0
Ribbon snake	10	4.6		
Coachwhip	2	4.6		
Water snake (Natrix)	7	11.7		
Turtles:				
Red-eared turtle			1	172
Slider	1	2.2		
Lizard, unidentified	1	5.0		
Amphibians				
Bullfrog	2	13.5		
Leopard frog	2	13.0		
Green frog	6	1.5		
Toads	2	19.4		
Fish				
Sunfish	3	9.0		
Bluegill	5	46.5		
Catfish	2	6.6		
Black bullhead	1	17.5		
Spotted sunfish	1	44.5		
Gizzard shad	1	0.4		
Sucker	1	0.4		
Bowfin	1	0.8		
Unidentified	1	0		
Crustaceans				
Crayfish	3	3.9		

Table 5. Heptachlor epoxide content of individual tissues of mammals and reptiles from areas treated with 2 pounds of heptachlor per acre

Species	Liver		Kidney		Heart		Brain	
	No.	ppm	No.	ppm	No.	ppm	No.	ppm
Mammals								
Cat	3	21.8	3	11.4	3	17.4	2	6.1
Squirrel, gray	5	21.6	4	34.6	4	15.1		
Fox, red	3	18.3	3	16.1	3	21.4	3	22.8
Raccoon	12	12.8	12	13.7	11	16.6	4	15.7
Opossum	4	9.1	4	8.4	4	12.4	4	9.6
Rabbit, cottontail	26	8.1	21	17.6	20	9.2	13	20.5
Armadillo	1	7.7	1	2.2	1	Trace	1	Trace
Skunk	1	2.2	1	18.7				
Beaver	1	2.0	1	11.8	1	6.1	1	11.9
Nutria	1	0.8	1	9.5				
Deer, whitetail	1	0.0	1	30	1	0	2	2.5
Reptiles								
Snakes:								
Rat snake	2	17.1			2	168		
Corn snake	2	27.4			2	Trace		
Kingsnake	2	53.5	1	0	2	30		
Cottonmouth	1	6.5			1	<65		
Timber rattlesnake	1	17.9			1	29		
Coachwhip	1	9.1			1	0		
Racer	1	9.5			1	0		
Natrix sp.	1	20.6			1	15.0		
Turtles:								
Box turtle	4	173.9	4	144	4	103.9		

Table 6. Heptachlor residues in woodcock

Date collected	Collection area	Number analyses	Number containing residues	Heptachlor epoxide[1] in tissues				Remarks
				ppm		Total mcg/bird		
				Max.	Av.	Max.	Av.	
December 1958	Louisiana	9	1	Trace	<0.01	Trace	<0.1	
January 1959	Louisiana	27	6	3.5	0.26	67	8.4	
February 1959	Louisiana	9	5	0.7	0.23	47	16.4	
Spring 1959	North[2]	[3] 11	5	0.4	0.11	-	-	
Fall 1959	North[4]	8	4	3.2	0.5	147	22.9	Adults
Fall 1959	North[4]	12	0	-	-	-	-	Immatures
Fall 1959	New Brunswick	9	6	3.7	1.8	135	51.3	Adults
Fall 1959	New Brunswick	7	5	4.3	1.2	154	37.1	Immatures
December 1959	Louisiana	15	9	5.6	0.8	205	26.5	
January 1960	Louisiana	20	15	4.0	1.4	110	44.7	
February 1960	Louisiana	66	42	13.2	1.6	180	29.2	
Spring 1960	North	15	8	2.6	0.6	96	17.5	
Spring 1960	New Brunswick	10	-		0.6	-	-	Pooled sample
Fall 1960	North	39	29	3.3	1.1	120	38.6	Adults
Fall 1960	New Brunswick	6	2	1.8	0.9	72	35.5	Adults

1/ Entire carcass, exclusive of feathers, beak, feet and intestinal tract, analyzed.
2/ Collected in Ohio, Maine, Massachusetts, Pennsylvania, New Brunswick, Wisconsin, Michigan, Minnesota, and Nova Scotia.
3/ Includes 3 pooled samples of 5 birds each.
4/ Does not include samples from New Brunswick.

Table 7. Mortality of bobwhite quail kept in enclosures where the ground was treated with heptachlor

Experimental plan	Mortality[1/]								
	Bobwhite breeder pens (3 x 10-foot cages)								10 x 22 ft. cage
	Heptachlor treatment (pounds per acre)								
	0	0.25	0.50	0.75	1.00	1.25	1.50	2.00	2.00
1. Clean food in container; clean water; ground sprinkled with water after chemical applied.	0/4	0/4	0/4	0/4	0/4	0/4	0/4	2/4	20/20[2/]
1a. Same as 1, but no rainfall.									0/20
2. Clean food in container; contaminated water.[3/]	0/4	0/4	0/4	0/4	0/4	0/4	0/4	0/4	1/6
3. Food scattered on ground[4/]; clean water.	0/4	0/4	0/4	0/4	0/4	0/4	4/4	4/4	
4. Food scattered on ground[4/]; contaminated water.[3/]	0/4	0/4	0/4	0/4	0/4	2/4	4/4	2/4	0/6
5. Food scattered on ground[5/]; clean water; ground sprinkled with water after chemical applied.	0/4	0/4	2/4	0/4	2/4	4/4	2/4	4/4	6/6

1/ The first figure shows number of deaths ; the second shows the number of birds in the experiment. Thus 0/4 means none of four birds died .

2/ There was a heavy rainfall within 12 hours of treatment.

3/ Water in container before treatment so that it received heptachlor when the ground was treated.

4/ Food distributed after the ground was treated.

Table 8. Summary of quail populations as indicated by dog censuses on treated and untreated areas[1/]

Census period	Treated area		Check area	
	Number of coveys	Number of quail	Number of coveys	Number of quail
Winter 1957-58 (before treatment)	15	139	8	76
Spring 1958 (after treatment)	2	18	8	74
Fall 1958	13	147	7	135
Spring 1959	11	96	2/	2/
Fall 1959	18	214	11	125
Spring 1960	3/ 15	3/ 165	2/	2/

1/ A 3,600-acre area in Wilcox County, Alabama, was treated with heptachlor and dieldrin in March 1958. Heptachlor (2 lb/a) was applied to 2,400 acres and dieldrin (2 lb/a) was applied to 1,200 acres. The 600-acre untreated check area was 2 miles distant. Table adapted from unpublished report by Maurice F. Baker.

2/ Spring covey breakup interrupted these censuses.

3/ Covey breakup interrupted the completion of the census. These figures are estimated from 5 coveys with a total of 86 birds; 3 fall covey ranges where no birds could be found, and 3 fall ranges that were not censused, but were assumed to have coveys. The figure probably is generous.

Table 9. Pesticide residues in fish-eating birds from Tule Lake and Lower Klamath Refuges, 1960

Sample	Residues in parts per million wet weight basis			
	Toxaphene	DDT-DDE	DDD-DDM 1/	Total
White pelican: liver	8	2/ -	7	15
kidney	13	-	7	20
White pelican: liver	9	-	6	15
kidney	14	-	8	22
White pelican: ½ bird	4	48	15	67
liver	7	64	15	43
kidney	4	24	12	83
American egret: whole bird	17	138	52	207
Great blue heron: whole bird	10	3	-	13

1/ DDM is used to designate the degradation products of DDD.
2/ A dash is used to indicate that no residues were found.

Table 10. The highest concentration of a selected series of pesticides tolerated by 5 kinds of phytoplankton utilized by molluscan larvae as food

Compound	Parts per billion
Herbicides	
Monuron	0.02
Diuron	0.04
Lignasan	0.06
Neburon	0.40
Fenuron	290.00
Insecticides	
Sevin	100.00
Lindane	500.00
DDT	1,000.00
Dipterex	10,000.00
TEPP	100,000.00

Table 11. Preliminary data on the concentration of certain pesticides required to cause paralysis in small, 25 mm, stone crabs within 24 hours

Pesticide	Parts per billion
Endrin	10
Dieldrin	10
DDT	10
Sevin	1,000

Table 12. Preliminary data on the toxicity of a selected series of pesticides to medium size brown and white shrimp. Values shown are 48-hour median tolerance limit in parts per billion

Pesticide	Brown shrimp	White shrimp
Endrin	2.5	6.5
Sevin	27.0	13.0
DDT, Dieldrin	25-50	25-50
Toxaphene	40-50	75-90
TDE	150-200	75-90
Heptachlor	700.0	250.0

Table 13. Preliminary data on the effects of selected pesticides on mollusks at a concentration of 1.0 ppm. Figures represent approximate percentages of development or growth as compared with untreated control cultures

Pesticide	Development of clam eggs	Development of oyster eggs	Growth of oyster larvae
DDT			0
Lindane	100	85	
Guthion	30	0	75
Parathion			20
Toxaphene	50		
Aldrin	70		
Dieldrin	90	65	850
Endrin		20	95
Sevin	95	60	

Table 14. Percentage decrease in growth of mature oysters compared with control animals after 7 days exposure to a concentration of 0.1 ppm of the indicated pesticide

Chemical	Percent
Endrin	51
Chlordane	55
Toxaphene	64
Dieldrin	66
Heptachlor	83
Aldrin	95
DDT and DDE	100

Table 15. Toxicity of 55 commonly used pesticides (the approximate lethal dose or levels in diet reducing reproduction 25 percent or more) to bobwhite, ring-necked pheasant, and mallard

Compound	Approximate lethal dose (mg/kg)						Levels in diet reducing[1/] reproduction 25 percent or more (ppm)		
	Bobwhite		Pheasant		Mallard				
	Young	Adult	Young	Adult	Young	Adult	Bobwhite	Pheasant	Mallard
Aldrin	5	6	12	21			1	0.5	
ATA	26,000	>65,000	35,000	>12,000	15,700	>20,000			2,500
ATA-T	>75,000	>50,000	16,000			17,000			2,500
Bayer 22408	2,000								
Bayer 22684	2,125								
Bayer 25141	40	65							
Bayer 29493	40	70							
Benzene hexa-chloride	850	140	170	435			25	25	
Ceresan		190		190		80			
Chlordane	350		690	335			10	25	
Chlorobenzilate			7,000						
Chlorthion	700	>600							
Dacthal	5,500								
Dalapon	56,000	>70,000		>40,000	15,000	>26,000		5,000	
Delnav	2,100	25,000	15,000	25,000			25	10	
Dexon	500			150					
DDT	1,600	>2,000	1,100	>300	1,600	2,000	100	10	10
DDVP	1,700								
2,4-D amide	1,600				3,400	>35,000		2,500	1,250
2,4-D butoxy-ethanol ester	38,000		30,000		8,250	>34,000			2,500

(Continued)

1/ Based upon number of viable young per female produced by birds fed at indicated levels. Additional tests and statistical analysis of data have not been completed.

Table 15. Toxicity of 55 commonly used pesticides (the approximate lethal dose or levels in diet reducing reproduction 25 percent or more) to bobwhite, ring-necked pheasant, and mallard (continued)

Compound	Approximate lethal dose (mg/kg)						Levels in diet reducing reproduction 25 percent or more (ppm)[1/]		
	Bobwhite Young	Bobwhite Adult	Pheasant Young	Pheasant Adult	Mallard Young	Mallard Adult	Bobwhite	Pheasant	Mallard
2,4-D dimethyl amine salt	28,000	>38,000		>16,500		>35,000			1,250
Diazinon	65								
Dibrom	2,300			10,600					
Dieldrin	30	40	30	45	260	420	10	1	
Dimethoate	200	100	600	2,900					
Dipterex	600	>4,000	2,600	>800			25	25	
Disyston	800			>12,000					
Dyrene	>63,000	>83,000							
Endrin	5	8	19	22			10	0.5	
EPN	220			>200					
ET-14		2,500							
GC-3707	1,600		>6,000	>500					
Guthion	4,000	>1,500	2,000	>300			5	10	
Heptachlor	150	160	140	175	425	400	5	25	
Heptachlor epoxide	60								
Kelthane			1,750						
Kepone	600	530	600	115	400		5	25	
Lindane	1,400	>700	650	>600			1	5	
Malathion	725	5,300	1,025	1,000			25	500	
MCPA	19,000	47,000		>36,000	10,700			5,000	

(Continued)

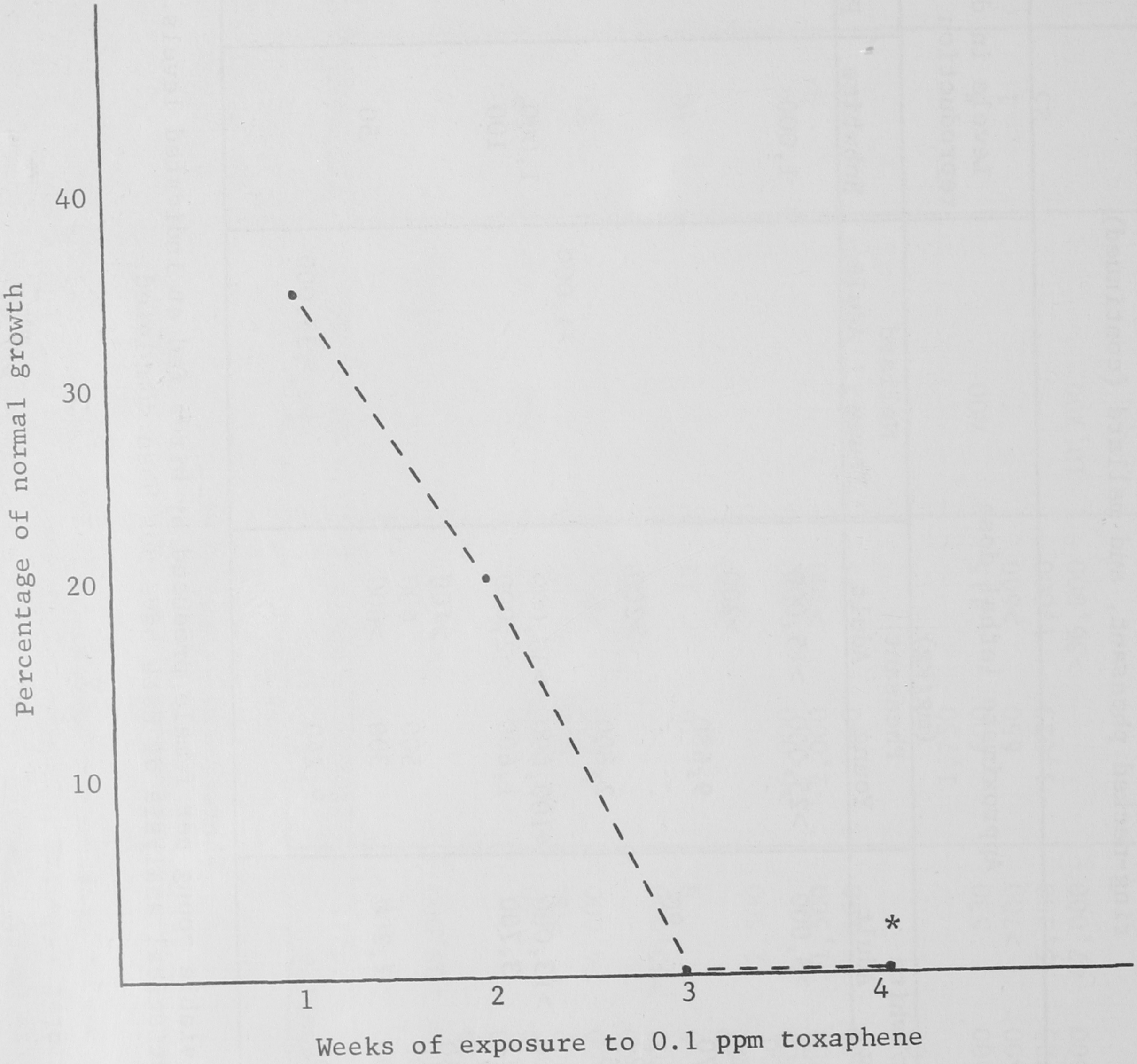
1/ Based upon number of viable young per female produced by birds fed at indicated levels. Additional tests and statistical analysis of data have not been completed.

Table 15. Toxicity of 55 commonly used pesticides (the approximate lethal dose or levels in diet reducing reproduction 25 percent or more) to bobwhite, ring-necked pheasant, and mallard (continued)

Compound	Approximate lethal dose (mg/kg)						Levels in diet reducing[1/] reproduction 25 percent or more (ppm)		
	Bobwhite		Pheasant		Mallard				
	Young	Adult	Young	Adult	Young	Adult	Bobwhite	Pheasant	Mallard
Methoxychlor	15,000	>3,000	>25,000	>15,000			1,000	500	
Muscatox	400								
Parathion	240			>200					
Perthane	9,170		9,680						
Phosdrin		90							
Phosphamidon	65			>200					
Rhothane	2,250		2,800						
Semesan						>1,000			
Sevin	2,000	>13,000	>100,000	>30,000			1,000	100	
Strobane	675	3,700	1,600	>2,000			100	50	
Systox	675								
Thimet	850			>100					
Thiodan	800		500	600					
Toxaphene	1,400	>2,200	300	>600			50	25	2,500
2,4,5-TP butoxy-ethanol ester	9,400		9,240			33,000			

1/ Based upon number of viable young per female produced by birds fed at indicated levels. Additional tests and statistical analysis of data have not been completed.

Figure 1. Effects of toxaphene on 1½-inch oysters



*50 percent mortality

References

Agricultural Chemicals.
1961a. 1960 pesticide sales up 3%. Agricultural Chemicals, 16(1): 33, 76-77.

Agricultural Chemicals.
1961b. Current and future chemicals are topics at annual entomological meeting. Agricultural Chemicals, 16(1): 41-42.

Agricultural Research Service.
1960. The nature and fate of chemicals applied to soils, plants, and animals. United States Department of Agriculture, Agricultural Research Service, ARS 20-9, ii + 221 p.

Baker, M. F.
1958. Observations of effects of an application of heptachlor or dieldrin on wildlife. Proceedings of the Twelfth Annual Conference Southeastern Association of Game and Fish Commissioners, p. 244-247.

Barlowe, R.
1958. Our future needs for nonfarm lands. p. 474-479 in "Land, the 1958 Yearbook of Agriculture," United States Department of Agriculture, 605 p.

Bridges, W. R.
1961. Disappearance of endrin from fish and other materials of a pond environment. Transactions of the American Fisheries Society, 90(3): 332-334.

Bridges, W. R., and A. K. Andrews.
1961. Effects of DDT spray on fish and aquatic insects in Gallatin River drainage in Montana. United States Fish and Wildlife Service Special Scientific Report: Fisheries, No. 391, p. 1-4.

Butler, P. A.
1960. Effects of pesticides on commercial fisheries. Proceedings of the Gulf and Caribbean Fisheries Institute Thirteenth Annual Session, p. 168-171.

Butler, P. A., A. J. Wilson, Jr., and A. J. Rick.
1960. Evaluation of effects of pesticides on oysters. Proceedings of the National Shellfisheries Association, vol. 51 (in press).

Chin, E., and D. M. Allen.
1957. Toxicity of an insecticide to two species of shrimp, *Penaeus aztecus* and *Penaeus setiferus*. Texas Journal of Science, 9(3): 270-278.

Clawson, S. G., and M. F. Baker.
1959. Immediate effects of dieldrin and heptachlor on bobwhites. Journal of Wildlife Management, 23(2): 215-219.

Davis, H. C.
1960. Effects of some pesticides on eggs and larvae of oysters (Crassostrea virginica) and clams (Venus mercenaria). Proceedings of the National Shellfisheries Association, vol. 51 (in press).

DeWitt, J. B., C. M. Menzie, V. A. Adomaitis, and W. L. Reichel.
1960. Pesticidal residues in animal tissues. Transactions of the Twenty-Fifth North American Wildlife Conference, p. 277-285.

Ennis, W. B., Jr.
1960. Use of herbicides, growth regulators, nematocides, and fungicides. p. 17-27 in "The Nature and Fate of Chemicals Applied to Soils, Plants, and Animals," United States Department of Agriculture, Agricultural Research Service, ARS 20-9.

Frear, D. E. H., editor.
1959. Pesticide handbook. 11th Edition, College Science Publishers, State College, Pennsylvania, 249 p.

Frear, D. E. H., editor.
1960. Pesticide handbook. 12th Edition, College Science Publishers, State College, Pennsylvania, 265 p.

Frey, P. J.
1961. Effects of DDT spray on stream bottom organisms in two mountain streams in Georgia. United States Fish and Wildlife Service Special Scientific Report: Fisheries, No. 392, p. 1-11.

George, J. L.
1960a. Possible effects of widespread use of forest chemicals on wildlife populations. Louisiana State University Ninth Annual Forestry Symposium - The Use of Chemicals in Southern Forests, p. 140-152. Louisiana State University Press, Baton Rouge.

George, J. L.
1960b. The pesticide problem. Wildlife - the community of living things. Massachusetts Audubon, 44(5): 226-232.

George, J. L.
1960c. Effects on wildlife of pesticide treatments of water areas. Proceedings of the Symposium on Coordination of Mosquito Control and Wildlife Management, Washington, D. C., p. 94-102.

George, J. L.
1960d. Some primary and secondary effects of herbicides on wildlife. p. 40-73 in "Herbicides and Their Use in Forestry," Forestry Symposium Pennsylvania State University, University Park.

Hickey, J. J., and L. B. Hunt.
1960. Initial songbird mortality following a Dutch elm disease control program. Journal of Wildlife Management, 24(3): 259-265.

Hunt, E. G., and A. I. Bischoff.
1960. Inimical effects on wildlife of periodic DDD applications to Clear Lake. California Fish and Game, 46(1): 91-106.

Hunt, L. B.
1960. Songbird breeding populations in DDT-sprayed Dutch elm disease communities. Journal of Wildlife Management, 24(2): 139-146.

Knipling, E. F.
1960. Use of insecticides, attractants, and repellents. p. 28-36 in "The Nature and Fate of Chemicals Applied to Soils, Plants, and Animals," United States Department of Agriculture, Agricultural Research Service, ARS 20-9.

Loosanoff, V. L.
1947. Effects of DDT upon setting, growth and survival of oysters. Fishing Gazette, 64(5): 94, 96.

Loosanoff, V. L.
1960. Some effects of pesticides on marine arthropods and mollusks. The Robert A. Taft Sanitary Engineering Center Technical Report W60-3, p. 89-93.

Loosanoff, V. L., J. E. Hanks, and A. E. Ganaros.
1957. Control of certain forms of zooplankton in mass algal cultures. Science, 125: 1092-1093.

Radeleff, R. D., and R. C. Bushland.
1960. The toxicity of pesticides for livestock. p. 134-160 in "The Nature and Fate of Chemicals Applied to Soils, Plants, and Animals," United States Department of Agriculture, Agricultural Research Service, ARS 20-9.

Rosene, W., Jr.
1958. Whistling cock counts of bobwhite quail on areas treated with insecticide and on untreated areas, Decatur County, Georgia. Proceedings of the Twelfth Annual Conference Southeastern Association of Game and Fish Commissioners, p. 240-244.

Shepard, H. H., J. N. Mahan, and C. A. Graham.
1960. The pesticide situation for 1959-1960. United States Department of Agriculture, Commodity Stabilization Service, ii + 21 p.

Shepard, H. H., J. N. Mahan, and C. A. Graham.
1961. The pesticide situation for 1960-1961. United States Department of Agriculture, Agricultural Stabilization and Conservation Service, iv + 22 p.

Ukeles, R.
1960. The effect of several toxicants on five genera of marine phytoplankton. Proceedings of the National Shellfisheries Association, vol. 51 (in press).

United States Department of Agriculture.
1960. National forests report 81½ million recreation visits. United States Department of Agriculture Press Release 541-60, 1 p.

United States Department of Agriculture.
1961. USDA sprays planes to destroy foreign beetle. United States Department of Agriculture Press Release 1158-61, 2 p.

United States Department of the Interior.
1960. Fish and wildlife report for December 1960. United States Department of the Interior, 15 p.

Warner, K., and O. C. Fenderson.
[1960]. Effects of forest insect spraying on northern Maine trout streams. Maine Department of Inland Fisheries and Game, Federal Aid Project F-8-R-7, 32 p. [Processed.]

Westlake, W. E., and J. P. San Antonio.
1960. Insecticide residues in plants, animals, and soils. p. 105-115 in "The Nature and Fate of Chemicals Applied to Soils, Plants, and Animals," United States Department of Agriculture, Agricultural Research Service, ARS 20-9.

Wooten, H. H., and J. R. Anderson.
1958. The uses to which we put our land. p. 53-62 in "Land, the 1958 Yearbook of Agriculture," United States Department of Agriculture, 605 p.

Wright, B. S.
1960. Woodcock reproduction in DDT-sprayed areas of New Brunswick. Journal of Wildlife Management, 24(4): 419-420.