BUREAU OF SPORT FISHERIES AND WILDLIFE
PESTICIDE - WILDLIFE REVIEW, 1959

UNITED STATES DEPARTMENT OF THE INTERIOR
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United States Department of the Interior, Fred A. Seaton, Secretary
Fish and Wildlife Service, Arnie J. Suomela, Commissioner
Bureau of Sport Fisheries and Wildlife, Daniel H. Janzen, Director

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PESTICIDE-WILDLIFE REVIEW: 1959

by

James B. DeWitt and John L. George
Patuxent Wildlife Research Center
Branch of Wildlife Research

Fish and Wildlife Service
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FOREWORD

The Bureau of Sport Fisheries and Wildlife has a primary obligation to preserve fish and wildlife values. Its responsibilities in the field of pesticides are to evaluate effects of new chemicals, formulations, and methods of application; to assist in development of chemicals and techniques that will minimize losses of fish and wildlife; and to inform the public of its findings and recommendations. These responsibilities are defined most recently in Public Law 85-582 of the 85th Congress.

The Bureau recognizes that pest control is essential at certain times and places; consequently, its policy is to encourage development of better and more specific methods that will permit effective pest control but will result in minimal fish and wildlife losses. Research findings of the Bureau, State agencies, and independent research workers are summarized in this report, together with recommendations for reducing damage from pest control operations.

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INTRODUCTION

During World War II normal supply lines were cut off and various countries attempted to develop substitutes of needed imported materials. Perhaps in no field were chemists more successful than in the development of synthetic organic pesticides to replace the botanicals and inorganic materials temporarily unavailable or in short supply. The first of these compounds to be developed was DDT. Production of this compound began in 1943, and its success in overcoming insect-borne diseases made it a potent military weapon.

In 1945 the U. S. Fish and Wildlife Service began tests in cooperation with the Division of Forest Insect Investigations of the U. S. Department of Agriculture to determine the side effects of pest control programs. Annual summaries of these early studies were reported by Cottam and Higgins [13], Nelson and Surber [45], and Linduska and Surber [42]. Since then the Service has not prepared annual summaries, but Service personnel have contributed 88 special reviews or papers in this field and numerous unpublished reports.

This report discusses the scope of the pesticide-wildlife problem; reviews the current activities and findings of the Bureau of Sport Fisheries and Wildlife, cooperators, and others in this field; summarizes the legislative developments of the past few years; and gives the Bureau's recommendations for use of pesticides with minimum harm to wildlife.

In the preparation of this report the authors have had the benefit of the advice and thinking of many of their colleagues in the Bureau of Sport Fisheries and Wildlife. At the Bureau level, Director D. H. Janzen and Assistant Director L. A. Parker have offered comments; in the office of the Branch of Wildlife Research, Dr. D. L. Leedy, Mr. C. E. Carlson, Dr. E. H. Dustman, and Mr. W. W. Dykstra reviewed the manuscript; at the Denver Wildlife Research Center, Dr. R. B. Finley reviewed the report and contributed unpublished information on pesticide-wildlife studies in western United States; at the Fish-Pesticide Research Laboratory, Dr. O. B. Cope reviewed the report and, with Mr. P. J. Frey, contributed unpublished information on the effects of pesticides on fish and other aquatic organisms; at the Patuxent Wildlife Research Center, Dr. J. L. Buckley, Mr. C. M. Menzie, Mr. V. Adomaitis, Mr. W. Reichel, Mr. and Mrs. W. H. Stickel, Mr. W. Rosene, Jr., Dr. P. A. Stewart, Mr. C. Vance, Mr. J. Spann, Mr. S. Leskosky, Mr. D. Landon, and Mrs. F. Fochler have aided in the studies reported and/or preparation of this report.

Professional biologists who have kindly consented to our use of their unpublished findings include:

Alabama: Dr. Maurice F. Baker of this Bureau and Mr. Dan W. Speake, Leader and Assistant Leader, respectively, of the Alabama Cooperative Wildlife Research Unit, and various of their graduate students, including Messrs. Sterling G. Clawson and George Matschke, who studied (partly under contract with the Bureau) the effects of 20 pounds of 10% heptachlor granules on wildlife in Wilcox County; and Mr. Ralph Allen and his associates, of the Alabama Department of Conservation, who observed the effects of 20 pounds of 10% heptachlor granules in Autauga County and other counties. Escambia County studies were by Mr. Walter Rosene, Jr. and Montgomery County studies were by Dr. Paul A. Stewart, both of the Bureau's pesticide-wildlife staff.

Arkansas: Messrs. Harold E. Alexander, Clyde Goddard, and Sam Gooden, of the State Game and Fish Commission, who supplied reports on the wildlife effects of 20 pounds of 10% heptachlor granules as used in the fire ant program in Union County; and Mr. W. P. Boyer, entomologist at the Agricultural Experiment Station, University of Arkansas, who furnished a summary of a study of insects in hibernation in treated and untreated fire ant areas in Union County.

Florida: Mr. Donald D. Strode, of the Game and Fresh Water Fish Commission, who furnished reports on the effects of 20 pounds per acre of 10% heptachlor granules as used in the fire ant program in Jefferson County.

Georgia: Dr. James H. Jenkins, of the University of Georgia, who supervised the studies of Mr. Curtis Wilson and furnished reports on the wildlife effects of 20 pounds per acre of 10% heptachlor granules in Decatur County, and of the results of pen tests at the University. The extensive quail censuses in Decatur County were taken by Mr. Walter Rosene, Jr., of the Bureau's pesticide-wildlife staff.

Louisiana: Dr. Leslie L. Glasgow, of Louisiana State University, who conducted studies, partly under contract with the Bureau, of the effects of 20 pounds per acre of 10% heptachlor granules as used in the imported fire ant control program on various vertebrate and invertebrate populations in Acadia, West Baton Rouge, Concordia, St. Landry, Iberville, and Vermillion Parishes; and Mr. John D. Newsom, of Louisiana Wild Life and Fisheries Commission, who studied the effects of heptachlor on wildlife in Concordia Parish.

Massachusetts: Dr. William G. Sheldon of this Bureau and Leader of the Massachusetts Cooperative Wildlife Research Unit, and Mr. Wendell B. Dodge, who furnished, under contractual arrangement with the Bureau, a report of the effects of DDT, heptachlor, and dieldrin on penned woodcock.

Michigan: Professor George J. Wallace, of Michigan State University, who studied (partly under contract with the Bureau) the effects of DDT as used in Dutch elm disease control on birds in 1 sprayed and 1 unsprayed community.

North Dakota: Mr. Charles F. Knedel, of the Game and Fish Department, who reported on the effects of aldrin as used in grasshopper control on waterfowl in marsh areas.

Texas: Mr. Daniel W. Lay, who reported effects of 20 pounds per acre of 10% heptachlor granules as used in the fire ant program in Hardin County.

Wisconsin: Professor Joseph J. Hickey and Mr. L. Barrie Hunt, of the University of Wisconsin, who studied (partly under contract with the Bureau) the effects of DDT as used in Dutch elm disease control on birds in 3 sprayed and 3 unsprayed communities. A report on these studies is in press in the Journal of Wildlife Management.

I. SCOPE OF THE PESTICIDE-WILDLIFE PROBLEM

Following World War II new materials, particularly DDT, were used to reduce agricultural loss, alleviate nuisances, or eliminate insect vectors of disease. The initial success led to additional demand, and during the last decade and a half a new type of pollution - chemical pollution - of our environments has taken place. The wholesale value of pesticidal chemicals has increased from $40 million to over $290 million [18]. Predictions are that the wholesale value will increase to $1 billion in about a decade. Over $2 billion are spent on pest control each year (Table 1). At the present time about one billion pounds of technical material are produced each year, and over 100 million acres are treated annually. Table 3 lists some commonly used pesticides and their annual production from 1952 to 1958.

Not only has the use of pesticides increased, but also their number and variety have multiplied. Today there are more than 200 basic types of technical materials. These are prepared and usually diluted in over 6000 various formulations to get a more effective distribution of the toxicant. The number of basic compounds in 5 major groups of pesticides is listed in Table 2. The trend seems to be toward more highly toxic materials and heavier dosage rates. Table 5 is taken from a U. S. Department of Agriculture review which shows how the newer pesticides are replacing the older pesticides.

Application techniques are improving, and there is an increasing trend toward aerial application (Table 4). In January, 1958, in Agricultural Chemicals, it was stated that 5000 pesticide planes distribute one billion pounds of dry type chemicals and 100,000,000 gallons of liquids at a cost of over $100,000,000 yearly.

II. EFFECTS ON WILDLIFE: GENERAL

In the use of modern pesticides direct wildlife damage is known to have resulted, but side effects of many programs have received little or no study. Of the higher forms of life, fish and other aquatic vertebrates are most sensitive to pesticides. Fish have died after applications of 0.25 pound per acre of DDT in oil; whereas cold-blooded terrestrial vertebrates have tolerated amounts up to 1 pound per acre. Birds have tolerated up to 2 pounds of DDT per acre and most mammals, up to 5 pounds, with little or no apparent, immediate effect (Table 6). Of the lower forms of life, arthropods are most sensitive. Many aquatic arthropods are killed after applications of 0.1 pound of DDT per acre. The microfauna (mainly protozoa) are reported to be relatively resistant as are the adults, at least, of the Mollusca and Annelida. Most of the newer insecticides that are commonly applied to wildlife habitat are more toxic to vertebrate animals than is DDT (Tables 7, 8, 9 and 10). On the other hand, some herbicides and most fungicides are less toxic than is DDT.

Specific examples of damage have recently been summarized in various ways by Service personnel: for large area treatment [11], for forest areas [24], for aquatic areas [25], for specific programs such as Dutch elm disease [16], and for the fire ant program [33]. General surveys also have been prepared [15], [22], [26], [58], [60]. The more recent and significant findings are summarized here. Laboratory studies are presented first; then studies of direct effects of pesticides on field populations are summarized; and finally indirect effects of pesticides are discussed.

III. LABORATORY STUDIES AND TOXICOLOGY

The Patuxent Wildlife Research Center has conducted tests on captive bobwhite quail and ring-necked pheasants for many years. Laboratory populations of mallard ducks have been established and maintained during the past 2 years and tests on them are under way. Approximately 5000 young and adult of these and other game birds are available as subjects and controls. Experiments are commonly conducted with 25 young subjects in a group and replicated 2 or 3 times. More limited tests on adult game birds, and on blackbirds, starlings, and small mammals also are being conducted at Patuxent and at educational institutions under contract with this Bureau.

These tests are designed to determine quantities of common pesticides which will produce acute or chronic poisoning, and to furnish information upon the effects of repeated or prolonged exposure to sublethal dosages. Appraisals are complicated by the fact that effects of a chemical vary with the species of animal, dosage rate, duration of exposure, time of year, sex, age, vigor, and nutritional status of the individual. For example, male pheasants are more susceptible than females to chlorinated insecticides; particularly during the breeding season; and young birds are less resistant than adults. The data in Table 7 show quantities of insecticides which will produce at least 50% mortality of birds at all stages of the life cycle.

Feeding of low levels of insecticides prior to or during the breeding season produced adverse effects upon reproductive capacity of quail (Tables 8 and 9). Production, fertility or hatchability of eggs were reduced, and unusually high percentages of chicks were crippled or defective. Viability of the apparently normal chicks was reduced, and mortality of the young birds during the first 6 weeks of life was above normal.

Several hundred specimens from laboratory tests, or from areas treated for eradication of imported fire ants, have been analyzed to determine distribution of insecticides in tissues following varying degrees of exposure. Although only a few representatives of some species have been examined, it appears that the quantity stored varies from compound to compound and from species to species (Tables 10, 11 and 12).

Laboratory tests with rainbow trout are beginning at the Bureau's Fish-Pesticide Research Laboratory in Denver, Colorado, to measure acute toxicity resulting from exposure to common insecticides, and to understand the influence on toxicity of size, sex, physical condition, dosage rate, water chemistry, and other factors in the environment.

Chemical analyses for toxaphene in fish from Clayton Lake, New Mexico, have been made in the Denver laboratories. The resulting data, as well as DDT analyses from fish exposed in the Yellowstone River, show great variation from fish to fish in the amounts retained in the tissues. However, fish show a steady statistically significant increase in toxaphene concentration with time of exposure (Cope, unpubl.). Residues of DDT were highest in adipose tissue; all fish collected had DDT in their bodies (10).

IV. DIRECT EFFECTS OF PESTICIDES ON FIELD POPULATIONS

Direct intoxication in the field is correlated with the particular habitat, chemical, dosage rate, formulation, species involved, and a host of other ecological considerations.

A. Forest Insect Control

Forest insect programs using a pound of DDT or less per acre have covered about 20 million acres in the United States, but have not produced serious widespread immediate die-offs of terrestrial forest vertebrates. In local areas where operational control was faulty and dosages were considerably higher than intended, mortality has been evident. However, some invertebrates, which constitute important foods for many vertebrates, are seriously reduced in numbers during these applications, and losses of aquatic organisms result when water environments are contaminated.

Two recent serious die-offs of fish have emphasized the importance of keeping the pesticide from aquatic habitats. The first was the Miramichi River in New Brunswick, Canada. In 1954, a treatment of 0.5 pound of DDT per acre to control spruce budworm resulted in the loss of up to 91% of the young Atlantic salmon of three age groups and some adults in the treated area [35], [37].

Portions of the Miramichi River drainage were treated again in 1956 and 1957, with very much the same results as in 1954 [34], [36]. These repetitive treatments (5 million acres in 1957) have largely undone the fish restoration activities of the aquatic biologists who predict a decline in the salmon runs [34].

The other serious die-off of fish occurred in the Yellowstone River in 1955 [40]. In the fall, about 3 months after DDT was applied at 1 pound per acre for control of the spruce budworm, large numbers of trout, whitefish and suckers, including many or most of the young of the year, were found dead along more than a 100-mile stretch of the stream. The loss of food organisms may have been serious enough to have caused the death of the fish [11].

During spruce-budworm control treatment of almost one million acres with 1 pound of DDT per acre on 3 national forests in Montana in 1956, numbers of aquatic and terrestrial invertebrates were greatly reduced by the spray even though maximum concentration of DDT in water samples was 0.33 parts per million, one-half hour after spraying (Cope and Park, unpubl.; Graham and Scott, unpubl.). A day later no measurable amount of DDT was present in the stream samples. However, dead insects continued to be carried downstream for 5 days and trout fed freely upon them, apparently without harm. A year later there was a slight decrease in numbers of trout in 2 intensively studied streams, but insect numbers were near normal and live trout appeared to be in good condition despite the fact that analysis of their tissues showed that they contained DDT. Eleven other streams in the sprayed area were studied less intensively, with fish populations being studied in 5. In 2 of the latter there were serious game-fish depletions - a decline of about 75% during the second year after treatment. This indicates again that long-range effects may not be apparent until the second year.

The Fish-Pesticide Research Laboratory conducted field and laboratory studies on fish exposed to a 1957 spruce budworm DDT treatment at 1 pound per acre in the Yellowstone River drainage [10]. In analysis of salmonids, it was found that whitefish contained more DDT and DDE than did rainbow, cutthroat, and brown trout. All fish collected had DDT in their bodies. Fish taken 85 miles downstream from the sprayed area were positive for DDT. The poison was found in all fish at all seasons, and for more than 11 months after the spray.

Studies were made on control of elm spanworm, Ennomos subsignarus, in north Georgia in 1959. Aerial treatment of DDT, at the rate of 0.5 pound per acre, resulted in substantial reduction of fish-food animals in a stream which received the chemical. Another stream, avoided by the pilot, suffered no loss of fish-food (Cope, unpubl.).

B. Ornamental Tree Protection

Shade tree insect and disease control can be serious. In Dutch elm disease control, it has been estimated that the equivalent of over 2,000,000 acres has been treated [24]. Dosages in this type of treatment are from 2.5 to 5 pounds of DDT per tree; in areas where elms are numerous, dosages have been as high as 17 pounds per acre. Numerous reports indicate that wildlife mortality has occurred as a result of treatments for Dutch elm disease control.

Bureau studies during 1959 were concentrated in Michigan and Wisconsin, through research contracts with educational institutions. The Wisconsin studies were conducted by Mr. L. Barrie Hunt under the direction of

Dr. Joseph J. Hickey, and covered sample areas throughout southeastern Wisconsin [32]. In unsprayed communities (Madison, Portage, and Stoughton), songbirds numbered 409 pairs per 100 acres, while in sprayed communities (Janesville, Wauwatosa, and Shorewood) populations ranged from 31% to 90% lower. The familiar robin was especially hard-hit in the sprayed communities; there were 50 times as many robins in the average unsprayed community as in the most heavily treated community. House sparrows appeared to be little affected by the spray. Similar results in Michigan have been reported [43], [64]. Michigan studies are continuing (Wallace, unpubl.).

C. Agricultural Pest Control

1. Imported Fire Ant. During the past year, most field work by the Bureau on pesticide studies has been concentrated upon appraising the effects of granular applications of heptachlor and dieldrin, as used in the program for eradication of the imported fire ant. These studies have involved work conducted by Bureau employees, by two universities under research contracts, and by State conservation departments and other cooperating agencies. Study areas were established on which pre-treatment and post-treatment numbers of birds were determined; careful searches were made for dead birds and animals, and reproductive success measured.

Details on the size and scope of the program to eradicate the imported fire ant are given in various papers [1], [12], [23], [48]. Initially it was planned that all infested lands were to be treated with 20 pounds of 10% heptachlor or dieldrin granules per acre. This was considered sufficient to eradicate the ant and prevent reinfestation in the treated area for a minimum of 3 years, during which time the danger of reinfestation would be eliminated by the treatment of surrounding lands. The procedure was followed during the first 2 years of the program, with heptachlor being used more extensively than dieldrin and some forest and marsh land remaining untreated even though within treatment blocks.

At the start of the third year of the program, application rates were reduced to 1.25 pounds technical heptachlor per acre, and experiments with two 0.25 pound technical heptachlor per acre treatments (repeated after a 3-month interval) have reached the large area treatment testing stage in several States. Experiments with baits and various chemicals at low dosage rates are under way on small plots. Only limited studies of the side effects of these newer treatments have been made, and when discussed below the application rates are given.

All other studies reported in this section on side effects of the imported fire ant program pertain to the 2 pounds of technical heptachlor per acre applications.

Preliminary observations of the effects of the program on wildlife were summarized by Janzen [33]. Some of these studies are now in their second year. All intensive studies by Bureau employees, or of cooperating State conservation departments in Florida, Alabama, Georgia, Louisiana, Texas and Arkansas are summarized below.

a. Effects on Mammals. No exact quantitative figures are available on the effects of the program on mammals, but all studies indicate some mortality of game mammals. Published [2] and unpublished Bureau studies at the Experiment Station of Alabama Polytechnic Institute in Wilcox County, Alabama, are typical. Rabbits and raccoons showed a marked decrease soon after treatment, continued at a depressed level through the first summer, and returned to normal population levels by the end of the first post-treatment year. Comparable findings were reported for Autauga County, Alabama, where 6 rabbits, 3 opossums, 1 raccoon, 2 cotton rats, and 1 white-footed mouse were found dead on 10 acres (Allen, letter; and Kelley, unpubl.); for Decatur County, Georgia, where 7 rabbits, 3 rodents, and 1 cat were found dead on 2 acres [33]; for Jefferson County, Florida (Strode, unpubl.); for Acadia, West Baton Rouge, St. Landry, and Vermillion Parishes, Louisiana [29] and Glasgow (letter); for Concordia Parish, Louisiana [46]; and for Union County, Arkansas (Gooden, unpubl.). The Hardin County, Texas [38], [39] and Lay (unpubl.) studies indicate that opossums, armadillos, and an abundant raccoon population virtually disappeared on the study area and were still depressed in numbers during the second autumn after treatment. Bureau analyses showed that raccoons which repopulated the area were contaminated even a year later as follows:

		Heptachlor Epoxide in Tissues		
Specimens	Time after Treatment	Kidney p.p.m.	Liver p.p.m.	Remarks
1	2 weeks (Spring)	19.9	1.3	Found dead.
4	6 months (Fall)	3.8	3.3	Shot.
2	9 months (Winter)	7.8	4.0	Shot.
1	1 year (Spring)	4.5	1.7	Shot.

Cotton rat populations in Decatur County, Georgia, were reported to be little affected by treatment as judged by 1763 individual observations (Wilson and Jenkins, unpubl.). A few cotton rats were found dead in treated areas in Alabama (Allen, letter), Georgia [33], and Louisiana (Glasgow, letter); but some field reports indicate cotton rats may be more numerous than usual a year or so after treatment. Predators of cotton rats are known to have been killed by the treatment. On the Wilcox County, Alabama, area young foxes in a den were found dead.

b. Effects on Birds: General. All studies except one by Wilson and Jenkins (unpubl.) show severe mortality of birds following treatment. Chemical analyses of several hundred dead specimens from the study areas confirm that the birds had absorbed or ingested the insecticides used in the eradication program. More careful scrutiny of data of all studies reveal a virtual elimination or serious reduction of ground-feeders and other low-strata species on treated areas with little effect on the higher-strata or tree-top species. Also, birds of limited home range or territory may survive on small untreated tracts in large blocks. These findings are illustrated by the Bureau's studies in Montgomery County, Alabama, on land treated in the spring of 1959. Stewart (unpubl.) found that an over-all mortality of 49 species of breeding birds consisted of a decline from 457 to 220.5 pairs (51.8%). However, by strata the effects were:

Strata	Reduction
Low level or ground (7 species)	100%
Low to intermediate (17 species)	50-99%
Low to intermediate (5 species)	50%
Intermediate to high (19 species)	No effect.
Limited range untreated (1 species)	No effect.

Nesting success studies confirmed the heavy losses in the lower strata as follows:

	Treated		Untreated	
	No. Nests	% Successful	No. Nests	% Successful
Ground	23	17.4	13	53.8
Shrub	35	42.9	16	87.5
Tree	37	70.3	14	71.4

The most spectacular example of an abundant species with limited range surviving on small untreated tracts within a large treated block is the house sparrow (26 pairs) which continued unchanged in numbers around the untreated ranch buildings centered on a 2400-acre treated ranch. There is a possibility that the house sparrow is also relatively immune. This postulation would be in keeping with the findings of stable populations of this species in areas treated for control of Dutch elm disease (which also is a patch treatment in that only street elms on city blocks are treated). Numerous studies in Georgia [33], (Rosene, unpubl.), (Wilson and Jenkins, unpubl.); Florida (Strode, letter); Alabama (Baker, et al., unpubl.), [2], [8]; Louisiana [29], (Glasgow, letter), [46]; Texas [38], [39]; and Arkansas (Goddard, unpubl.) confirm Stewart's findings in Alabama. The degree of mortality encountered in these studies is clearly correlated with the strata and the ratio of untreated:treated land within each "block".

A spring, 1959, die-off of songbirds was reported one year after application on the Wilcox County, Alabama, area (Baker, et al., unpubl.). A total of 31 dead birds and mammals was found in two and one-half days of searching by two men. Chemical tests of specimens revealed significant amounts of insecticide in tissues. Also, much good bird habitat was unoccupied. Robins and meadowlarks were especially low in number. Counts were:

Date	Area	Miles Traversed	Live Birds Seen Robins Total:per mile		Meadowlarks Total:per mile	
March 7	Heptachlor	2.6	0	0.0	2	0.8
March 8	Heptachlor	2.0	12	6.0	0	0.0
March 9	Dieldrin	1.5	0	0.0	0	0.0
March 8	Check	2.1	48	22.8	54	25.7

Studies in Texas [39] and Louisiana (Glasgow, letter), where populations had declined over 85% soon after treatment and nesting success was reduced 89% or more, indicated the effects on songbirds during the second year to be depressed populations rather than nesting success. Populations were about 11% to 70% normal depending on the species and habitat group, and census method, but nesting success appeared to be almost normal for the population present. Nesting success in these studies is judged by percent of nests in which young were fledged. No data are available on fledgling survival in the field. Studies of this phenomenon are continuing.

c. Effects on Bobwhite Quail. This species has received special study and several investigations in at least 3 States give quantitative findings which enable rather precise predictions of the fate of quail on treated areas. In general, the bobwhite reflects the strata and area effects described earlier for songbirds, i.e., virtual elimination on treated areas with gradual repopulation during the first year after treatment but with some mortality and with depressed populations persisting into the second year. Also, individuals and/or coveys can survive on small untreated tracts within large treatment blocks. Third year effects will not be available in any area until the summer of 1960.

At the Alabama Polytechnic Institute Substation in Wilcox County, the Bureau's Alabama Unit Leader, Baker, and others [2] gathered the information presented in Table 14. It is evident that the quail on treated areas were virtually eliminated, with only a few peripheral birds (living largely off the treated area) surviving. Populations continued to be seriously depressed (by at least 35%) into the second year after treatment. Some die-offs continued into the spring of the second year and analysis of tissue of dead birds revealed appreciable amounts of insecticide. Populations appear to be approaching normal at the end of the second year (Baker, et al., unpubl.).

Studies by the Bureau [49] in Decatur County, Georgia, of treated and untreated areas are presented in Table 15. Populations of whistling cocks a year after treatment continued to be depressed by over 50% (Rosene, unpubl.). This is higher than the Wilcox County area and can be explained by the size and shape of the study areas. Baker's Alabama studies were on a long linear unit of about 3600 acres, and repopulation was more rapid from the surrounding untreated lands than on the extensive 10,000-acre plots Rosene studied in the heart of the extensive treatment blocks (approximately 100,000 acres) in Decatur County, Georgia. Probably, also, this explains why the number of coveys in the treated areas in Georgia continued to be depressed greatly during the first and second winters after treatment. Rosene's studies also show that quail can survive on small tracts of untreated land within big treatment blocks. On

700 acres of such land he found a population density of 12.86 whistling cocks per 1000 acres - about half the normal population density for the time and area. About the same figure - 12.29 whistling cocks per 1000 acres - was obtained during the summer of 1959 on a 10,000-acre census tract near Faceville, Georgia, after it was partly treated during the winter of 1958-59 (Rosene, unpubl.). This was less than half the population density of the area (27.43) in 1958 when it was untreated. In Montgomery County, Alabama, the Bureau's studies by Stewart (unpubl.) indicated that breeding bobwhite quail populations were reduced 76.9% immediately after treatment, and in West Baton Rouge Parish, Louisiana, Glasgow [29], (letter), found that bobwhite were eliminated on a small study tract. In Union County, Arkansas, Goddard (unpubl.) found that there was an 88% kill of bobwhite quail with populations declining from 72 per 1000 acres to 7 soon after treatment. There was a moderate decline (22%) on the control area from 49 birds per 1000 acres to 38.

d. Effects on Wild Turkey. Effects were reported by Clawson [7] for the Wilcox County, Alabama, area. A pre-treatment population of 80 declined steadily through the first breeding season after treatment. Some reproduction took place as evidenced by a clutch of unhatched eggs and a dead poult found on the area. No turkeys were present (or, at least, observed) during the first summer after treatment. During the first winter after treatment only 5 gobblers, 6 hens and 1 young of the year were present - as determined by systematic censusing from baited blinds. Populations continued to be seriously depressed into the second year. Second year winter figures are not available. It is of interest to note that the domestic turkeys on the area also had no reproduction. Three hens laid 50 eggs of which 7 hatched; all 7 young died soon after birth. Turkey populations on untreated areas nearby were normal.

e. Effects on Reptiles. Reptiles were seriously affected by the heptachlor applications, especially the aquatic and ground-dwelling forms. Quantitative figures for snakes are available from only the Wilcox County, Alabama, area. Matschke (unpubl.), [2] captured, marked and released 137 cottonmouths during the first year after treatment. New captures and recaptures declined steadily until mid-summer 1959 (15 months after treatment), after which no moccasins were found on the study area (a beaver swamp of about 8 acres of which only a part was treated). Also, all snakes of the genera *Storeria* and *Natrix* disappeared during the year after treatment. Some *Thamnophis* survived and reproduction took place the second summer after treatment, but 2 of 7 young of the year went into convulsions when captured. Studies are continuing.

Dead snakes were found after treatment in St. Landry Parish, Louisiana [29]. Snakes disappeared (none seen) after treatment in West Baton Rouge Parish, and in Vermillion Parish, 8 dead and 21 live water snakes (*Natrix*) were found after treatment but 14 live snakes of 3 other genera (*Thamnophis*, *Heterodon*, *Agkistrodon*) were found (Glasgow, letter).

Both aquatic and terrestrial turtles were seriously reduced in number after treatment. No quantitative data on population densities are available, but aquatic turtles were virtually eliminated in the herpetological study area (8-acre beaver swamp) on the Wilcox County, Alabama, area and box turtles

(Terrapene) were severely reduced over the entire study area (3600 acres), 4 being found dead within 50 feet of each other (Baker, et al., unpubl.). Turtle populations have continued depressed on this area during the second year. Studies are continuing.

In Vermillion Parish, Louisiana, 4 dead and 2 live sliders (Pseudemys) were found soon after treatment (Glasgow, letter).

In St. Landry Parish, Louisiana, 2 dead skinks (Eumeces) and 2 dead chameleons (Anolis) were found. None was seen alive [29]. In Vermillion Parish, 3 dead skinks and 1 dead chameleon were found; none was seen alive (Glasgow, letter).

f. Effects on Amphibians. The frogs show the same stratified susceptibility to heptachlor granules that is evidenced in the birds; ground dwellers (Rana) are severely reduced in numbers, whereas tree frogs (Hyla, Acris) are often able to maintain normal numbers despite some mortality around breeding ponds.

On the Wilcox County, Alabama study area, 4 species of the genus Rana virtually disappeared soon after treatment in 1958 and did not return in 1959. Tree frogs and salamanders (Desmognathus) seemed unaffected (Baker, et al., unpubl.).

Other studies also indicate that amphibians were affected. In Autauga County, Alabama, Kelley and Allen (letter) report dead and dying frogs were numerous; early observations in Decatur County, Georgia, revealed mortality of frogs in a plot checked by Rosene and DeWitt [33]. Other studies in Decatur County indicated little effect [33]. In Jefferson County, Florida, Strode (unpubl.) reported that large numbers of dead frogs were observed. Little evidence of damage to aquatic life was reported in Concordia Parish, Louisiana [46]; but dead frogs were found in St. Landry Parish, and in Vermillion Parish 7 dead ground frogs (Rana) were found and none was seen alive, whereas 2 live tree frogs (Acris) were seen and none was found dead (Glasgow, letter).

g. Effects on Fish. In the Wilcox County, Alabama, area Baker et al. (unpubl.) reported most adult fish were killed within a few days after treatment even though only a portion of the 2-acre pond was treated. Schools of small fish, however, were observed through 1958, and 68 pounds of fish of 10 species were found alive in the fall of 1959 when the pond was drained. Of these, only gar fish (Lepisosteus) were over 15 inches in length, but several fair-sized largemouth bass and catfish were taken. Numerous fish were recorded dying in Autauga County, Alabama (Allen, letter). In Decatur County, Georgia, Wilson and Jenkins (unpubl.) reported that experimental applications of 0.25, 0.50 and 1.25 pounds technical heptachlor per acre treatments showed little affect on fish; 5 pounds per acre was the maximum fish kill. Also, in early observations in Decatur County, Webb [33] found no damage to fish. An application in West Baton Rouge Parish, Louisiana, to a shallow canal resulted in 21 dead fish per 100 feet of bank along a 1500-foot stretch. Free-floating and dead fish in the canal and on the opposite bank were not counted but were at least as numerous (Glasgow, letter). Almost all were shad. In a 215-foot section of the canal blocked with seines there were 22 live shad though some were in distress. Little evidence of damage to aquatic life was reported in Concordia Parish, Louisiana [46]. In Vermillion Parish, Louisiana, 150 sunfish (Lepomis) of 3 species were found dead and 4 were seen alive; 41 individuals of 5 other species were found dead and none was seen alive; and 6 live individuals of a ninth species were seen alive and none was found dead (Glasgow, letter). In Hardin County, Texas, "fish kill was heavy and continued for over 3 weeks. Young fish died first. The few survivors were usually large and, except for shad and gambusia, were thin. Two months after the poisoning, larvae of several species were found, and the population of fishes appeared to be on the way to recovery. During a later treatment of the southern part of the farm, extreme care was taken to avoid contamination of water with heptachlor, and a fish kill was avoided" [4].

Bureau personnel studying fish ponds near Quincy, Florida (Frey, unpubl.) found mortality to bluegill and black bass in 2 ponds exposed to 0.25 pound of technical heptachlor per acre in granules. Three other adjacent ponds subjected to the same treatment had no immediate fatalities, but their fish populations are being studied for signs of damage.

In Florida, dieldrin treatment at 1 pound per acre in granular form (used in sandfly control) virtually eliminated fish in a salt marsh area [30]. Tarzwell [61] reports 0.07 pound of dieldrin or 0.16 pound of heptachlor per acre is sufficient to produce a 50% kill of fish in 96 hours, with concentrations of 7.9 and 19 parts per billion, respectively, being sufficient to kill bluegills in the laboratory. Toxicity varies with species and environments.

Studies to date, therefore, indicate that dieldrin produces heavy kills and heptachlor can produce substantial kills where the granules enter the water, but quantitative figures are lacking as to the total population effect. The Alabama and Texas studies would indicate that recovery of a population begins during the first year after treatment.

h. Effects on Aquatic Invertebrates. In the Wilcox County, Alabama, area water insects and crayfish were found dead within 14 hours after treatment and continued to die for at least 40 hours [2], (Baker, unpubl.). Many dead crayfish were found in St. Landry Parish, Louisiana [29], (Glasgow, unpubl.).

i. Effects on Earthworms and Terrestrial Insects. Earthworms, a major food item for woodcock and robins, contained up to 20 parts per million of heptachlor epoxide in their tissues 6 to 10 months after treatment of land in St. Landry and Acadia Parishes, Louisiana. In Wilcox County, Alabama, earthworms collected 1 year after application of insecticide contained 1 part per million of heptachlor epoxide in their tissues. The average heptachlor epoxide content of 32 samples, containing up to 100 earthworms per sample, taken 6 to 12 months after treatment in areas receiving 2 pounds of heptachlor per acre, was 3 parts per million (Table 14).

In Union County, Arkansas, there were 40% fewer insects of all types in treated than in untreated soil sampled 1 year after application of insecticide (Boyer, unpubl.).

2. Japanese Beetle. No special studies of the chemical control program to eradicate the Japanese beetle in the western outposts of its range are under way. Two pounds of technical heptachlor, dieldrin or aldrin per acre in granular form are being used in this program. Effects of dieldrin have been reviewed recently by Scott, et al. [52] and effects of dieldrin and heptachlor at comparable dosage rates are reviewed earlier in this paper for the fire ant program. Aldrin is a more toxic compound than dieldrin or heptachlor, but is quickly converted to dieldrin. Therefore, except for a different location, somewhat different fauna and much smaller areas, effects can be expected to be somewhat similar to those in the fire ant program. Recently 32,000 acres were treated in Michigan (the total known infestation in that State). Two days after treatment with aldrin in November, 1959, residents of Detroit reported seeing dead and dying birds and mammals [5]. In Joliet, Illinois, where heptachlor was used, dead birds, mammals and fishes were reported [5].

Other outlying infestations in 16 States from Georgia to Iowa to Maine, rimming the central general infestation in northeastern United States, total 1,954,920 acres.

3. Mediterranean Fruit Fly. The program to eradicate the Mediterranean fruit fly on over 800,000 acres in Florida used from 0.5 to 0.75 pound of actual malathion per acre in a bait spray. Infested areas were treated several times and about 7,000,000 acre-treatments were involved. The effects of this program on wildlife have recently been summarized by Bureau personnel [11]. Laboratory studies indicate malathion has about the same toxicity to fish as DDT, and primary mortality in the field has been to fish - in some cases the majority of killifishes [11].

D. Orchard Pest Control

Orchards are subjected to repetitive treatments of toxic chemicals at high dosage rates during the growing season, but they do sustain some wildlife during the non-growing season. The use of endrin as a rodenticide to control pine and meadow mice during the non-growing season has been increasing during the past several years, but effects of these treatments upon wildlife have not been determined. The feeding of apple pomace to livestock has been halted due to excessive pesticide residues, but wildlife in the areas also feed upon apples. Bureau studies have shown that when population densities of wildlife are greatly reduced in desirable habitat, there is an influx of individuals from suitable surrounding terrain. No special studies of this phenomenon in orchards have been made.

E. Range Insect Control

Over 6,000,000 acres were treated in 1957 to control grasshopper and Mormon cricket outbreaks in range and crop lands. Tens of millions of acres are at times infested with these pests and large control programs are conducted. Bureau personnel have summarized the effects of aldrin or heptachlor - 0.125 to 0.25 pound per acre; chlordan - 0.5 to 1 pound per acre; and toxaphene - 1 to 1.5 pounds per acre as used in these programs to control grasshoppers, and as used (in bait at about 1/10 the dosage) to control Mormon crickets [11]. Although the dosage rates are low, the full impact of the toxicant is felt as there is little filtering effect of higher strata of vegetation such as occurs in forests during aerial application.

Furthermore, under conditions of operational spraying of grasshopper-infested croplands and rangeland, Bureau investigators have found that parts of treated areas may receive as many as three overlapping doses in the same season. Certain land most heavily infested with grasshoppers, such as alfalfa, corn, wheat, and soil-bank land, are especially attractive habitat also for pheasants. A recent study of the food habits of pheasants in South Dakota by Trautman [62] revealed that grasshoppers are the most abundant kind of animal matter eaten by pheasants and that young pheasants eat a much higher proportion of grasshoppers than do adults. Hence young pheasants may be especially vulnerable to grasshopper control operations; as yet the Bureau does not have sufficient data to know to what extent pheasants in the field are actually affected by grasshopper insecticides.

Aldrin in bait form has been shown to kill a few birds [17] and up to 70% of mice present (Yeager and Sandfort, unpubl.). In marsh areas aldrin reduced duck production up to 33% (Knedel, unpubl.). Heptachlor was found to be very toxic to crayfish, and chlordan treatments reduced duck production by over 50% and are capable of killing large numbers of fish [11], [42]. Toxaphene treatments are very poisonous to fish and small losses of ducks and coots have also been reported [11], [61].

In July, 1959, the Bureau studied the effects on wildlife of 1.5 pounds of toxaphene per acre as used in control of grasshoppers on a 1600-acre plot in Montana. Most specimens found dead were associated with a stockpond and an intermittent stream. No fish were present, nor were any mammals found dead; but 53 salamanders and frogs, 17 turtles and snakes, and 20 birds of 7 species were found dead. Of these, 41 specimens were analyzed chemically; all but 1 dead bird contained significant amounts of toxaphene. Mortality was noted within a few hours of treatment.

Other effects noted included a loss of coordination and/or loss of equilibrium, or a torpid behavior on the part of surviving turtles and frogs; but turtles were wary and alert 12 days after treatment, when studies ended. Turtle counts dropped from 97 before treatment to 74 one day after treatment and 67 twelve days after treatment. Bird counts indicated a marked drop of insectivorous species (Finley, unpubl.).

F. Aquatic Pest Control

Treatment of aquatic areas to control nuisance or biting insects is usually at low dosages; however, such compounds as dieldrin sometimes are used at 1 pound per acre. In the latter cases, immediate mortality of aquatic forms (except adult mollusks and annelids which are relatively resistant) is essentially complete for the higher invertebrate and vertebrate forms [30]. These treatments annually involve millions of acres of the most valuable fish and wildlife marsh habitats. A recent survey of this problem by Bureau personnel is in press [25]. It concludes that knowledge of the full import of low dosage rates is still lacking. Indirect effects may be quite important.

V. INDIRECT EFFECTS OF PESTICIDES ON WILDLIFE

Direct mortality, however serious and spectacular, is not the only danger to wildlife from pesticides. Indirect mortality or loss of reproductive potential may result from consumption of minute amounts of poisonous chemicals over a period of time. In laboratory studies certain compounds are found to be additive, while others are synergistic. Some food organisms are relatively resistant and may store toxicants [3], [29], [59]. Others are very susceptible and there may be changes in numbers or relations of food-chain organisms. Even dying insects may be toxic [17], [28].

Adult quail and pheasants seemingly unaffected by minute amounts of toxicant in their feed may become deficient in reproductive potential [14], [15]. Penned quail whose diets contained DDT at the rate of 3 ounces per ton of food produced eggs whose fertility was reduced 30% [16]. They produced 33% fewer chicks per hen and 800% more cripples than did quail on diets uncontaminated by DDT. More than 90% of the chicks from treated birds died within 6 weeks - even though pesticides were not fed to the chicks themselves. In other pen tests, woodcock, which had first been fed DDT with little apparent effect, were more susceptible to dieldrin than uncontaminated birds (Dodge and Sheldon, unpubl.).

A. Earthworm Studies

Earthworms have been shown to be relatively resistant to pesticides, to be able to store toxicant in tissues, and to be able to poison vertebrates feeding on them. Earthworm studies in connection with the fire ant program have already been reviewed. Studies of the effects of feeding contaminated earthworms to captive birds are in progress.

B. Aquatic Pest Control

To control a bothersome gnat, Clear Lake, California, was treated in 1949 with DDD at 0.01 to 0.02 parts per million [9], [41], [51]. Treatment was repeated in 1954 and 1957. The summer breeding colony of western grebes disappeared soon after the first treatment. In November, 1957, hundreds of wintering grebes died. Both the breeding and wintering populations have been shown to be affected through the fish the birds consumed. Samples of tissue from fish and grebes contained very high concentrations of DDD, up to 1600 parts per million in grebes and 2500 parts per million in fish. For this reason control operations were suspended in 1958, despite the fact that larval counts of gnats in 1958 were the highest on record [50].

Wildlife also could be seriously affected by reduction in the amount of insect or crustacean foods, aside from direct or indirect poisoning. For example, many studies have shown that fiddler crabs are greatly decreased in numbers after pesticidal application [27], [59], and this reduction could affect the clapper rails for whom they are a principal food [47].

C. Grasshopper Control

Bureau studies of the side effects of an application of 1 pound of sevin per acre for grasshopper control in Montana during July of 1959 indicated vertebrates were not affected directly. No vertebrate casualty attributable to sevin was found. Counts of birds on the treated area, however, dropped from 173 before spraying to 30 two weeks after spraying. Counts on the control area for the same periods averaged 85 and 56 birds, respectively. The post-breeding population of birds apparently departed from the test area after destruction of their insect food supply by spraying (Finley, unpubl.).

Indirect effects on vertebrates through changes in the numbers of food-chain organisms are inherent in the use of any broad-spectrum insecticide. These faunal displacements sometimes lead to outbreaks of other pest species, e.g., an outbreak of red spider mites may follow spraying to control spruce budworm (Finley, unpubl.). The full import of population imbalances is unknown, but such phenomena as the development of invertebrate populations resistant to presently used insecticides or secondary outbreaks of pests, sometimes necessitates additional control measures.

VI. RECENT PESTICIDE LEGISLATION

Federal and State laws have been and are being enacted to regulate the use of pesticides. Federal laws include the Insecticide, Fungicide, and Rodenticide Act of 1947, amended in 1959 (Nematocide, Plant Regulator, Defoliant, and Desiccant Amendment). This Act is administered by the U. S. Department of Agriculture, and clearly states that wildlife values must be considered in the registration and use of pesticides. The Food, Drug, and Cosmetic Act was amended in 1954 (Pesticide Chemicals Amendment), and again in 1958 (Food Additives Amendment). This Act is administered by the Food and Drug Administration of the U. S. Department of Health, Education, and Welfare which sets tolerances on pesticide residues in food. Although the Act does not directly concern wildlife, it has had great effect on the procedures, dosage rates, and chemicals used in wildlife environments. Public Laws 85-582 (1958) and 86-279 (1959) specifically direct the Service to study the effects of pesticides on wildlife.

VII. VALUE OF WILDLIFE

Federal legislation recognizes the value of fish and wildlife. These values in the past often have been appraised by such terms as invaluable or priceless because many intangible aesthetic considerations are involved. However, in 1955, the Fish and Wildlife Service arranged for a survey to be made of expenditures by hunters and fishermen. In that year, expenditures for this sport were about $3 billion and there were about 25,000,000 licensed sportsmen [63]. Since then, the number of licensed sportsmen has increased by more than a third and the price index has gone up. Therefore, $4 billion probably are now being expended annually in sport fishing and hunting. On the Bureau's wildlife refuges, 60% of the use is by people not engaged in these sports (U. S. Dept. of the Interior, News Release P. M. 53743, April 22, 1959). While figures serve as an index to the value of fish and wildlife, they do not reflect the aesthetic appeal of living natural resources to the general public.

VIII. RECOMMENDATIONS FOR SAFEGUARDING WILDLIFE VALUES DURING PEST CONTROL

The Bureau of Sport Fisheries and Wildlife recognizes that control of certain pests is essential for the preservation of public health and the protection of valuable crops or commodities, but it also recognizes that many commonly used pesticides are toxic to fish, birds, and other wild creatures. To minimize these hazards, the Bureau has recommended close adherence to certain fundamental principles [11], [13], [21], [42], [45].

It should be clear from the initial presentation in this report that any applications in excess of those listed for DDT in Table 6 will produce wildlife loss in the various classes of animals as indicated. Table 10 gives a comparison of relative toxicities of other compounds with DDT = 1. With the aid of these two tables it should be possible to predict in advance the degree of direct effects on wildlife which will take place with any given application. By keeping the amount below the amounts listed in Table 6, or the relative equivalent, serious mortality can be avoided.

The following suggestions are in addition to this primary consideration.

(1) Chemical treatment should be used only when entomological research has proved it to be necessary.

(2) Before pesticides are used, the effects on different kinds of animals and on animals living in different habitats should be known and carefully considered.

(3) Only minimum quantities of chemicals necessary to achieve adequate control of pests should be applied.

(4) Pesticides should not be applied to areas that are any larger than is necessary and the chemicals that are used should be the ones whose effects are no more long-lasting than necessary.

(5) Whenever possible, chemicals should be applied at the seasons of the year when wildlife damage will be least. Some applications of pesticides can be made during the winter season when fewer birds are present in most northern areas than during the spring migration period; also, certain birds are relatively more mobile during the winter season.

(6) Conscientious effort should be made to be sure that pesticides are applied at no more than the intended rates and that no areas receive double doses.

Although these procedures will help to minimize damage they are not entirely satisfactory for the protection of wildlife [11].

More attention should be given to developing chemicals specifically toxic to only one particular group of animals. For example, in control of the lamprey in the Great Lakes, the Service screened thousands of compounds to obtain one or two that were fairly specific for lamprey larvae.

Biological methods of control also should have more study. Suppression of insects by other insects and by disease is a very important factor in regulation of insect numbers, despite all the use of pesticides [19], (Lilly, unpubl.). An unusual example of effective biological control was the result of research by the U. S. Department of Agriculture. Screw worms were controlled by releasing irradiated, sterile males, which in turn led to infertile eggs being laid by the females and thus reduced the population. Probably other insects could be controlled by biological means at least to a degree. Biological methods supplemented by judicious chemical control probably could control some insect pests more inexpensively than by chemicals alone.

Other promising control methods include planting and harvesting at particular times; proper fertilization and rotation of crops; destruction of insect wintering quarters; and manipulation of water levels.

Certain research entomologists who work with economic pests believe the development of varieties of plants and animals that are resistant to troublesome insects and disease holds the greatest promise of all from the long-time standpoint.

Table 1. PEST CONTROL EXPENDITURES AND LOSSES FROM PESTS

Pest Control Expenditures (Estimated Annual Cost, 1942-51)		Reference
Insects	$ 400 million	[20]
Plant Diseases	$ 118 million	[20]
Weeds	$ 1,486 million	[20]
Total	$ 2,004 million or $2 billion	
Losses from Pests		
Insects (1951	$ 3.6 billion	[20]
Plant Diseases (1951)	$ 3.4 billion	[20]
Weeds (1955)	$ 4.0 billion	[53]
Total	$ 11.0 billion	

Note: These figures have increased during the last decade or so, despite the use of pesticides. Agricultural economists state this is due to inflation, not due to the use of pesticides. The figures on loss are estimates.

Table 2. THE NUMBERS OF BASIC COMPOUNDS IN FIVE MAJOR GROUPS OF PESTICIDES

		Reference
81	fungicides (10-15 most important)	[31], [44]
66	insecticides (15-18 most important)	[31], [44]
41	herbicides (8-10 most important)	[31], [44]
17	fumigants (4-5 most important)	[31], [44]
11	rodenticides (4-5 most important)	[31], [44]
216	Total (41-53 most important)	[31], [44]

"These are formulated into more than 6,000 trade-named products by more than 300 companies in the United States." [31]

Table 3. U. S. PRODUCTION OF SOME MAJOR PESTICIDAL CHEMICALS BY CALENDAR YEARS, 1952-1958 [54], [55], [56], [57]

Chemical	1952	1953	1954	1955	1956	1957	1958 1/
	1,000 lb.	1,000 lb.	1,000 lb.	1,000 lb.	1,000 lb.	1,000 lb.	1,000 lb.
Aldrin, chlordan, dieldrin, endrin, heptachlor, and toxaphene (combined production)	49,000	29,000	45,169	77,025	86,659	75,424	98,280
Benzene hexachloride (gross) 2/	85,090	57,363	76,934	56,051	84,599	39,559	31,000
Benzene hexachloride (gamma equivalent) 2/	12,800	8,800	11,500	10,700	14,700	7,300	6,200
Calcium arsenate	7,634	7,260	2,758	3,770	27,106	19,478	9,000
Copper naphthenate	13,680	3,268	3,557	2,373	2,012	2,130	4/
Copper sulfate	189,072	145,888	130,616	156,176	133,616	141,360	97,192
2,4-D acid	30,718	25,928	30,184	34,516	28,835	34,251	28,500
2,4-D acid esters	21,108	18,826	16,994	22,879	19,476	24,137	22,827
2,4-D acid salts 3/	3,933	4,836	5,642	6,640	1,766	3,182	
DDT	99,929	84,366	97,198	129,693	137,659	124,545	143,216
Disodium methylarsonate					5/	618	4/
Lead arsenate	14,286	14,196	15,620	14,776	11,756	11,920	4/
Methyl bromide	4,620	6,167	5/	9,222	10,204	9,653	4/
Methyl parathion					5/	1,925	
Nabam			5/	5/	5,486	4,961	4/
Parathion ("ethyl parathion")	2,365	2,999	3,889	5,168	6,529	5,962	4/
Pentachlorophenol			5/	5/	31,385	28,346	4/
Phenothiazine	5,914	3,700	3,437	6,202			
Phenyl mercuric acetate		154	598	692	693	570	4/
Sodium chlorate	80,868	86,442	79,904	93,944	110,136	118,284	134,498
Sodium dimethyl dithiocarbamate			471	5/			
Tetraethyl pyrophosphate (40% basis)	922	229					
2,4,5-Trichlorophenol			2,785	3,806			
2,4,5-T acid	3,490	5,281	2,697	2,925	5,169	5,334	3,500
2,4,5-T acid esters and other derivatives	3,138	5,386	3,883	3,793	7,045	6,831	4/
Ziram	934	1,152	1,117	963	1,436	1,277	4/

1/ Preliminary.
2/ 1958 includes lindane; 1956 and 1957 without lindane.
3/ Sodium and amine salts.
4/ Figure not yet available.
5/ Figure not publishable because it would disclose individual operations.

Table 4. AERIAL APPLICATION OF PESTICIDES AND DEFOLIANTS IN THE UNITED STATES

A. Pesticide Application: Airplane

		Reference
1954	31.5 million acres aggregate	[6]
1955	45.5 million acres aggregate	[56]
1956	48.0 million acres aggregate	[56]
1957	57.0 million acres aggregate	[56]
1958	60.0 million acres aggregate	[65]

B. Details for 1957:

Activity	Area Treated	Materials Dispersed	
		Dry	Liquid
	1,000 acres	1,000 lb.	1,000 gal.
Insect control:			
Crops, orchards, etc.	30,472	213,902	51,946
Forests	10,338	151	7,698
Towns	2,695	517	2,251
Soils	2,652	699	2,723
Total	46,157	215,269	64,618
Plant disease control	1,048	13,725	3,103
Weed control	6,904	12	12,112
Brush control	585	172	2,294
Defoliation	2,094	12,968	11,415
TOTAL	56,788	242,146	93,542

Reference: [57]

Table 5. TREND TO NEWER AGRICULTURAL PESTICIDES; COMPARISON OF SOME CANADIAN SALES VALUES FOR 1947 and 1957-58 [57]

Pesticide	Calendar Year 1947	Crop Year 1957-58
Older materials:		
Lead arsenate	$ 511,672	$ 245,393
Calcium arsenate	171,823	19,545
Paris green	68,953	11,466
Liquid lime sulfur	119,438	38,282
Nicotine	199,825	20,745
Newer pesticides:		
DDT	439,578	699,926
Benzene hexachloride	4,335	47,613
Other chlorinated hydrocarbon insecticides	8,846	1,062,382
Organic phosphorus insecticides	16,195	576,699
Dithiocarbamate fungicides	56,940	987,474
2,4-D derivatives	543,724	2,666,978

Table 6. EFFECTS OF SINGLE APPLICATIONS OF DDT IN OIL SOLUTION ON VERTEBRATES AND CRUSTACEANS

Pounds DDT Per Acre	Crustaceans	Fish	Amphibians	Reptiles	Birds	Mammals
0.1	+	-	-	-	-	-
0.25	++	+	-	-	-	-
1.0	+++	++	+	-	+	-
2.0	+++	+++	++	+	+	-
5.0	+++	+++	+++	+++	+++	+(+)?

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

Table 7. TOXICITY OF INSECTICIDES TO CAPTIVE BOBWHITE QUAIL AND RING-NECKED PHEASANTS IN TESTS AT PATUXENT WILDLIFE RESEARCH CENTER

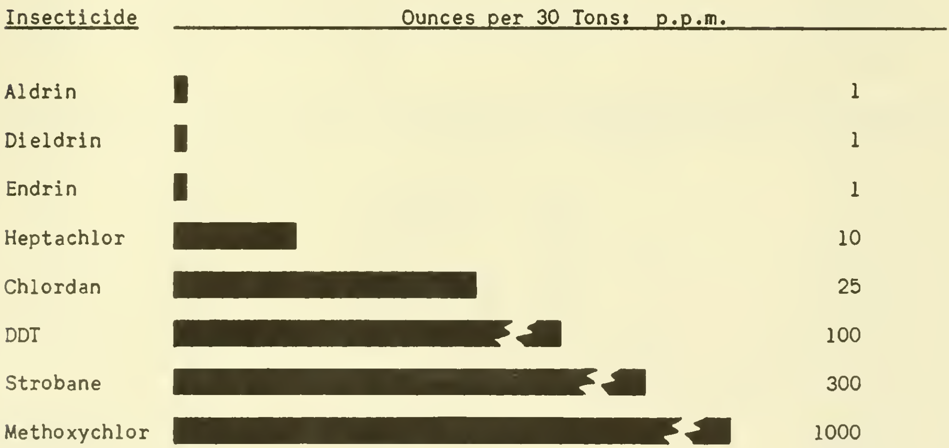
Compound	Approximate Lethal Dose to 50% or More of Subjects, Chronic Poisoning (mg./kg.)		Maximum Concentration in Diet Permitting Normal Survival (p.p.m.)	
	Quail	Pheasants	Quail	Pheasants
Aldrin	4	14	0.5	5
Endrin	5	14	0.5	1
Dieldrin	35	50	5	20
Phosdrin	90	-	<1000*	-
Heptachlor	125	150-400	25	25
Chlordan	250	500	50	50
Lindane	200***	400***	100	100
BHC	250	450	50	>100**
Malathion	400	1600	50	500
Co-Ral	400	-	<1000*	-
Toxaphene	500	450	200	100
DDT	500	300	200	50
Kepone	500	<1000	<200	<500*
Strobane	500	1600	<500*	<500*
Dylox	500	2500	100	500
Chlorthion	700	-	<500*	-
Disyston	800	-	<1000*	-
Rhothane	-	<2800	-	<5000*
Kelthane	-	<3200	-	<2000
Delnav	3000	15000	1000	2500
Guthion	5000	6000	100	500
Perthane	9000	>9000	5000	<5000*
Methoxychlor	22000	25000	2500	1000
Sevin	-	>40000	-	>5000**

* Not tested at lower levels.
** Not tested at higher levels.
*** Inadequate number of birds.

Table 8. EFFECTS OF INSECTICIDES UPON REPRODUCTION OF QUAIL

Insecticide	Level in Diet (p.p.m.)	Chicks per Hen Hatched	Surviving 6 Weeks	% Mortality	Crippled and Defective Chicks %
——— CONTROL ———		40.3	31.6	21.7	1.7
Aldrin	1	27.1	17.1	36.9	12.3
Dieldrin	1	29.1	21.8	25.0	14.6
Endrin	1	32.9	21.2	35.7	9.6
Heptachlor	10	24.8	11.0	55.6	4.1
Chlordan	25	26.6	15.6	41.2	4.7
Lindane	25	30.4	22.0	27.7	1.5
Guthion	50	28.3	18.0	36.4	2.4
DDT	200	36.4	4.7	87.1	8.9
Strobane	300	13.2	5.6	57.9	30.5
Methoxychlor	5000	37.5	21.4	42.9	3.2

Table 9. AMOUNTS OF INSECTICIDES CAUSING 40% OR MORE DECREASE IN REPRODUCTION OF QUAIL



(1 ounce per 30 tons = 1 p.p.m.)

Table 10. TABULATIONS OF RELATIVE TOXICITIES ON INSECTICIDES TO BOBWHITE QUAIL AND RING-NECKED PHEASANTS BASED ON TOXICITY OF DDT

(DDT = 1)

1. Based upon amounts required to produce 100% kills in 10 days.

	Species			
	Quail		Pheasants	
Compound	Young	Adult	Young	Adult
Aldrin	70-100	150-200	30-40	15-20
Endrin	70-100	150-200	40-60	20-30
Dieldrin	15-20	15	12	4
Heptachlor	5-10	2.5-5	1.5	1.6
Chlordan	5	1.2	1.5	1.1
Strobane	1.1	1.2	0.4	0.4
Methoxychlor	0.25	0.5	0.6	0.3

2. Based upon amounts required to produce 100% kills in 100 days.

Aldrin	150-200	110-130	30-40	10-15
Endrin	300-350	75-100	15	10
Dieldrin	40	27	20	2.5
Heptachlor	30	11	2	2.1
Chlordan	7.5	4.5	1.5	1.1
Strobane	2.5	0.3	0.6	0.4
Methoxychlor	*	0.27	0.2	0.1

3. Based upon maximum levels in diet permitting normal survival for more than 100 days.

Aldrin	200	100	50	50
Endrin	200	100	50	50
Dieldrin	20	20	5	5
Heptachlor	10	10	5	5
Chlordan	10	10	5	5
Strobane	0.4	0.5	0.2	0.5
Methoxychlor	0.1	0.13	0.1	0.1

4. Based upon levels affecting reproduction.

Compound	Quail	Pheasants
Aldrin	200	100
Endrin	200	25
Dieldrin	200	1
Heptachlor	20	1
Chlordan	20	0.5
Strobane	0.7	1
Methoxychlor	0.2	0.1

5. Tentative relative toxicity of certain additional pesticides based on current research - tested against young quail or pheasants.

Compound	Relative Toxicity
Phosdrin	4.0
Lindane	2.5
Kepone	1.0
Chlorthion	0.75
Co-Ral	0.75
Disyston	0.65
BHC	0.6
Malathion	0.25
Kelthane	0.24
Toxaphene	0.15
Guthion	0.12
Sevin	0.11
Perthane	0.05

* Insufficient data.

Table 11. INSECTICIDE CONTENT OF TISSUES: EXPRESSED AS PARTS PER MILLION IN DRIED TISSUE

		Insecticide		
Species	Tissue	DDT	Chlordan	Heptachlor*
Quail	Entire Body	2-19 1/	23 2/	22-35 2/
	Entire Body	40-78 2/		
	Muscle	32-39 2/		
Pheasant	Muscle	3.6 1/	60 2/	
	Muscle	11-33 2/		
	Entire Body	100 2/		
	Brain		62 2/	
	Liver		54 2/	
Rat	Heart			37 2/
	Liver			18 2/
	Kidney			60 2/
	Brain			63 2/
	Testes			29 2/

* As heptachlor epoxide.
1/ Killed after 6 or more weeks of exposure to treated food.
2/ Died after 2 or more weeks of exposure to treated food.

Table 12. HEPTACHLOR EPOXIDE CONTENT OF SPECIES OF BIRDS FROM AREAS TREATED WITH 2 POUNDS OF HEPTACHLOR PER ACRE

	Found Dead Within 3 Wks. After Treatment		Found Dead 11-12 Mos. After Treatment		Shot 6-12 Mos. After Treatment	
Species	Number Specimens	Av. p.p.m. In Tissues	Number Specimens	Av. p.p.m. In Tissues	Number Specimens	Av. p.p.m. In Tissues
Water Pipit	1	38.0	-	-	6	8.0
Swamp Sparrow	2	33.9	-	-	-	-
Mockingbird	4	27.4	-	-	-	-
Savannah Sparrow	6	26.2	1	6.2	18	2.1
Field Sparrow	5	24.6	-	-	-	-
Orchard Oriole	1	23.7	-	-	-	-
Chipping Sparrow	8	22.3	2	1.0	-	-
Myrtle Warbler	3	20.2	-	-	-	-
White-th. Sparrow	13	20.0	3	11.3	1	Trace
Brown Thrasher	11	16.6	-	-	3	22.3
Red-b. Woodpecker	1	14.9	-	-	-	-
Yellowthroat	1	14.5	-	-	-	-
Yellow-br. Chat	1	14.0	-	-	-	-
W. Meadowlark	1	13.4	-	-	-	-
Blue Jay	3	12.8	-	-	-	-
Hermit Thrush	3	12.6	-	-	-	-
Red-wing	3	12.2	-	-	-	-
Robin	4	12.1	4	13.5	1	0.0
Vesper Sparrow	8	11.9	-	-	1	0.0
Common Grackle	6	10.9	-	-	-	-
E. Kingbird	1	10.9	-	-	-	-
E. Meadowlark	16	10.7	1	9.6	6	0.7
Cardinal	18	10.3	-	-	-	-
Bobwhite	12	7.6	-	-	-	-
Starling	1	7.4	1	30.2	-	-
Virginia Rail	1	7.1	-	-	-	-
Carolina Wren	1	6.0	-	-	-	-
Mourning Dove	1	5.8	-	-	4	1.0
Y.-shafted Flicker	2	3.9	-	-	-	-
Loggerhead Shrike	2	3.3	-	-	-	-
E. Bluebird	1	3.2	-	-	-	-
Common Snipe	3	2.7	-	-	5	0.0
Green Heron	1	0.8	-	-	-	-
Y.-th. Warbler	1	Trace	-	-	-	-
Slate-col. Junco	-	-	1	30.8	-	-
E. Phoebe	-	-	1	28.3	-	-
Killdeer	-	-	-	-	26	1.1
Br.-headed Cowbird	-	-	-	-	2	1.0
Total Specimens	146		14		73	

Table 13. HEPTACHLOR EPOXIDE CONTENT OF CLASSES OF VERTEBRATES, CHAETOPODS, AND CRUSTACEANS FROM AREAS TREATED WITH 2 POUNDS OF HEPTACHLOR PER ACRE

Classes	Found Dead Within 3 Wks. After Treatment		Shot or Collected 6-12 Mos. After Treatment	
	Number Specimens	Av. p.p.m. In Tissues	Number Specimens	Av. p.p.m. In Tissues
Mammals				
Entire Carcass	6	10.8	4	8.6
Heart	14	6.4	9	6.3
Liver	12	8.1	10	2.5
Brain	4	4.4	3	Trace
Kidney	11	8.3	10	4.1
Birds	146	13.6	73	3.3
Reptiles	8	6.6	-	-
Amphibians	9	4.2	-	-
Fish	15	14.7	-	-
Chaetopoda (Earthworms)*	-	-	32	3.0
Crustaceans (Crayfish)**	4	1.6	-	-

* All chaetopods were earthworms. Thirty-two samples, each containing up to 100 individuals, were collected by digging into the soil.

** Four samples, each containing up to 10 individuals.

Table 14. STATUS OF THE BOBWHITE QUAIL ON THE WILCOX COUNTY, ALABAMA, STUDY AREA [2], (Baker, *et al.*, unpubl.)

	PRE-TREATMENT		POST-TREATMENT										
	March 1958		April 1958			Fall 1958			Spring 1959			Fall 1959	
	Coveys	Birds	Coveys	Birds	Decline	Coveys	Birds	Increase	Coveys	Birds	Decline	Coveys	Birds
Treated	15	139	2*	18*	87%*	13**	147**	6%	11***	96***	35%***	15	200
Control	8	76	8	74	3%	7	135	75%	****	****	****	****	****

* Die-off usually within 10-15 days; 17% of the disappearing quail recovered. The two coveys surviving used the treated area only sparingly (less than 14% of time).

** Two coveys with 21 birds used the treated area only sparingly.

*** Die-off of quail still continuing during spring census; 2 coveys disappeared during the winter.

**** Not available.

Table 15. SUMMARY OF COUNTS OF BOBWHITE QUAIL ON TREATED AND UNTREATED LAND IN DECATUR COUNTY, GEORGIA, AND UNTREATED LAND NEAR ATMORE, ALABAMA [49]

Whistling Cock Counts:

Area	May-July Count of Number of Whistling Cocks per 1000 Acres	
	1958	1959
Climax (Treated 1957-58)	3.74	10.6
Faceville (Untreated 1958)	27.43	
Faceville (Partly treated 1959)		12.29
Climax (Small untreated plots in treated areas)	12.86	27.14
Atmore (Untreated)	24.13	23.87

Covey Counts:

Area	December - February Number of Coveys per 1000 Acres	
	1958-59	1959-60
Climax (Treated 1957-58)	3	10*
Faceville (Untreated 1958-59)	25	-
Faceville (Partly treated 1959-60)	-	**
Atmore (Untreated)	25	**

* Preliminary findings; final figures not yet available.
** Not yet available; studies are continuing.

Literature Cited

1. Allen, R. H. 1958. History of the imported fire ant in the southeast. Proceedings of the Twelfth Annual Conference Southeastern Association of Game and Fish Commissioners: 227-233.

2. 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: 244-247.

3. Barker, R. J. 1958. Notes on some ecological effects of DDT sprayed on elms. Journal of Wildlife Management, 22(3): 269-274.

4. Boudreaux, J., K. Strawn, and G. Callas. 1959. Fire ants, heptachlor, and fish kill. The Southwestern Naturalist, 3: 7-12.

5. Briggs, S. A. 1960. Mass spraying of insecticides. Atlantic Naturalist, 15(1): 19-21.

6. Brodell, A. P., P. E. Strickler, and H. C. Phillips. 1955. Extent and cost of spraying and dusting on farms - 1952. United States Department of Agriculture, Statistical Bulletin Number 156; 25 pages.

7. Clawson, S. G. 1958. Wild turkey populations on an area treated with heptachlor and dieldrin. Alabama Birdlife, 6(3-4): 4-8.

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

9. Cope, O. B. 1948. Toxicities and tolerances of new insecticides in relation to fish and wildlife. California Mosquito Control Association Proceedings and Papers, 1948: 26-29.

10. Cope, O. B. 1960. The retention of DDT by trout and whitefish. Transactions Second Seminar on biological problems in water pollution. United States Public Health Service, Cincinnati: (in press).

11. __________, and P. F. Springer. 1958. Mass control of insects: The effects on fish and wildlife. Bulletin of the Entomological Society of America, 4: 52-56.

12. Cottam, Clarence. 1958. A commentary on the fire ant program. Proceedings of the Twelfth Annual Conference Southeastern Association of Game and Fish Commissioners: 257-260.

13. ______________, and E. Higgins. 1946. DDT: Its effect on fish and wildlife. United States Fish and Wildlife Service Circular 11; 14 pages.

14. DeWitt, J. B. 1956. Chronic toxicity to quail and pheasants of some chlorinated insecticides. Journal of Agricultural and Food Chemistry, 4(10): 863-866.

15. ___________. 1957. H-bomb in the pea patch. Wildlife in North Carolina, 21(9): 1-4.

16. ___________. 1958. Birds and Dutch elm disease control. Arborist's News, 24(4): 25-29.

17. Eng, R. L. 1952. A two-summer study of the effects on bird populations of chlordane bait and aldrin spray as used for grasshopper control. Journal of Wildlife Management, 16(3): 326-337.

18. Fischer, C. D. 1956. Pesticides: past, present and prospect. Chemical Week, pages 59-90, October 27, 1956; pages 53-88, November 3, 1956; pages 68-100, November 17, 1956.

19. Fleschner, C. A. 1959. Biological control of insect pests. Science, 129: 537-544.

20. Fracker, S. B., Chairman. 1954. Losses in agriculture - a preliminary appraisal for review. United States Department of Agriculture, ARS-20-1; 190 pages.

21. George, J. L. 1958. Pesticides: Where do we go from here? Forty-eighth Convention of the International Association of Game, Fish and Conservation Commissioners: 130-136.

22. ___________. 1958. Pesticides and wildlife. Papers given at the 54th Annual Convention of the National Audubon Society, New York, November 10, 1958: 1-3.

23. ___________. 1958. The program to eradicate the imported fire ant - Preliminary observations. Conservation Foundation, New York, 8 + 39 pages.

24. ___________. 1959. Effects on fish and wildlife of chemical treatments of large areas. Journal of Forestry, 57(4): 250-254.

25. ___________. 1960. Effects on wildlife of pesticide treatments of water areas. Presented at Symposium on Coordination of Mosquito Control and Wildlife Management, Washington, D. C.: (in press).

26. ___________. 1960. Wildlife - The community of living things. Massachusetts Audubon, 44(5): 226-232.

27. ___________, R. F. Darsie, and P. F. Springer. 1957. Effects on wildlife of aerial applications of Strobane, DDT, and BHC to tidal marshes in Delaware. Journal of Wildlife Management, 21(1): 42-53.

28. ____________, and R. T. Mitchell. 1947. Studies on the effects of feeding DDT treated insects to nestling birds. Journal of Economic Entomology, 40(6): 782-789.

29. Glasgow, L. L. 1958. Studies on the effect of the imported fire ant control program on wildlife in Louisiana. Proceedings of the Twelfth Annual Conference Southeastern Association of Game and Fish Commissioners: 250-255.

30. Harrington, R. W., Jr. and W. L. Bidlingmayer. 1958. Effects of dieldrin on fishes and invertebrates of a salt marsh. Journal of Wildlife Management, 22(1): 76-82.

31. Hitchner, L. S. 1956. Strong growth trend seen continuing in pesticide field. New York Journal of Commerce, November 27; page 11.

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

33. Janzen, D. H. 1958. Effects of the fire ant eradication program upon wildlife. United States Fish and Wildlife Service, processed report, 7 pages.

34. Keenleyside, M. H. A. 1959. Insecticides and wildlife. Canadian Audubon, 21(1): 1-7.

35. Kerswill, C. J. 1956. The research programme. Part 1 of "Investigation and management of Atlantic salmon in 1955". Trade News (Department of Fisheries of Canada), 8: 5-11.

36. ______________. 1957. The research programme. Part 1 of "Investigation and management of Atlantic salmon in 1956". Trade News (Department of Fisheries of Canada), 9: 5-15.

37. ______________, and P. F. Elson. 1955. Preliminary observations on effects of 1954 DDT spraying on Miramichi salmon stocks. Progress reports of the Atlantic Coast Stations of the Fisheries Research Board of Canada, 62: 17-23.

38. Lay, D. W. 1958. Fire ant eradication and wildlife. Proceedings of the Twelfth Annual Conference Southeastern Association of Game and Fish Commissioners: 248-250.

39. _________. 1959. Aftermath of waste. Texas Game and Fish, 17(10): 16-19.

40. Leffler, R. L. 1958. Letter of May 1, 1957 to the Honorable Herbert C. Bonner, Chairman on Merchant Marine and Fisheries. House of Representatives, 85th Congress, 2nd Session, Report Number 2181.

41. Lindquist, A. W., and A. R. Roth. 1950. Effect of dichlorodiphenyl dichloroethane on larvae of the Clear Lake gnat in California. Journal of Economic Entomology, 43(3): 328-332.

42. Linduska, J. P., and E. W. Surber. 1948. Effects of DDT and other insecticides on fish and wildlife - Summary of investigations during 1947. United States Fish and Wildlife Service Circular 15; 19 pages.

43. Mehner, J. F., and G. J. Wallace. 1959. Robin populations and insecticides. Atlantic Naturalist, 14(1): 4-10.

44. Miller, D. L. 1958. Two pressing problems in pesticide research. National Agricultural Chemicals News and Pesticide Review, 16(3): 5-7.

45. Nelson, A. L., and E. W. Surber. 1947. DDT investigations by the Fish and Wildlife Service in 1946. United States Fish and Wildlife Service Special Scientific Report Number 41; 8 pages.

46. Newsom, J. D. 1958. A preliminary progress report of fire ant eradication program, Concordia Parish, Louisiana - June, 1958. Proceedings of the Twelfth Annual Conference Southeastern Association of Game and Fish Commissioners: 255-257.

47. Oney, J. 1951. Fall food habits of the clapper rail in Georgia. Journal of Wildlife Management, 15(1): 106-107.

48. Plant Pest Control Division. 1959. Facts about the imported fire ant program. United States Department of Agriculture, Washington, D. C.; 8 pages.

49. 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: 240-244.

50. Rudd, R. L. 1958. The indirect effects of chemicals in nature. Papers given at the 54th Annual Convention of the National Audubon Society, New York: 12-16.

51. __________, and R. E. Genelly. 1956. Pesticides: Their use and toxicity in relation to wildlife. California Department of Fish and Game, Game Bulletin Number 7; 209 pages.

52. Scott, T. G., Y. L. Willis, and J. A. Ellis. 1959. Some effects of a field application of dieldrin on wildlife. Journal of Wildlife Management, 23(4): 409-427.

53. Shaw, B. T. 1956. Weed control as a part of American agriculture. Paper presented at Weed Society of American Charter Meeting, New York, and abstracted in National Agricultural Chemicals Association News and Pesticide Review, 14(3): 8-9.

54. Shepard, H. H. 1956. The pesticide situation for 1955-56. Commodity Stabilization Service, United States Department of Agriculture; 17 pages.

55. ____________. 1957. The pesticide situation for 1956-57. Commodity Stabilization Service, United States Department of Agriculture; 19 pages.

56. ____________. 1958. The pesticide situation for 1957-58. Commodity Stabilization Service, United States Department of Agriculture; 23 pages.

57. ____________, J. N. Mahan, and C. A. Graham. 1959. The pesticide situation for 1958-59. Commodity Stabilization Service, United States Department of Agriculture; 24 pages.

58. Springer, P. F. 1956. Insecticides - Boon or bane? Audubon Magazine, 58(3): 128-130, and 58(4): 176-178, photographs.

59. ____________, and J. R. Webster. 1951. Biological effects of DDT applications on tidal salt marshes. Mosquito News, 11(2): 67-74. Also Transactions 16th North American Wildlife Conference: 383-396.

60. Stickel, L. F., and P. F. Springer. 1957. Pesticides and wildlife. United States Fish and Wildlife Service Wildlife Leaflet 392; 12 pages.

61. Tarzwell, C. M. 1958. The toxicity of some organic insecticides to fishes. Proceedings of the Twelfth Annual Conference Southeastern Association of Game and Fish Commissioners: 233-239.

62. Trautman, C. G. 1952. Pheasant food habits in South Dakota and their economic significance to agriculture. South Dakota Department of Game, Fish and Parks, Technical Bulletin Number 1: vi + 89 pages.

63. U. S. Department of the Interior. 1956. National survey of fishing and hunting. United States Fish and Wildlife Service Circular 44; 50 pages.

64. Wallace, G. J. 1959. Insecticides and birds. Audubon Magazine, 61(1): 10-12.

65. Wall Street Journal. 1958. Report of National Aviation Trades Association, page 1, August 5, 1958.

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