MINNESOTA DEPARTMENT OF CONSERVATION
DIVISION OF GAME AND FISH

Special Publication No. 66

PESTICIDES AND THE ENVIRONMENT, WITH SPECIAL REFERENCE TO FISH AND WILDLIFE IN MINNESOTA

By

John B. Moyle
Technical Assistant to the
Director of the Division of Game and Fish

May 8, 1969

MINNESOTA DEPARTMENT OF CONSERVATION
DIVISION OF GAME AND FISH

PESTICIDES AND THE ENVIRONMENT, WITH SPECIAL REFERENCE TO FISH AND WILDLIFE IN MINNESOTA

Introduction

We live in a chemical age; an age of extensive application of chemistry to manufacturing, medicine, public health, food processing, transportation and agriculture. One aspect of this is the development and extensive use of herbicides, insecticides and other pesticides to increase the production of food on farms and protect human health.

Since DDT was first used for insect control during World War II (1944) there have been hundreds of pesticides developed and these used in tens of thousands of formulations. (One recent estimate places the number of compounds at 900 and the number of formulations at more than 60,000.) When it is considered that about one-third of the world's food production is lost to plant pests and diseases and that much food loss is now being eliminated through application of chemicals, it is obvious that use of chemical tools by agriculture is not going to decline. Similarly, there is no reason to believe that use of chemicals to protect public health by controlling insects that carry diseases is going to decrease.

The problem is one of using these chemical tools with the greatest possible degree of safety to us, our environment and to the innocent bystanders in it--bystanders such as our fish and wildlife and beneficial insects.

The use of pesticides and their effects is a very complicated subject. It is one about which there is much to be learned and on which much research is being done. It is one about which there has been and is much public concern--sometimes more emotional than rational. And it is important, however, that the public be concerned for all pesticides are poisons, at least to some extent, and are dangerous if improperly used.

"Pesticide" is a very general term and includes herbicides, insecticides and other chemicals of a great variety of kinds. Different pesticides vary greatly in toxicity to different kinds of plants and animals. There is even considerable variation in toxicity of any pesticide to organisms of a specific kind, making necessary to rate toxicity in terms of concentrations at which half the "target" organisms are killed (LD 50's). Often these distinctions and complications are not generally recognized.

Most pesticides now in use are synthetic (manufactured) organic compounds that do not occur naturally in living things. There are, however, other kinds. Many plants and some animals naturally contain substances that are toxic or repellent. A few of these, such as rotenone and pyrethrin, are extracted from plants and used as insecticides. Rotenone is also used as a fish poison. Others, such as digitalis and quinine, are important drugs. Other substances, such as compounds of copper or arsenic, have long been used as pesticides. Use of sulfur and common salt goes back to ancient times.

Some pesticides are quite selective as to the kinds of plants or animals they will kill but others, such as DDT, have a "wide spectrum" of toxicity and can kill animals of many kinds. Toxicity of any pesticide varies with the concentration used and with the kind and even the age of the animal exposed to it. Toxicity and persistence in the environment often depends on how a pesticide is used (application method and formulation). Any pesticide can be made to kill experimental animals if they are exposed to high enough concentrations and cannot escape. Thus, a caged rat or quail or pheasant must eat poisoned food put before it or starve. The fish in an aquarium to which a pesticide has been added cannot swim away from it. But this is not how things are in nature and caution should be exercised when applying laboratory findings to natural conditions.

The pesticides of greatest concern as environmental contaminants are the synthetic chlorinated hydrocarbons (organochlorine) insecticides. In this group is DDT and its breakdown compounds (metabolites) DDD (TDE) and DDE. This group also includes aldrin with its analogue dieldrin, heptachlor, lindane, toxaphene, chlordane, and endrin. These compounds may persist in the environment for several years because they do not break down rapidly. They are only slightly soluble in water but highly soluble in fats. They become rapidly bound to soil particles, especially in organic soils. Stability and long life after application cause organochlorines to be especially effective as insecticides. This stability, however, combined with the solubility in body fats allows them to accumulate in animals that are the upper links of food chains or pyramids (such as in fish-eating birds and in coho salmon and lake trout in the Great Lakes). The compounds exhibiting this accumulation or "magnification" of concentrations to the greatest extent at present are DDT with its metabolites DDD and DDE and dieldrin (the metabolite of aldrin). Discussion will, therefore, be concerned primarily with these.

Another important group of insecticides are the organophosphate compounds, such as malathion, parathion and Abate. These break down quite rapidly in the environment. Although some organophosphates, such as parathion, may be highly toxic to non-target organisms (such as humans) when initially used, there is little or none of the "magnification" effect found with chlorinated hydrocarbons. Organic compounds of other types, such as carbamates and mercurials, are also used as pesticides.

Since DDT was first used in the early 1940's many insect pests have developed a tolerance to it. Because of this and because of fear of long-term environmental contamination and uncertain effects on non-target organisms, the use of DDT in the United States has declined from a peak of 79.7 million pounds in 1956 to 45.6 million pounds in 1966. About two-thirds of the DDT now produced in the United States is shipped overseas. In the United States other insecticides have now replaced DDT on many control jobs and often non-persistent kinds other than organochlorines have been used.

Direct Short-term Toxic Effects on Fish and Wildlife

General

At various places there have been serious direct losses of fish and wildlife under natural conditions[15], especially during the earlier years of the use of organochlorine insecticides. DDT, heptachlor, toxaphene, endrin and aldrin have all been involved. Some of these cases have received wild publicity--such as in the book "Silent Spring" by Rachel Carson. Many of these losses were the result of insufficient knowledge of these compounds and of inexperience and errors in judgment. Often the harmful effects could have been avoided if we had known then what we know now, and at present most of these cases would not have occurred. Sometimes, however, calculated risks have been taken in emergency situations where values gained greatly exceeded possible wildlife losses.

It is well documented that many robins and other songbirds have been killed in more eastern states by spraying of elm trees with DDT to destroy bark beetles that carry Dutch elm disease[8,29,30]. Sometimes as many as 80 percent of the robins in the sprayed areas have been killed by eating contaminated earthworms. However, a point that often is not emphasized is that on such spraying jobs 5 to 10 pounds of DDT per acre in emulsion (which makes it readily available) were used, and in some places as much as 17 pounds per acre were used. These are very high concentrations. Such DDT was applied in formulations that could easily be washed from trees by rain and accumulate in the soil and earthworms inhabiting it. In most forest spraying that has been done in the past, such as that for control of forest tent caterpillar or spruce budworm, not more than one pound per acre has usually been used. With this concentration a Minnesota investigation[4] showed no appreciable direct damage to bird life. There has, however, been damage to fish and fish foods in streams where DDT spraying has not been carefully planned and controlled[26]. Because of possible environmental contamination and damage to wildlife state and federal forest management agencies in Minnesota have not used DDT for forest spraying since 1962.

In Minnesota

The Division of Game and Fish of the Minnesota Department of Conservation has been gathering information on effects of pesticides on fish and wildlife for more than 10 years. Conservation officers, managers and biologists have been instructed to report immediately any unusual kills of fish and wildlife on forms provided, or by telephone, and to bring in specimens of animals killed. If conditions warranted, a field investigation was made.

Our files as far back as 1961 and records of our bacteriologist who receives and examines any animals brought in have been summarized. During this period if pesticide poisoning was suspected, specimens have often been forwarded to laboratories for pesticide analyses. Between 1961 and the present we have a record of one clear-cut case of a fish-kill in a stream caused by mist spraying of the shoreline with DDT and malathion. DDT probably did the damage. There have been three cases of small fish-kills in which pesticides were suspected but not proven. Two of these followed fogging of shoreline with DDT and one may have resulted from inflow of drainage water containing endrin. Some gulls are known to have been killed by feeding on a dump on which bait poisoned with 1080 (not an organochlorine) had been placed to kill rats. There is one case where pheasants were killed in the vicinity of a grain elevator from feeding on endrin-treated bait put out for pigeon control and two or three similar but unproven reports. During the period we have received several calls each year regarding suspected poisoning of songbirds from pesticides and we know there are more such cases for such calls often go to the Museum of Natural History of the University of Minnesota. In two cases robins have been seen that showed typical tremors of DDT poisoning. Another case was diagnosed by the U. S. Fish and Wildlife Service as arsenic poisoning of robins due to use of a crab grass killer. There has also been one suspected case of poisoning of birds by an organo-mercury compound.

We are also aware of an analysis of a dead loon that showed high concentrations of DDT and a similar situation for a great blue heron. There is one case of death of a bald eagle in Minnesota that could be attributed to pesticides. Many of the dead or ailing eagles that have been examined by the U. S. Fish and Wildlife Service have been found to have been injured by shot. There are probably other cases of death of wildlife from pesticides that are not recorded in our files.

Several field investigations were made upon reports that proved unfounded. One of these concerned "hundreds" of pheasants, but we were unable to either find the birds or verify the source of the report. Another concerned waterfowl that were found to have a bacterial disease (botulism).

In general, therefore, it is concluded that known direct losses of fish and wildlife from pesticides in Minnesota have been quite minor since records were first kept in 1961. It should be emphasized, however, that dead wild animals are often hard to find and are soon eaten by scavengers.

A point worth emphasizing, is that the formulation or mixture in which an insecticide is applied has great influence on its availability and toxicity to fish and wildlife. For example, it has long been known that DDT as a wettable powder or in granules (such as has been used for control of mosquito larvae) is much less toxic to fish and fish foods than DDT applied as an oil spray or emulsion[14/]. Shoreline fogging with DDT in oil or emulsion is especially hazardous to fish. Powdered or granular DDT settles to the bottom where it kills the mosquito larvae; an emulsion or oil solution spreads over or through the water where it can kill fish.

There has been some confusion because of misunderstanding of the units and terms referring to pesticides and amounts of them used. The amounts are important since high concentrations may kill or do other direct damage, while low concentrations may not. For example, it is alarming to hear that the egg fertility of pheasants fed food containing DDT fell one-third unless it is realized that this food contained many times the amount of DDT (100 milligrams per kilogram) that could be expected in natural foods in sprayed areas. As a matter of fact, the average number of eggs per pheasant nest and number of chicks hatched per nest in southern Minnesota study areas--farms on which farmers used some pesticides--has been about the same over the past 20 years.

It has long been known that chlorinated hydrocarbon insecticides will kill fish when applied to waters in concentrations designed to do this. Toxaphene has been used for this in Minnesota and elsewhere. Although there has been no observed loss of birds or mammals from such fish eradication jobs in Minnesota, this work is now being done with rotenone or antimycin (Fintrol) both of which are not organochlorines and disappear rapidly from the environment.

Similarly, past use of DDT as wettable powder or on vermiculate granules by the Metropolitan Mosquito Control District of the Twin Cities Area (the largest Mosquito Control District in the United States) resulted in no reports of losses of birds and mammals. The District, however, since 1967 has been using the organophosphate Abate to avoid the possibility of long-term contamination of the environment with DDT.

Herbicides, such as 2,4-D, 2,4-5-T and many others are used for control of upland weeds, brush, and water plants, are, for the most part, not toxic to fish and wild animals at the concentrations ordinarily used. They have a fairly wide safety margin. Their effect on fish and wildlife is mostly one of destroying or modifying habitat. Such habitat modification is obviously important although we have no real measure of its total effect in Minnesota. Use of herbicides on farmlands results in fewer weeds and weed seeds (which is good for the farmer but not for farm game) and elimination of patches of brush destroys nesting and winter cover both on farms and along roads.

The Department of Conservation is trying to offset this loss by acquiring and managing game lands (wildlife management areas and wetlands) on which cover is undisturbed or improved, and to use its influence to delay mowing which desstroys wildlife cover along highways. We are also working with federal agricultural agencies to help provide more game cover on private lands. In forested areas, use of herbicide brush killers is often of considerable value in promoting the growth of more desirable kinds of deer browse[17].

Indirect (Long-term) Effects on Fish and Wildlife

It can be concluded from the foregoing section that the observed direct or short-term effect of insecticides on fish and wildlife in Minnesota has been quite minor. It is the indirect or long-term effects that conservationists fear and are principally concerned. Regarding DDT, and possibly other organochlorine insecticides which accumulate in fats of animals, the demonstrated indirect harmful effects are:

1. Killing fish fry at or shortly after hatching of fish eggs. DDT and its derivatives dissolved in fats in the fish egg are concentrated as these fats are used up by the developing fish fry. If initial concentration of DDT in the egg is great enough the fry may be killed. This has been shown for lake trout eggs and fry at Lake George, New York--an area in which there was considerable forest spraying with DDT. DDT has also probably been the cause of the loss of some coho salmon fry (11 percent) hatched from eggs of fish taken from Lake Michigan in 1968.

   There is no indication that this has occurred in Minnesota inland walleye hatcheries or in Wisconsin walleye hatcheries[10]. It is difficult, however, to separate any possible effects of pesticides on the hatching of fish eggs from other causes, such as variation in water temperature.

2. Decreased hatchability of eggs of predatory, especially fish-eating, birds. Apparently DDE has an adverse effect on calcium metabolism of the birds, causing thinner egg shells to be produced. It is known that egg shells of some predatory birds have become thinner since DDT has been used as a pesticide. When this occurs the parent birds may break and eat their own eggs[21]. Adverse effects on reproduction have been claimed for eagles, osprey, gulls and peregrine falcon. Proof that this is causing a population decline of eagles and ospreys is still uncertain in Minnesota where in 1968 nesting success for bald eagles was about 70 percent of occupied nests (a good success rate) but was poor (about 30 percent) for ospreys[12]. This is being studied in the Chippewa National Forest.

3. Alteration of the behavior pattern of predaceous birds because of accumulation of DDT and metabolites in the brain and nerve tissue. This may cause them to be "nervous", and thereby poorer parents and, therefore, less amenable to successful nesting. This is, as yet, mostly an unproven hypothesis but is a possibility.

4. Mortality of adult predaceous birds because of gradual accumulation of insecticides through the food chain. This has been demonstrated in a few cases for DDT in eagles and for toxaphene in grebes and in other cases mentioned in the discussion of direct effects.

As to physiological effects, organochlorine insecticides may act as nerve poisons and interfere with normal working of body enzyme systems. The details are poorly understood.

Concentrations of Pesticides in Fish and Wildlife

It is well known that low concentrations of DDT and its degradation products, DDE and DDD, are widely distributed over the globe and have been found in most animals that have been analyzed for it[20]. DDE, which itself is not toxic enough to be used as an insecticide and which is formed from DDT under aerabic conditions—such as in body tissue--is probably the single commonest pesticide environmental contaminant. The wide occurrence of DDT and derivatives reflects the stability of these compounds, the extensive use of DDT, and the fact that it has been used world-wide for more than 25 years. It is ingested with food and the average person in the United States is reported to carry about a fifth of a gram of DDT, mostly stored in body fat. Early estimates were half a gram[3]. This is about 2 milligrams per kilogram (p.p.m.) in terms of whole body weight. Some humans carry more and some less--but carry it without apparent damage. It should be noted that the amount carried represents a balance or plateau level between intake and loss. DDT and its metabolites are not stored in the body permanently but gradually break down and are excreted and lost. This DDT in our bodies can also come from sources other than food.

Standards for maximum permissible concentrations of DDT and other insecticides in some foods have been set by the U. S. Food and Drug Administration[27]. For example, the maximum permitted for fruit, such as apples, and some green vegetables is 7 milligrams per kilogram and 7 for fat of cattle, hogs and sheep. None is allowed in eggs and milk. Many other foods have intermediate values. It should be emphasized that these are maximum permissible levels and actual amounts in foods may be less. Recently a tentative level of 5.0 p.p.m. has been set by the FDA for whole fish. This level is subject to change with further investigation.

How do these concentrations compare to those found in fish and wild animals? Minnesota game fish that have been analyzed each year since 1962 usually have had less than 1 p.p.m. DDT and DDE in the flesh[13]. The game fishes analyzed were perch, smallmouth bass, crappie, sunfish, walleye, northern pike, trout, and white bass. Analyses were also made of the flesh of rough fishes, including bullheads, carp, sheepshead, redhorse, carpsucker, white sucker, catfish, and buffalofish. Rough fish feed principally on bottom invertebrates and plant material, in contrast to game fishes which have a more varied diet. The Minnesota analyses show that some rough fish accumulate greater concentrations of DDT and its derivatives than do game fish, but usually have quite low concentrations in the flesh.

The most obvious feature of the Minnesota DDT analyses is the general but irregular decline in concentrations of DDT and DDE found in fish since 1962. Whereas in 1962 and 1963 half the DDT analyses of flesh of game fish were 1.0 p.p.m. or higher (up to 3.43 p.p.m.), only 1 in 8 game fish analyzed in 1967 exceeded the 1 p.p.m. level. The intervening years were generally intermediate. It should be noted that many of the higher concentrations recorded are from fish taken in 1962 in forested areas of northeastern Minnesota. At that time DDT was still used for control of forest insects. Analyses of the flesh of rough fishes also show a general decline in concentrations of DDT over the period.

DDE levels in flesh have been fairly low throughout the period both for game and rough fish. Two of the 44 analyses for game fish exceeded 1 p.p.m., as did four of the 90 analyses from rough fish.

A feature of these analyses for DDT and DDE is the occurrence of occasional fishes, especially rough fish, with quite high concentrations. Such fish have probably come in contact with high concentrations of DDT in localized areas. In recent years fish with high concentrations have usually come from larger rivers. In these waters such fish are associated with others that have much lower concentrations, again suggesting quite localized exposure to DDT.

In the flesh analyses for game fish no concentrations of DDT higher than 3.43 p.p.m. were found. There were five analyses higher than 7 p.p.m. for flesh of rough fish. The highest analyses found were 54 p.p.m. for a sucker taken from the Mississippi River in 1966 and 30 p.p.m. in a carpsucker taken from the Minnesota River in Blue Earth County in 1967.

In most cases, DDT levels in fish flesh have been below that permitted on some other kinds of foods.

Brain tissue of fish, like that in other animals, is rich in fatty material (lipids) in which DDT and its derivatives can accumulate. For both game and rough fish DDT and DDE levels were generally higher in brain tissue than in body flesh.

The Minnesota Department has no pesticide analyses for fish from Lake Superior.

Regarding mammals and birds there is little specific Minnesota information on DDT levels. Ducks and geese averaged 0.7 p.p.m. for a series of flesh from wings gathered nationwide by the U. S. Fish and Wildlife Service. Rabbits averaged about the same. Big game in South Dakota average 0.2 p.p.m.[5/]. We have no DDT analyses from pheasants in southern Minnesota but in the same general habitat type (prairie farm land) there was a series of analyses made of pheasants taken in 19 selected counties in Iowa in 1962. No pheasants with DDT concentrations greater than 1 p.p.m. were found[25/].

At the concentrations usually found it appears that, considering the amounts usually eaten, any increase in ingestion of pesticides from eating fish from inland waters and from wildlife is not appreciable. It should be emphasized again, however, that the long term effect of low concentrations of pesticides is poorly understood. However, we have found no study that indicates harm to humans from eating food containing permitted concentrations of DDT higher than those usually found in our fish and wild animals.

In 1966 and 1967, eight analyses were made for aldrin levels from fish taken from the agricultural area of southern Minnesota.. They are:

Location	County	Date	Species	Tissue	p.p.m. aldrin
Minnesota R.	-	10/18/66	Carpsucker	Muscle	.002
Minnesota R.	-	Fall 66	Carp	Brain	.046
Mississippi R.	Goodhue	9/26/66	Sucker	Brain	.012
Mississippi R.	Goodhue	9/26/66	Sucker	Brain	.007
Root R.	Houston	Fall 66	N. Pike	Brain	.8
Budd L.	Martin	9/29/67	Sucker	Brain	.24
Minnesota R.	Blue Earth	10/5/67	Redhorse	Brain	.1
Root R.	Houston	10/30/67	Walleye	Muscle	.017

There are too few aldrin analyses to draw definite conclusions, other than to state they are all below 1 p.p.m. and within the same range reported for dieldrin (an analogue of aldrin that is somewhat more toxic to fish) for "whole" Wisconsin fish (range--trace to 10 p.p.m., mean--0.17, median--0.004)[10/].

Activities of the Minnesota Department of Conservation to Minimize Pesticide Damage

1. In Minnesota all conservation officers and field personnel of the Division of Game and Fish have been instructed to report immediately any suspected cases of damage to fish and wildlife from pesticides or other pollution. They have been supplied forms for this and are instructed to telephone in obvious cases. They have also been asked to collect any animals when pesticide damage is suspected. This approach has been used for about 10 years.

2. The Department of Conservation has a written pesticide policy whereby use of pesticides on any area larger than 40 acres, that is under the control of the Department, must be reviewed and approved by the Commissioner. Use of organochlorine insecticides is specifically prohibited except in special situations where there is no substitute.

3. The Division of Forestry routinely consults with the Division of Game and Fish before forest spraying to make sure the necessary precautions are taken to prevent injury to fish and aquatic life. DDT is banned for forest spraying and has not been used for this since 1962. Only insecticides of short persistence in the environment may be used in State parks for control of nuisance insects.

4. The Metropolitan Mosquito Control Commission has worked closely with the Division of Game and Fish in planning application of pesticides. Areas regarded by us as being important for game fish and wildlife have not been treated with chemicals. Only oil or larvae-eating fish are used on such sites. No DDT has been used as a mosquito larvicide since 1967, chemical control being done with the organophosphate Abate--at a cost for chemicals about 10 times that for DDT.

5. Since 1962 fish have been collected from Minnesota lakes each year by field personnel of the Division of Game and Fish and analyzed for DDT and DDE, and in a few cases for aldrin, by the Minnesota Department of Health. The Division of Game and Fish has recently (1969) purchased a gas chromatograph for doing this. Some analytical work has been done for the Department by the U. S. Bureau of Sport Fisheries and Wildlife.

6. In 1967 a Minnesota Pest Control Advisory Board was organized to consider and advise on application of pesticides by State agencies to lands and waters under their control. On it are representatives of the Departments of Agriculture, Conservation, and Health and the University of Minnesota.

7. The kinds and concentrations of herbicides for control of aquatic plants and algae and chemicals for control of swimmer's itch and leeches in public waters are regulated by an Order of the Commissioner of Conservation. Kinds of herbicides which can be used are specified and application of herbicides to areas larger than one-half acre requires a permit from the Commissioner, as does the use of kinds of herbicides not having official approval on any area.

John B. Moyle
Technical Assistant to the Director
May 8, 1969

SOME SELECTED REFERENCES ON PESTICIDES AND WILDLIFE

1. Dustman, E. A.
1959. Pesticide-wildlife research in the Bureau of Sport Fisheries and Wildlife. Paper presented at the Midwest Wildlife Conference, Minneapolis, Dec. 1959. 9 pp. mimeo.

2. Dustman, E. H. and L. F. Stickel
1966. Pesticide residues in the ecosystem. In "Pesticides and Their Effects on Soils and Water". Am. Soc. Agron. Spec. Pub. No. 8. pp. 109-121.

3. Environmental Pollution Panel Report
1965. Restoring the quality of our environment. President's Science Advisory Committee. Washington - 317 pp.

4. Fashingbauer, B. A., A. C. Hodson, and W. H. Marshall
1957. The inter-relations of a forest tent caterpillar outbreak, songbirds and DDT application. The Flicker, 29(4), pp. 132-147 and 160.

5. Greenwood, R. J.
1966. A survey of pesticide residues in whitetail deer, male deer, elks and pronghorn in South Dakota. Quart. Rep. S. Dak. Coop. Wildl. Res. Unit, Vol. 4, No. 1, pp. 20-21, July-Sept.

6. Hickey, J. J.
1966. Birds and pesticides. In Birds in Our Lives. U.S.D.I., pp. 318-329.

7. Hickey, Joseph J. and Daniel W. Anderson
1968. Chlorinated hydrocarbons and eggshell changes in raptorial and fish-eating birds. Science, Vol. 169, pp. 271-273. July 16.

8. Hickey, J. J. and L. B. hunt
1960. Initial bird mortality following a Dutch elm disease control program. Jour. Wildl. Mgt., Vol. 24, No. 3, pp. 259-265. July.

9. Jones, B. R. and J. B. Moyle
1963. Populations of plankton animals and residual chlorinated hydrocarbons in soils of six Minnesota ponds treated for control of mosquito larvae. Trans. Am. Fish. Soc., Vol. 92, No. 3, pp. 211-215. July.

10. Kleinert, S. J., P. E. Degurse and T. L. Wirk
1968. Occurrence and significance of DDT and dieldrin residues in Wisconsin fish. Wis. Dept. Nat. Res. Tech. Bull. No. 41, 43 pp.

11. Mathisen, John E.
1967. Bald eagle-osprey status report, 1967, Chippewa National Forest, Minnesota. The Loon 39 (4); pp. 121-122, Dec.

12.
1968. Bald eagle-osprey status report, 1968. The Loon. Sept. 1968, 2 pp.

13. Moyle, John B. and John L. Skrypek
1969. Levels of DDT, DDE and aldrin in muscle and brain tissue of some Minnesota fishes, 1962-67. Minn. Dept. Cons., Div. Game and Fish. Spec. Pub. No. 59. 4 pp. + 6 tables. Mimeo. Feb. 18.

14. National Technical Advisory Committee to the Secretary of Interior
1968. Water Quality Criteria. Federal Water Pollution Control Administration. x + 235 pp.

15. Reichel, W. L., T. G. Lamont, E. Cromartie and L. N. Locke
1969. Residues in two bald eagles suspected of pesticide poisoning. Bull. Env. Contamination and Toxicology. Vol. 4, No. 1, pp. 24-30.

16. Rosene, W.
1965. Effects of field applications of heptachlor on bobwhite quail and other wild animals. Jour. Wildl. Mgt., Vol. 29, No. 3, pp. 555-580. July.

17. Schacht, A. J. and H. L. Hansen
1963. Long-term vegetational changes following aerial application of 2,4-D and 2,4,5-T in northern Minnesota. Minn. Dept. Cons. Game Res. Quart. Vol. 23, No. 2, pp i-xi + 93 pp. and 55 tables.

18. Shell Chemical Company
1968. Symposium on the science and technology of residual insecticides in food production with special reference to aldrin and dieldrin. 244 pp.

19. Springer, P. F.
1957. Effects of herbicides and fungicides on wildlife. 1957 Pesticide Manual, N. C. State College. Raleigh, N. C. Jan.

20. Sladen, W. J. L. et al.
1966. DDT residues in Adelie penguins and a crabeater seal from Antarctica: ecological implications. Nature, Vol. 210, No. 5037, pp. 670-673. May 14.

21. Stickel, Lucille F.
1968. Organochlorine pesticides in the environment. U.S.D.I. Spec. Sc. Rep. - Wildlife No. 119. 32 pp. Oct.

22. Stickel, L. F., N. J. Chura, P. A. Stewart, C. M. Menzie, R. M. Prouty and W. L. Reichel
1966. Bald eagle pesticide relations. Trans. 31st N. Am. Wildlife and Nat. Res. Conf., pp. 190-200.

23. Stickel, L. F., W. H. Stickel and R. Christensen
1966. Residues of DDT in brains and bodies of birds that died on dosage and survivors. Science, Vol. 141, No. 3717, pp. 1549-1551. March 25.

24. Stickel, W. H. et al.
1965. Effects of heptachlor-contaminated earthworms on woodcocks. Jour. Wildl. Mgt., Vol. 29, No. 1, pp. 132-146. Jan.

25. Swope, H. M., compiler
1965. Midwest Pheasant Council 1965 Pesticide Committee Report. 13 pp. mimeo.

26. Tarzwell, Clarence D.
1950. Effects of DDT mosquito larviciding on wildlife. U. S. Pub. Health Service, Public Health Reports, Vol. 65, No. 8, pp. 231-255. February 24.

27. U. S. Federal Register. Vol. 33, No. 125, Part 120 Subchapter B. June 27, 1968. (Pesticide tolerances in food).

28. U. S. Dept. Interior, Fish and Wildlife Service
1965. The effects of pesticides on fish and wildlife. Fish and Wildlife Service, Circular 226, 77 pp.

29. Wilson Ornithological Society
1961. Some effects of insecticides on terrestrial birdlife in the Middle West. The Wilson Bull. Vol. 73, No. 4, pp. 398-424.

30. Wurster, C. F. et al.
1965. Bird mortality after spraying for Dutch elm disease with DDT. Science, Vol. 148, No. 3666, pp. 90-91, April 2.

31. Wurster, D. H. et al.
1965. Bird mortality following DDT spraying for Dutch elm disease. Ecology, Vol. 46, No. 4, pp. 488-499.