PESTICIDES AND WILDLIFE

David B. Peakall and Walter R. Spofford
State University of New York Upstate Medical Center

The objective of this paper is to place before the members of the Federation some basic information on pesticides. Since it is impossible to give more than a fraction of the information available, further sources will be indicated.

Most of you are aware that the problem of the effect of pesticides on wildlife exists, but an additional problem is getting this information across to the general public. We feel that it is essential that more persons interested in wildlife should be well informed and be prepared to speak at town meeting, etc., pointing out some of the dangers. Having been to some of these meetings we are appalled at the lack of knowledge of many persons who undertake spraying programs.

Since the effects of a spraying program depend a good deal on the pesticides used, it is necessary to consider the main chemical classification of these materials. Classification of pesticides from several viewpoints has been given by Rudd. (An introduction to pesticides, *Audubon Magazine,* July/August 1964). In general, pesticides can be classified, according to their chemical composition, into three major categories: chlorinated hydrocarbons (aldrin, dieldrin, endrin, DDT), organo-phosphorous compounds (malathion, parathion) and inorganic poisons (sodium arsenite, 1080, lead arsenate, thallium). There are many more pesticides of each type and innumerable trade names. A full listing of trade names and chemical compositions is given in the *Pesticide Handbook* (Frear, College Science Publishers, State College, Pa.).

Tables of toxicity are to be found in *Pesticides and the Living Landscape* by Robert L. Rudd (Table 2, page 20) and in the *Audubon Magazine* article referred to above. The acute toxicity of a compound is the single dose needed to kill and is usually expressed as its LD_{50}. The letters stand for the dose lethal to 50% of the population. That is, the amount of the compound, expressed as weight per unit of body weight, that will kill half the individuals of a population of a given species. It is more difficult to express chronic toxicity as a numerical value because it must be defined in terms of time as well as amount. Often absolute toxicity is less important than the relative toxicity to various kinds of animals. None of the common pesticides are highly selective in their toxicity, but the chlorinated hydrocarbons are more toxic to fish than to other forms of life and the organo-phosphorous compounds are less toxic to warm-blooded animals than to insects.

Another important factor is the persistence of the pesticide. This varies considerably with the type of vegetation and soil but it has been found that up to 35% of DDT has remained in the soil for five years after treatment and 30% of dieldrin after a year. Furthermore, much of the remainder has merely been carried away by water passing through the soil. Most of the inorganic compounds and the chlorinated hydrocarbons are highly stable. The organo-phosphorous compounds are much less persistent and are broken down to inert compounds by water.

Another word often used is tolerance, which refers to the limits set by the Federal Food and Drug Commission as the maximum amount of a pesticide residue that is permitted in food. Thus the tolerance of DDT on potatoes is set at one part per million (ppm). These levels are set, after experiments on laboratory animals, at a figure considered safe for prolonged consumption. In some cases the tolerance is set at zero, i.e.: dieldrin on corn, indicating that *no* residue of the pesticide is permitted. Tolerances are listed in the *Pesticide Handbook.*

The last technical term that we wish to define is "insecticide resistance" or more correctly resistance of insects to insecticides. A small percentage of insects of a given species have a much higher ability to resist poisoning by a given pesticide. This ability is genetically inherited. When a population of insects is sprayed with a pesticide, those resistant individuals survive. If spraying is carried out frequently, eventually most of the insects remaining are of this resistant variety and as they breed, the new generations become more and more resistant to the pesticide. Then much larger amounts of pesticides must be used to obtain the same degree of control, or new pesticides substituted. Resistance increases of a thousand-fold have occurred under natural conditions. In some areas of pesticide use, such as in malaria control and in the cotton fields of the south, this is already a serious limitation on the materials that can be used. (Brown, *Resistance in Arthropods.* Geneva, 1958; Peakall, *Audubon Magazine* January/February 1964).

Types of Pest Control Programs

The use of pesticides is not a black and white matter. At one end of the spectrum of pesticide use is the control of malaria and at the other the attempted eradication of the fire ant in the southeast. One of the best attempts to evaluate the various types of programs in which pesticides have been used was made by Drury (*Mass. Audubon Magazine,* September/October 1961, Contribution 39, Hathaway School of Conservation Education). We shall consider the various types of programs under three major headings: public health, agricultural, and others.

Public Health. This is the great success story so beloved by the chemical manufacturers. Pesticides, especially DDT, have been used to control the insect carriers of many diseases including malaria, yellow fever, cholera and typhus. It has been estimated (Muller, *DDT,* Vol 2, 1959) that in the period 1942-1952 some five million lives were saved by the use of DDT. The malaria eradication program run by the World Health Organization has removed malaria as a serious disease from areas containing 280 million persons. The benefits to human welfare of these programs are enormous. At the present time there is no substitute for non-selective pesticides in public health work. However, the problem of insect resistance is causing trouble and it is to be presumed that this will increase.

Despite the many situations where the benefits appear to outweigh the risks, spraying with pesticides should not be used to cover up poor sanitation, nor should the fact that DDT has saved many lives in a malaria control program in South America be considered reason for spraying non-malaria-carrying mosquitoes in New York.

Agricultural Use. One thing that should be made clear is that the use of pesticides is not going to provide the extra food needed to make up for the current population explosion. It may act as a temporary prop, but the only cure is to control the rate of birth. The greatest problem caused by pesticides may well be the explosive increase in human population made possible by the virtual elimination of many diseases while our approach to population control is medieval (Holway, R.T., 1964, *Bio Science* 14 (11).

How necessary are pesticides in current agricultural practice? A recent World Health Organization Report (No. 240) makes this statement:—"Pesticides are indispensable to the farmer in his fight against pests and diseases. Without their use, many foods could not be produced economically or perhaps at all, and the yield of all crops could be seriously reduced; for example, without pesticides, present production in the U.S.A. of potatoes, apples, citrus fruits and cotton would be reduced by 50% and meat, milk and wool by at least 25%".

While the use of pesticides may be an essential part of agricultural practice at the present time, this does not mean that the types of materials used should not be questioned. In particular, how necessary is the use of the persistent chlorinated hydrocarbons? This question has been considered in detail by a scientific advisory committee appointed by the British Ministry of Agriculture (Review of the persistent organochlorine pesticides, Her Majesty's Stationary Office, London, 1964). Most of the committee were in the agricultural science field, although wildlife experts were included. The committee's findings were that the equivalent of 250,000 acres out of 7,700,000 (3.5%) would be lost if the use of chlorinated hydrocarbons were discontinued completely and that of this amount 150,000 acres could be saved by the use of other pesticides. Thus, if the use of chlorinated hydrocarbons were discontinued, the overall loss would be about 1.5%. The committee recommended that the use of compounds of the dieldrin group be banned except for a few highly specific uses (mainly food storage) and that the use of other chlorinated compounds be re-examined in three years with a view to phasing out their use. This report was adopted by the British Government. Thus this committee of agricultural scientists considered that the dangers to wildlife of this group of pesticides was proven and that continued use could only be justified if no effective alternative was available. There are indications of an increasing realization of the limitations of non-selective pesticides. The 12th International Congress of Entomology held recently in London had a markedly different approach than its predecessors. A resolution was issued warning that unless ecological principles are applied to large scale land development programs the world is threatened with prodigious outbreaks of pestilent insects . The pesticide limitations that are slowly becoming serious to agriculture are insecticide resistance and the kill-off of natural predators. Due to these factors alone the whole problem of pest control in agricultural practice may have to be reconsidered.

A classical example of these two factors is the case of the spotted alfalfa aphid in California (*Hilgardia*, Vol. 29 No. 2, 1959, University of California, Berkeley). The spotted alfalfa aphid appeared in the alfalfa fields of

California in 1954 and the farmers, faced with serious losses, attacked with pesticides. Two years later resistance to pesticides was noted and a thorough entomological survey was made. It was found that the aphids were still present, but, with the exception of a few species of spiders and mites, the pesticide program had exterminated all of the several hundred species of arthropods normally present in alfalfa. Predators, such as parasitic wasps and lady-beetles, were introduced and now, with occasional light spraying at times of high aphid population, the situation is under control.

Although not strictly an agricultural program, the widespread spraying of forests may be included here. A recent government bulletin for the general public, on the importance of pesticides in pest control in forests, states that 1.8 billion board feet of lumber are lost annually to pests and disease. On reading this booklet one wonders how the forests existed before the development of modern pesticides. However, when one realizes that this loss represents 0.11% of the total U.S. resources the problem falls into perspective.

Non-agricultural Programs. From the wide variety of programs that could be considered, two examples have been selected, mosquito control and eradication of Dutch Elm disease.

Control of non-malaria mosquitoes in suburban areas is a considerable problem. People do not like being bitten by mosquitoes and have a right to deal with the problem. However, it is not generally realized that fogging with pesticides is only effective for a few hours. Thus this method of control is useful only for special events lasting a few hours. If fogging is used, compounds such as malathion have less long-range effects than DDT. The official bulletin of the U.S. Department of Agriculture places the greatest emphasis on the elimination of trash and stagnant water.

Spraying elms with heavy doses of DDT to prevent Dutch Elm disease is a widespread practice. Yet the official recommendations of the New York State College of Agriculture now consider that spraying is of little value and should not be generally used. What is important is the removal of diseased timber.

Many people expect miracles in the way of insect control without a thought as to the effects that pesticides can have on wildlife. Today people expect to camp in the Adirondacks without being bitten by blackflies. They do not realize that all the fish and birds will be dead long before the last fly is eliminated.

Pesticides and Food Chains

The direct kills of animal life which follow indiscriminate application of various poisons, usually directed at an insect target, are immediate and spectacular, often attracting attention and causing concern. However, direct kills and immediate secondary poisoning are far less serious than the long-term indirect effects now to be considered. These may become apparent only years later as such inadvertently poisoned non-target species as Ospreys, harriers, and Cooper's Hawks fail to raise young and become rare or disappear entirely. This is true only of the persistent poisons, the chlorinated hydrocarbons, which diffuse widely into many or all kinds of animal life even in remote regions. These poisons become concentrated as they pass up the food-chains to the higher forms of life. Woodcock shot in New York carry poisons accumulated by soil animals from both spruce budworm programs in New Brunswick and fire ant programs in southern United States, and who knows the biological history of the poison residues recently reported in Whooping Cranes by the Fish and Wildlife Service?

We speak of "indiscriminate" application of these poisons simply because the poisons can never be applied in such fashion that they hit only the desired target. All animals live in variously complex communities and most or all of these species and populations are exposed to direct and/or indirect poisoning, All talk of proper labelling and proper usage becomes meaningless when a scavenger or predator feeds upon poisoned target species; when poison is directly eaten by non-target animals; when the poison penetrates the soil where it is taken up into the tissues of the soil microcosms, populations of which may be thousands of species and millions of individuals per square meter; when poison is carried off by the soil waters into streams and ponds, into lakes and oceans, where it is taken up into tissues of minute plankton animals in dilute amounts, a few parts per million, concentrated by larger plankton, especially small arthropods, further concentrated by small fish, eventually reaching concentrations of hundreds or thousands of parts per million in larger fish, in herons, grebes, Ospreys and eagles.

These persistent poisons applied locally to relatively small areas have now become widespread over most of our continent, being found in the tissues in examples of practically all animals from the greater part of North America together with its air and water, and the oceans of its continental shelves. Tuna far out to sea have been found to harbor insecticide poisons at 200 parts per million.

To understand how these poisons, often dilutedly applied, reach increasing concentrations in the higher forms of life, such as herons, grebes and eagles, one must consider the feeding relationship of animals both in broad perspective and in detailed particulars. All animals are consumers of foods synthesized by plants with the energy supplied by sunlight, and yet the whole animal kingdom consumes only a small fraction of the total vegetable production. Herbivores (ranging from minute insects to elephants) feed directly upon vegetation, carnivores feed upon herbivores, "second-level carnivores" feed upon the first-level carnivores, the whole in a sharply diminishing series of trophic levels. Many decades ago, the British ecologist Charles Elton recognized a "pyramid of numbers" in which the lowest level (herbivores) is in greatest numbers and breeds most rapidly, and each succeeding carnivore level is in successively smaller numbers of usually larger size. Top-carnivores such as eagles and tigers are in relatively small numbers and breed very slowly. Food-chains and food-web refer to parts of the total pattern of feeding relationships. A single eagle feeds upon hundreds of rabbits which graze thousands of acres. An Osprey consumes hundreds of large fish which consume thousands of smaller fish, which in turn feed upon millions of minute plankton animals and these in turn upon great quantities of plant plankton.

It is now becoming clear that this "pyramid of numbers" furnishes a basis for an understanding of how a persistent poison applied even dilutely to vegetation later accumulates in progressively concentrated amounts in the higher levels of food-chains in the food-web. Thousands of poisoned insects poison hundreds of insectivorous birds, and these in turn poison a hawk or falcon. Non-lethal levels of poisoning appear to interfere with reproductive success, the eggs failing to hatch, as has been found in laboratory tests with various birds. Populations of hawks and eagles dwindle and eventually may disappear entirely, as has the Peregrine Falcon as a breeding species in eastern United States. Most predators now cannot avoid consistently taking poisoned prey. An animal with some poison is not so quick in avoiding capture, and predators capture the most available prey. A poisoned fish is seized by an Osprey, and dead fish loaded with poison are time-bombs for scavenging Bald Eagles.

A particularly instructive example of the progressive concentration of poison at each successive level as it ascends the food-chains in an aquatic community (see Figure 1) is given in a study made California. The chlorinated hydrocarbon DDD was applied to the waters of Clear Lake at a concentration of only 0.02 parts per million, to destroy the annoying midge population. A few years later Western Grebes breeding on the lake began to die, the population dropping in ten years from over a thousand pairs to only thirty, and these failing to produce young. Investigation showed that the DDD soon disappeared from the water itself, having been taken up by

Figure 1

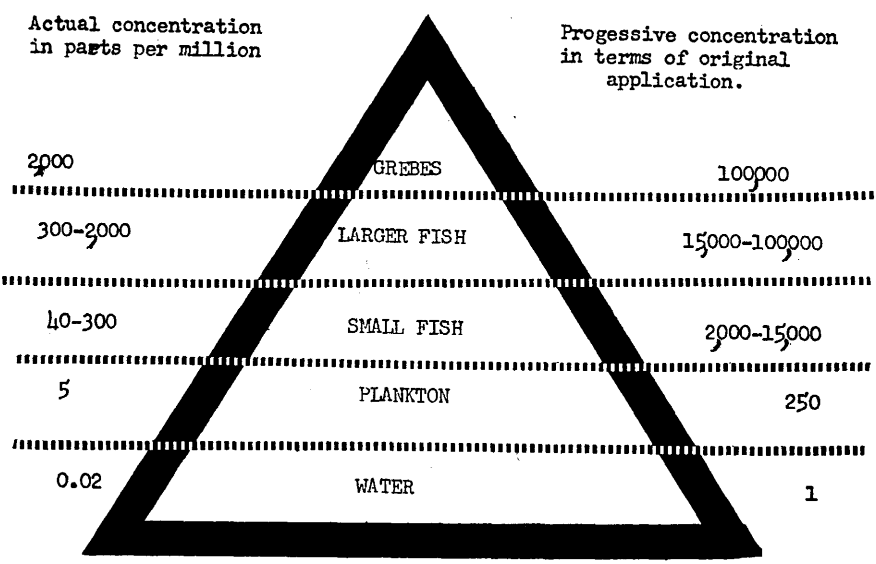

Diagram showing the progressive concentration of DDD along the food chain in Clear Lake, California. (Hunt and Bischoff, California Fish and Game, Vol 46, pp 91-106, 1960).

small plankton organisms and now cencentrated to 5 parts per million (a "magnification" of 250 times its original application). In turn, small fish feeding upon the plankton had 40-300 ppm. Larger fish had much greater concentrations and, of course much larger total accumulations; dead Western Grebes even 2,000 ppm., a concentration of the poison 100,000 times that of its original application of only 0.02 ppm. With examples such as this biologists now believe they are beginning to understand what is happening to our eagles, Ospreys, hawks, and other forms of wildlife. Our food-chains are already so loaded with persistent poisons that the problems will continue to get worse for years to come, even if all usage of persistent poisons were to stop today.

Damage to Wildlife

Several examples of damage to wildlife have been mentioned in the previous section. Here a few specific examples will be cited.

In a survey of Peregrine eyries in 1964 (Berger, to be published) covering the entire eastern United States not a single bird, let alone an active nest, was found. Formerly the population of this fine bird was 200-300 pairs. A study of this species in the British Isles (Radcliffe, *Bird Study* 10:56, 1963) has also shown a marked decline and this is correlated in time and area with the use of pesticides. The Bald Eagle has declined over most of North America, the only exceptions being Alaska and extreme southern Florida (Sprunt, *Audubon Magazine,* January/February 1963). The Osprey has also suffered severe losses. Along the Connecticut River the breeding population has decreased from 200 pairs in the early 1940's to 24 pairs in 1963. Similar decreases have been found in other parts of New England and Long Island. It is considered that the species is likely to cease breeding in these areas before the end of the decade (Ames and Mersereau, *Auk* 81:173, 1964).

The pattern of the decline of raptors has been the same in all cases studied. There is a period of low or even zero breeding success followed by a catastrophic decline as the old birds die off. More specifically, it is the failure of eggs to hatch that occurs in these cases. This has been documented for the Peregrine and Golden Eagle in the British Isles and for the Bald Eagle and Osprey in North America. The breeding success of the Golden Eagle in Scotland was found to have decreased from 72% to 29% over the last few years (Lockie and Radcliffe, *British Birds* 57:89, 1964). The failure of eggs to hatch has been correlated with high residues of chlorinated hydrocarbons in some cases. This pattern of low breeding success is consistent with the laboratory finding that 1/5 to 1/20 of the lethal dose of chlorinated hydrocarbons causes considerable decrease in reproductive capacity.

The effects of DDT on Lake Trout reproduction in New York State have been so serious that the Conservation Department has discontinued the use of DDT in its forest pest control program and has also forbidden its use on state land within the drainage basins of rivers containing Lake Trout. The story of poisoning of trout begins in 1955 when all of over a third of a million eggs taken from Lake George died. The fry hatched from the eggs normally, but at the stage when the yolk-sac (which serves as a built-in food supply) is absorbed the fry died. Biologists at the State

Fish Hatchery at Rome found that if the fat of the egg contained 3 ppm or more of DDT the fry died. Investigation of the DDT in the oil from tissues of mature trout from various parts of the Adirondacks varied from zero to 850 ppm. It appears that a concentration of about 100 ppm or above in the oil of the female leads to toxic effects in the young (Dean, *Conservationist,* December/January 1963/64).

Information on possible wide-spread decreases of fish-eating birds is less definite than it is for hawks. It resembles the information that was available on raptors five years ago. The Brown Pelican, state bird of Louisiana, has decreased to the vanishing point in that state (*Audubon Field Notes* 18:333, 1964). In New York there are scattered reports of decrease in numbers of herons which suggest that the effects of contamination of the aquatic food-chain are starting. Mr. Walter Benning, of Clyde, is making a census of heronries in this state that should prove a valuable index of population changes. We would like to ask our readers to assist him in this work.

In the case of song-birds there is virtually no information on the long-range effects of persistent pesticides. It is hoped that the North American nest-record card program run by the Laboratory of Ornithology at Cornell University will provide a means of obtaining this information and we urge the widest possible support for this program.

Conclusion

Both the chemical industry and such agricultural interests as the U.S. Department of Agriculture have been slow to recognize the wide-spread and long-persistent damage they have done and are doing today to our total biological environment, a persistent and increasing poisoning of our "ecosystem" and particularly the higher forms of animal life. Repeated applications of even dilutely applied persistent poisons are inevitably dispersed by progressive diffusion into various habitats over wide parts of the continent by both physical and animal vectors. Furthermore, the poison, however dilute its appplication, is progressively concentrated in its inevitable ascent of the food-chains until, in such top-predators as eagles, Ospreys and falcons, residues accumulate in hundreds or thousands of parts per million, bringing about drastic curtailment of reproduction and precipitous population decline.

SUNY Upstate Medical Center, 766 Irving Avenue, Syracuse 13210

Selected Reading

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