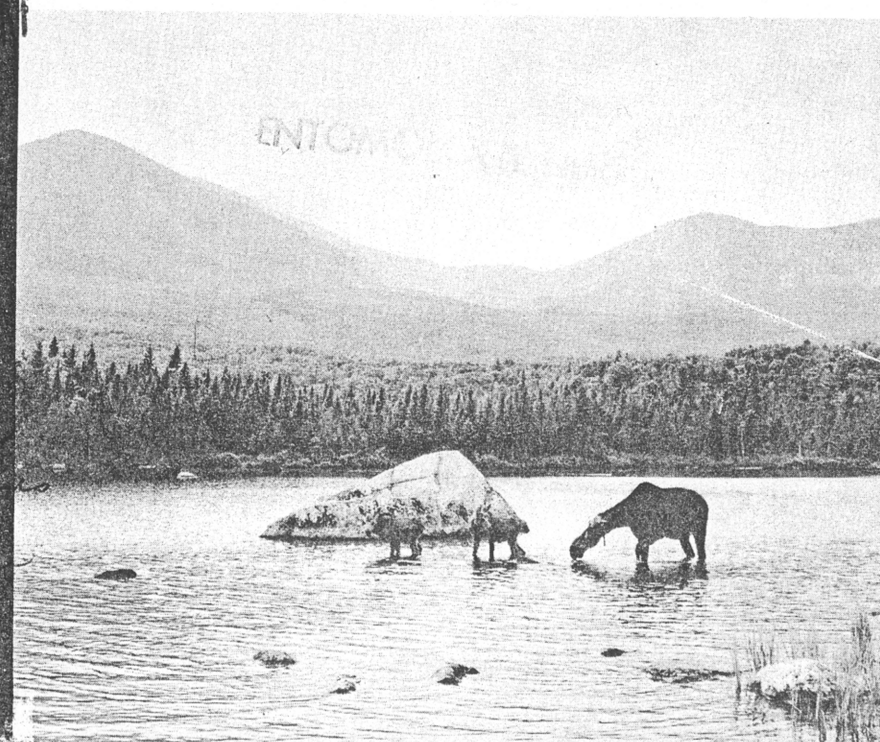
CONTROL AND
LIFE RELATIONSHIPS

PART I

Evaluation of Pesticide-Wildlife Problems



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PEST CONTROL AND
WILDLIFE RELATIONSHIPS

PART I

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Evaluation of Pesticide-Wildlife Problems

A Report by the
Subcommittee on
Evaluation of Pesticide-Wildlife Problems
of the Committee on
Pest Control and Wildlife Relationships

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FOREWORD

This is the first of several reports presenting the consensus of experts with diverse interests in the various phases of pest control and wildlife relationships. The information in this publication was assembled, evaluated and compiled by the subcommittee on Evaluation of Pesticide—Wildlife Problems. Similar material has been assembled for Part II, a Report on Policy and Procedures for Pest Control and Part III, a Report on Research.

Cooperation of many industrial organizations, trade and scientific associations, agencies of Government, and individuals made this project possible and is gratefully acknowledged. Without the generous voluntary participation of the following committee members this work could not have been accomplished.

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The background photograph on the cover was generously furnished by the State of Maine Inland Fisheries and Game Department.

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INTRODUCTION

Man depends on living things to provide the food, fiber, and timber needed for his survival. Destructive pests often make the efficient production of these necessities very difficult, while other organisms constitute a threat to man's health and comfort. There is an obvious need to keep these pests under control, provided it can be done without serious hazard to man and desirable forms of plant and animal life. In undertaking an objective evaluation of the problem there is first a need for a general understanding of what is meant by the word "pest."

From a human standpoint, not all plants and animals are beneficial. They may appear in unwanted places or their numbers may be too great. A weed, for example, has been defined as a plant which is growing where it is not wanted. In this context, a corn plant in a lawn is a weed; a morning glory in the corn field is a weed. Some animals have been domesticated and provide us with food and fiber; others furnish recreation through hunting or fishing; still others are destructive or carry diseases. There are birds which eat destructive insects or provide aesthetic enjoyment and are accordingly beneficial; certain other birds are generally regarded as public nuisances. Although there are insects which destroy crops or transmit diseases, many are parasites, predators, pollinators, or have aesthetic values. By and large, those species of plants or animals that conflict with the immediate or long-range needs and desires of man may be regarded as pests.

To control pests, chemical pesticides are widely used. In their use the objective is to follow methods of application that will accomplish the desired effects with a maximum of safety to man and to forms of life useful to him. At times, however, doubt has been expressed that certain effective pest-control measures have provided a reasonable margin of safety to beneficial organisms. Conflicts of opinion on this score have increased in recent years as a great array of newly discovered pest-control chemicals have been put to use on an increasingly wide scale to protect man and those plants and animals essential to his welfare.

To add to the difficulty there is a lack of general agreement as to the relative value of certain animal and plant species, and of the importance of pest depredations. This constitutes a major conflict of interest. For example, those who enjoy birds may be distressed by any pest-control measures that result in damage to birds and to their food supply or habitat. On the other hand, people most concerned with preserving shade trees may favor use of every means, including application of insecticides that may at times kill some birds, in an effort to control insects that threaten the survival of trees.

Where a conflict of interest occurs relative to the use of a pesticide, the decision rests on the weighing of advantages that will accrue against the disadvantages, always considering the general public good. Such differences in opinion point up the need for objective evaluation. No one wants to choose between trees and birds, though occasionally the choice may have to be made. Preferably both are wanted.

There is a broad interest in the problem among all biologists, be they entomologists, botanists, ecologists, physicians, or those concerned primarily with wildlife. They all work with living organisms, desirable or undesirable from the standpoint of man's welfare, convenience, or economy. Thus there is need for an interdisciplinary approach to the study. Such an approach has been followed in this evaluation and, through it, every effort has been made to achieve a reasonable reconciliation of scientific opinion.

While it is generally recognized that the use of pesticides is only one of many human activities that affect wildlife, a discussion of the impact of cultural practices, removal of forests or brush, land drainage or irrigation, urbanization, highway and industrial development, grazing, hunting, etc., is outside the scope of this study.

PESTICIDES A MODERN NECESSITY

In Agriculture

Present-day efficiency in agriculture is the result of a number of major developments. These include providing better conditions to meet the requirements of domestic plants and animals through such means as: (1) mechanization of farm operations, (2) improving the fertility of soils, (3) crop and livestock improvement through selection and breeding, and (4) better control of pests.

Cultivated crops grown in North America are adversely affected by over 3,000 economically important species of insects, perhaps as many plant diseases, and an unestimated number of nematodes, rodents, weeds, and other pests. Estimates of the crop destruction caused by agricultural pests range from eight to 15 billion dollars annually—a quarter of our annual production—and this occurs despite the widespread use of control practices now available. The insects and microorganisms that attack food and fiber in transit and storage cause food destruction, food deterioration, and food contamination. Hence, the necessity of protecting food products as well as growing crops from attack by insects, plant diseases, and other pests is generally recognized.

Many factors have contributed to the increased prevalence and destructiveness of insects, weeds, fungi, bacteria, nematodes, and viruses during the past 100 years: (1) The growing of the same crop repeatedly in the same field or in a crop area permits the pests to adapt themselves to the crop cycle, multiply extensively and attack the host plants. (2) After several generations certain pests, which at first rarely attacked cultivated crops, became adapted to introduced plants in the new environment to such an extent that they became extremely destructive. (3) The breeding of crops for increased yields, uniformity, and other desirable characteristics has in some instances made them susceptible to one or more pests. (4) Many destructive pests of foreign origin have become established in this country. (5) Man has altered the basic ecology of large areas by the removal of forests, by drainage, by irrigation, by cultivation, by the introduction of new crops, and by the use of pesticides, all of which have affected the natural biological controls. Pests have responded to this changed environment: some species have declined in destructiveness; many others have increased.

Diligent efforts have been made and are still being made to control insects, weeds, diseases, and other pests through biological and ecological measures. These include the introduction and release of parasitic or predatory insects and other organisms to hold the pests in check, and manipulation of the environment to create conditions unfavorable to their growth and survival. Good cultural practices, improved sanitation, use of resistant varieties of crops, observance of planting dates most unfavorable for specific pests, crop rotation, and fertilization to promote proper growth are some of the practices developed through years of research by entomologists, plant pathologists, and weed-control specialists. Insofar as they are practical, these practices are generally followed by most farmers. Such cultural practices were about the only means of control available in the early days of agriculture in the United States. But as the numbers of pests increased and the need for better pest control grew, it became increasingly apparent that natural and cultural measures alone were in themselves not enough, so farmers resorted to the use of chemicals.

Even so, on the basis of our present knowledge it is safe to say that without the use of chemical pesticides most fruits and vegetables would be much scarcer in the market and the prices of the meager quantities produced would be prohibitive. It is known from studies conducted over the years that 40 to 80 per cent of the apples produced without the protection offered by pesticides in many areas will be damaged by codling moth, and 60 to 80 per cent damaged by apple scab, plus an equal or even greater degree of damage by other insects or diseases. To this fruit damage must be added the destruction that would be wrought by wood borers, scale insects, and other pests that affect the trees.

Without the benefit of pesticides, the yield of staple fiber, cereal, and forage crops could be expected to drop from 10

to as much as 25 per cent. Careful studies have shown that the omission of insecticide treatments resulted in reduction of cotton yields of 25 to 40 per cent.

Agronomists have demonstrated quite conclusively that, in general, a given acre of land devoted to a specific crop is able to produce only so much dry matter in any given season. With weeds partially uncontrolled, crop yields are reduced in proportion, and with some weeds completely uncontrolled, yields may be practically nil.

The rise in pesticide usage has been closely associated with and has paralleled the advances in farm mechanization. Thus, in these days of automation and labor-saving devices, pesticides must be regarded as chemical tools which are just as indispensable as mechanical tools in the production of agricultural crops. It would be economically unsound for farmers to abandon the use of pesticides. Capital investments in farms and farm equipment today are such that occasional complete or even partial crop failures cannot be absorbed.

In Forestry

One of every three acres in the United States is forest land. So common are the products and services of the forest in everyday living that their presence is often taken for granted and their essentiality overlooked. But when the relationship of the forest to the Nation's economy is analyzed and all its products and services are considered, the part they play in the lives of all the people is self evident.

The forest-pest relationship closely resembles the agricultural pest situation. More than 160 destructive insects are of major importance in their effect on forest production. Forest insects each year kill one billion cubic feet of young growing stock and seven billion board-feet of saw timber. Also, they cause loss in growth of another 1.8 billion cubic feet in growing stock and 8.6 billion board-feet in saw timber. Bark beetles as a group are considered to be the most destructive, followed by defoliators and sucking insects. Losses in timber growth due to diseases are even greater than those caused by insects. And mammals (including deer and rodents) cause extensive, but largely unassessed losses.

As in agriculture, there are three general types of control for forest insects: cultural, biological, and chemical. Much can be done through various types of cutting to control outbreaks and make timber stands ecologically less susceptible to insect attack. This is a long-term method and is not effective against all insects. Biological control by the introduction or release of parasites, predators, and insect diseases, while inadequate in most cases, has proven helpful, especially against introduced insects. This, too, is a long-term method but one which, no doubt, will be expanded as further information on its applicability becomes available. Chemical control is the method most suitable for combating emergency outbreaks. It is the last resort, reluctantly taken. Aerial spraying, first utilized in the 1920's, was greatly expanded after World War II. With the advent of DDT and other similar insecticides, many kinds of insect-caused losses previously unpreventable can now be controlled.

The principle of weed control, long practiced in agriculture, also applies to forestry. Undesirable and harmful species of trees and shrubs may be removed either mechanically or by use of selective herbicides. The use of chemicals for this purpose was largely experimental until recent years, but is now being practiced on an increasingly extensive scale.

In Public Health

In the last half century man's life-expectancy has increased by approximately 20 years. Moreover his general state of health and bodily comfort during the years allotted to him have been improved. Many factors have contributed to this increased life-span and the improvement in the general health of our population. For example, a great step toward the conquest of yellow fever was made possible when it was shown that the disease was carried by mosquitoes. Through the application of environmental and chemical methods of mosquito control, yellow fever has been eradicated from the United States.

At one time malaria was prevalent over a large portion of the United States. This debilitating disease was still present in epidemic proportions in 1936, and there was a small outbreak in Michigan as late as 1943. After World War II, when DDT became available for general use, it provided an improved

means of controlling malaria mosquitoes, and, through its use to supplement other effective measures, malaria has been essentially eradicated from the United States. Thus encephalitis now becomes the mosquito-borne disease of principal importance in this country.

Control of mosquitoes is also widely justified economically due to the nuisance and discomfort caused by the pests. Many of our large seashore resorts, such as Atlantic City and Miami Beach, owe much of their success to mosquito control, for, without this protection, these areas would be less attractive during much of the year. Moreover, there has been a significant shift of city populations into the suburbs where mosquito control has become a major factor in the health and comfort of the people.

The application of chemicals is not the only means of controlling mosquitoes. In many instances they may be more permanently controlled by the elimination of breeding places. In many localities a combination of habitat adjustment and the use of insecticides may be the most efficient control method.

Mosquitoes and flies are the principal insects subjected to control for reasons of the public health. But in addition there is a number of arthropods of lesser public health importance that require limited control, such as lice, ticks, and chiggers. Diseases such as typhus and dysentery are kept in check through sanitary practices and chemical control of the insect vectors. It is likely that other diseases and nuisance insects of potential public health importance are not problems today only because of man's ability to control the insect vector or the nuisance insect.

WILDLIFE VALUES

Attempts to destroy or repress harmful and undesirable pests frequently affect the well-being of many desirable forms of wildlife. The term "wildlife," used in its broad sense, includes fishes and all other forms of animal life that have not been domesticated. Some wild animals, both vertebrates and invertebrates, are considered to be game, while others are non-game species. Many of the marine forms are important commercially as sources of food. Wild animals are widely distributed in water, wetlands, deserts, lowlands, and uplands. Some species are found primarily in wilderness areas (grizzly bears); others may occur in backyards (robins), or in the middle of large metropolitan areas (starlings), or far out at sea (albatrosses). Some animals (migratory birds) are highly mobile; others (bobwhite, quail, and cottontail rabbit) are sedentary and are referred to as resident species. Under certain circumstances, some species may be harmful; under other circumstances the same species may be beneficial. Certain animals that are destructive may, at the same time, have aesthetic values.

Plants and insects sometimes are disseminated by wildlife. Some forms of wildlife cause damage to crops, food products, and property. They may constitute a hazard to man and his domestic animals as carriers of diseases.

With the wide public interest in wildlife, the question of ownership is pertinent. Excluding oceanic species outside of territorial limits, it may be said that ownership of wildlife is vested in the several States. The owners of the land, however, subject to regulations imposed by his State government, have the right to take and control the wildlife on their own lands. Migratory birds and certain marine species are subject to regulations formulated and administered in accordance with international treaties.

Indians and early settlers of this country, when the human population was low, used game and fur animals mainly for essentials. Excluding commercial fisheries, today's emphasis is on recreational and aesthetic uses, but because of the increase in population the number of persons affected is far greater. This change in use has created a new kind of demand, which tends to increase with the increase in income and leisure time of the people as well as with the increase in population. Originally most wildlife other than fish was produced and harvested on public land. Today, the greater portion of game birds and mammals is produced and harvested on agricultural land—most of it privately owned.

In recent years much land which formerly served as productive wildlife habitat has been taken over for airports, super highways, sprawling cities, and other types of construction. Wetlands are being drained extensively. Dams and reservoirs continue to be built. Such changes may improve conditions for some species of fish and wildlife and destroy habitat needed by others. Likewise, applications of chemical pesticides increasingly influence the ecological complex. Some treatments improve conditions for certain species of wildlife (such as the control of non-palatable shrub species by use of herbicides and their replacement by more valuable food and cover); other treatments have injurious direct or indirect effects. The net result of population and industrial growth has been more competition between man and wildlife for living space and greater desire on the part of man, with his increased leisure time, to enjoy hunting, fishing or other recreational values afforded by wildlife.

A survey of sport-fishing and hunting activities of people 12 years of age and over showed that more than 30 million Americans spent nearly four billion dollars in some 658 million days of hunting and fishing in 1960. These sportsmen came from 20 million households. Moreover, there are countless people who enjoy wildlife for its aesthetic value and as a source of relaxation from the pressures and tensions of modern living.

Any attempt to assign monetary values to the food, fur, and other products obtained from fish, game birds, and mammals taken for sport is fraught with difficulty, as only incomplete records on the take and use of such items are

available. However, the overall dollar value of the products is in the millions. Some fish and fur animal resources serve also as the basis of large commercial industries. Therefore, wildlife values need to be given due consideration in decision-making processes that precede pest-control operations.

THE IMPACT OF PESTICIDES ON WILDLIFE

Hazards to Wildlife

Unfortunately, many species of wildlife are subjected to pesticide hazards not encountered by man or by his domestic animals. The latter are afforded considerable protection by label directions specifying definite time-lapse intervals between insecticide applications and consumption of the crop. This in itself offers protection. In addition, food destined for man and domestic animals often is given special treatment to reduce or eliminate pesticide residues. Wildlife, of course, does not receive such protection, and consumption of contaminated food may start immediately after the pesticides are applied and residues are highest.

The simultaneous treatment of large contiguous areas by a pesticide poses special problems to wildlife. Such programs frequently may involve applications to areas of diverse ecological character and varied habitat including substantial portions of the entire range of certain plants and animals.

In a highly diversified environment it is often difficult to select a chemical or a time and method of application that will pose minimal hazards to all of the wildlife species involved. The greater the complexity of the fauna and flora, the greater the risk that unfavorable food chain and other unfavorable reactions may occur.

Treatment of large areas also reduces the opportunity for animals to escape to non-treated areas. Insectivorous species of birds, attracted to a generous supply of dying insects, may consume large numbers of poisoned insects.

Depending at least in part upon the mobility of the various species concerned, reinvasion of depopulated areas may be rapid or slow. The rate of repopulation also is related to the size and nature of the treated areas, the residual properties of the pesticidal material, and the time of year of the treatment. Generally, the larger the area treated, the longer the period required for re-establishment of previous population levels.

There are numerous other problems peculiar to wildlife requiring special consideration. For example, it is well known that food consumption of some animals is more or less inversely proportionate to their size. Thus birds, rabbits, and some other forms of wildlife consume relatively far greater quantities of food than their size would indicate. As a result they actually ingest larger amounts of pesticidal chemicals in terms of mg/kg of body weight than larger animals. The intake of insecticides by various forms of wildlife may be by ingestion, inhalation, or absorption, and under some conditions certain species may be subjected simultaneously to all three avenues of exposure. It is obvious that relatively small species moving in, around, and under a vegetative cover are subjected to greater and more prolonged exposure than are larger domestic animals standing well above the contaminated vegetation.

Species vary greatly in their tolerance to specific chemicals. There is also variation in the extent and duration of their exposure to chemical residues. For these reasons any evaluation of adverse effects must take into account the characteristics and habits of the species (susceptible-tolerant; resident-migrant; size; food habits, etc.). Hazard to wildlife, however, is dependent upon many factors in addition to innate toxicity of the material. Among these are type of formulation and site of application, chemical stability of the compound, kind of degradation products, volatility, persistence in the living animal, and frequency and time of application. Aquatic and semi-aquatic environments and in some cases temporary moist conditions resulting from rain increase the hazards to many species of animal life.

It is generally recognized that many aquatic and semi-aquatic forms of life such as fish, aquatic reptiles, amphibians, and numerous arthropods are more susceptible to poisoning by some pesticides than are mammals and birds. There have been numerous cases of fish loss following contamination of streams and lakes by a general aerial application

of an insecticide, or inadvertently by lack of proper care in avoiding areas of water. At times pesticides applied to terrestrial areas have been washed into aquatic habitats and have killed fish and other organisms. Besides these direct effects there are indirect ones such as the reduction in the food supply of fish, birds, and other wildlife.

With DDT as with other chemical pesticides the time and method of application, as well as the influence of manufacturing impurities, wetting agents, solvents, diluents, activators, and other ancillary chemicals are important in relation to hazards to wildlife. Thus, insecticides applied over an aquatic habitat in emulsions are harmful to many species of fish because they mix with water and remain distributed through it. Wettable powders and granules tend to settle to the bottom where they are not readily available except to catfish, suckers, and other bottom feeders. Insecticides in oil solutions float and are hazardous to surface-feeding fish. Also, through wind and wave action, accumulations of insecticides in oil solutions may occur on the leeward side of lakes and ponds at concentrations greater than those originally applied.

These observations are primarily concerned with insecticides because most of the damage to wildlife recorded to date has been from use of such pesticides. Insecticides have, of course, been purposely selected for their toxicity to insects, one of the lower forms of animal life. Accordingly, it is not surprising that most of them show toxicity in varying degrees to other arthropods, especially crustaceans, and to fishes.

Most herbicides, fungicides, and nematocides are relatively less toxic to mammals, birds and fish than are insecticides. There are exceptions, however, to the general rule. Rotenone, an insecticide, is relatively safe for mammals but very toxic to fish. On the other hand, mercury fungicides and arsenical and chlorate herbicides are relatively toxic to mammals.

The paucity of reported damage from fungicides may be attributed in part to the fact that they are less widely used than insecticides and their side-effects are less well known.

Furthermore, they are applied primarily by ground equipment so as to obtain complete coverage of the plants to be protected. (Only two per cent of all aerial applications of pesticides in the United States contain fungicides.) The use of soil disinfectants and fumigants undoubtedly disturbs the microflora and affects soil inhabiting forms of animal life, but apparently these potential disturbances are not severe enough or so well recognized as to attract comment. Likewise, some pheasants, crows, songbirds and squirrels conceivably could be affected by mercury seed treatments.

There is experimental and some field evidence that some pesticides in sufficient amounts affect animal fecundity by upsetting the normal physiological function of the animal. However, practical implications and possible significance of such effects have not been fully evaluated in the field. This represents one of the areas in which additional research is needed.

In view of these many special considerations, it is not surprising that there have been numerous instances where wildlife of various types have been adversely affected by pesticides. Such instances can often be traced to carelessness, accidents, experimentation, or to highly specialized programs such as the eradication of a pest where dosage rates or practices involve anticipatable hazards. With the thousands of tons of pesticides that are used each year in the control of pests, it may be concluded that, to date, the impact on wildlife, although not disastrous, is just cause for concern. Considered from a broad point of view, the known impact of pesticide use on wildlife has been considerably less than that caused by other everyday activities of man; yet it is important and every effort should be made to keep losses to the minimum as the use of chemicals increases. Additional research is needed to evaluate the impact of pesticides on fish and wildlife.

Pesticide Uses Posing Unusual Hazards

A very high percentage of all reports of serious wildlife losses relate to specialized programs which involve considerably less than 10 per cent of the acreage treated with pesticides annually, and which may be only indirectly related or perhaps unrelated to agricultural, forestry, or public health pest-control practices.

When eradication of a pest species is the objective, pesticidal operations may involve the use of dosage rates considerably in excess of those used in other pest-control practices. The program with respect to the imported fire ant in the Southeast is an example. Since this program is aimed at eradication or suppression and containment rather than immediate practical control, the dosage rate of the insecticide used has been high. A review of the accumulated literature on wildlife losses attributable to the use of pesticides seems to indicate clearly that increased dosage rates are a major factor. In such cases it should be the responsibility of the control agencies to keep dosages to the minimum required to obtain desired results. The pest-control agencies are hopeful that two properly spaced applications of an insecticide at a greatly reduced dosage rate now in use will be as effective as one application at the higher and more hazardous rate formerly used in fire-ant control.

High dosage rates produce high initial chemical deposits which, despite rapid dissipation, may for a time expose certain species to residues in the subacute or, under some conditions, even the acute toxicity range. Thus, in many cases significant mortality occurs during the first few days or weeks and then declines to relatively low levels.

In non-cultivated areas, pesticide residues do not readily move downward into the soil but tend to remain at or near the surface, where they stay for a prolonged period. This enhances the hazard for species living in close contact with the soil.

Heavy applications of DDT to control the bark-beetle vectors of the Dutch elm disease, under certain conditions, can be concentrated in earthworms to produce a lethal effect on robins and several other species feeding on the worms as much as a year later. Thus, in intensive control programs involving relatively high dosages of DDT, as in the case of Dutch elm disease control, higher mortality of birds occurs than in the agricultural, forestry, and public health programs. Also, under such conditions nesting populations of certain species such as robins have remained at low levels in subsequent years. In such cases pest-control agencies should and do look for substitute control measures. For example, limited research has shown that methoxychlor, which has shown some promise as a substitute for DDT in control efforts such as those for Dutch elm disease, has a low toxicity to warm-blooded animals but may have an equal or even greater toxicity to certain species of fish.

More than six million acres of mostly range lands in 15 western and midwestern states were treated in 1957 to control grasshoppers and Mormon crickets. Treatment was by a spray and by use of baits—both distributed by airplane. Insecticides used were aldrin, chlordane, dieldrin, heptachlor, and toxaphene. Dosage rates for aerial application have been low but there is no beneficial effect of filtering by higher strata of vegetation, as occurs in forests so treated; consequently the wildlife receives a fuller impact of the spray. The toxicity of these insecticides to game birds and mammals is relatively high and, used in bait form when faulty application occurs, they have been found to kill some birds and small mammals. In marsh areas adjacent to range and crop lands there have been some duck losses.

Areas treated with chlordane for grasshopper control often show some wildlife loss, the type and extent depending on local conditions. The spraying of a lake area in North Dakota with chlordane in oil at the rate of one pound per acre resulted in some losses of ducklings and coots. In grasshopper control, as with other programs, there have been some operational difficulties, resulting in parts of treated areas receiving duplicate applications of insecticides and some water areas being treated.

Wildlife Losses due to Pest Control in Agriculture

Approximately 100 million of the 358 million acres of crop land under cultivation in the United States receive one or more applications of chemical pesticides each year to control or reduce damage from insects, mites, fungi, bacteria, nematodes, and weeds, or to regulate plant growth and development. For this operation, approximately one billion pounds of biologically active compounds are produced annually and formulated into several thousand different mixtures. After blending with various diluents, surfactants, and other types of conditioning agents, they aggregate some three billion pounds.

Pesticides used in agriculture may injure wildlife directly: (1) by contact with wild animals in the fields at the time of pesticide application, (2) by drift or misapplication to water areas and to nearby fence rows and woods occupied by wildlife, or (3) by the washing of chemicals from treated fields to streams and ponds following heavy rainfall. Indirectly, there may be injury by chemical contamination or destruction of wildlife food sources.

In cotton fields which receive unusually heavy applications of pesticides, little damage to wildlife has been reported. Although doves and quail sometimes use such fields in the fall for cover and feed on weed seeds found there, such fields do not constitute attractive habitat for most wildlife species. But occasionally, under certain conditions not clearly defined, pesticide runoff may cause fish kill in streams and ponds.

An increasing percentage of the corn fields of the Midwest are treated with DDT and with other materials for control of corn borers, chinch bugs, grasshoppers, and other insects. These applications are made relatively early in the season and no appreciable damage to pheasant, quail, duck, and other wild fowl that use such fields later in the season has been observed. In the growing of wheat and other cereal grains, insecticides are seldom applied at critical times; consequently there is little or no direct hazard to wildlife.

Definite injury to wildlife has been observed, however, in some agricultural situations involving specialized crops grown in limited areas. Application of insecticides to flooded rice fields in Louisiana has destroyed many fish and wild fowl by direct contact. Heavy treatment of rice seed with insecticides in California, Texas, and Louisiana has resulted in extensive mortality to mammals and wild fowl that visited the fields to feed upon the exposed seed. Repeated applications of spray to apple orchards in Canada and Washington have led to such heavy deposits (12 to 15 pounds per acre) on the ground cover that some pheasants, quail, and other wild fowl and mammals were killed when they came into the orchards to roost or to feed during the fall. A similar effect has been recorded in California pear orchards where the ground cover had been sprayed to control spittle bugs.

From the evidence reviewed on the effect of pesticides used in agriculture, it is concluded that relatively little known loss to wildlife has resulted from the proper application of pesticides to major crops such as cotton, corn, and wheat. Nevertheless, insofar as possible, application of pesticides on the farm and range should be timed and applied in such formulation and dosage as to attain maximum destruction of the pest with minimum residues present during periods of utilization by wildlife. In agricultural practices, as with all control programs, care must be exercised to avoid pollution of streams and ponds, as well as accidental distribution of toxicants to wildlife habitats bordering fields and meadows. Treatments in orchards and rice fields which pose unique hazards are in need of further study.

Pesticide—Wildlife Problems in Forestry

The chlorinated hydrocarbon, DDT, is used more extensively than any other pesticide in combating forest and shade-tree insects. Recognizing the possible effects of DDT on wildlife, the U. S. Department of Agriculture, working cooperatively with the U. S. Department of the Interior, conducted studies of the problem primarily during the period from 1945 to 1950. Productive as this research has been there is still much to be learned regarding direct effects on fish and some of the lower organisms and on members of the food chain of fish, birds, and mammals, as well as effects on reproduction in wildlife species.

The dosage usually recommended for DDT is one pound or less per acre. With single applications at this rate, direct effects on birds, either young or adult, are negligible, but indirect effects due to reduction of insect populations, an important food supply for birds, are likely to occur. For example, birds that feed on the wing sometimes leave a treated area in which the insect population has been reduced. In general, little direct harm to adult birds has been noted in forest habitats from single aerial treatments below two pounds of DDT per acre. Above this, populations of birds, and especially young birds, are affected.

Forest areas treated with DDT usually are extensive in character and may include many lakes and streams. For this

reason it is essential to evaluate the impact of forest insect-control programs on aquatic forms of wildlife. Single applications of one pound per acre, the usual recommended rate, have killed some frogs and water snakes. Many insects, spiders, and such crustaceans as crayfishes, crabs, and shrimps are readily killed by this chemical, often by amounts as low as two ounces per acre. Of the vertebrates, fish are usually the most sensitive to DDT. There have been instances where individuals of some fish species in exposed situations have been killed following single treatments of 0.2 pound per acre of this insecticide in oil.

Serious die-off of fish occurred in the Miramichi River drainage in New Brunswick, Canada, following scheduled applications of 0.5 pound of DDT per acre to control spruce budworm. Here, up to 91 per cent of the young Atlantic salmon of three age groups and some adults were killed, presumably because of operational difficulties which resulted in far higher rates of treatment than were intended. Young salmon, however, are more sensitive to DDT poisoning than the young of many other species of fish.

Another heavy loss of fish, including trout, whitefish, and suckers, took place several months after application of DDT at one pound per acre in a spruce-budworm control program in Montana. In this instance, the relationship of spraying to fish mortality was suspected since there was no known reason. Loss of food organisms may have been serious enough to cause the death of the fish. In another case, populations of brook trout and other fishes were reduced considerably in 1958 and 1959 following application of DDT at one pound per acre to control spruce budworm in Aroostook County, Maine. The most serious effect was on young-of-the-year trout and on trout food organisms.

Wildlife losses associated with the gypsy moth and other forest insect-control programs have been minimal and confined largely to a few fish and other aquatic forms. This is in general accord with research findings which have shown that DDT, applied at the rate of one pound per acre, poses no serious hazards to wildlife except fish and some other aquatic life where the threshold may range between 0.1 and 0.5 pound per acre, depending on a number of factors such as the depth, turbidity, chemistry, and the temperature of the water. Instances of mortality are in part the result of treatment of local water areas. It seems essential, therefore, that great care be exercised to make sure that safe rates are not exceeded and that lakes and streams are not unintentionally treated.

Pesticides are applied to forests more for the control of insects than for any other reason. In recent years, however, there has been an increasing use of phytocides such as 2, 4, 5-T and 2, 4-D to control hardwoods of low economic value. Here the objective is usually the replacement of low-value hardwoods with high-value pines. The chemicals are applied both on the tree trunks and on the foliage. The treatments appear to have little direct effect on terrestrial wildlife. But squirrels, deer, turkey, and other forest animals are affected through loss of mast or forage. After the first year, the forage recuperates, but not the crowns of the trees. When two applications are made 12 months apart, a greater percentage of hardwoods are crown-killed and the more sensitive under-story shrubs are reduced for several years.

Use of Pesticides in Public Health Programs

The quantity of pesticides used for mosquito and fly control in the United States is not great compared to the total used for all purposes, yet in the aggregate large amounts are used. In view of the low dosage requirement and the operational controls under which pesticides are employed for public health purposes, adverse effects on wildlife are minimized. Enforcement of operational controls, however, presents some difficulty in the more remote, non-urban areas.

Mosquito control, the major category of insect control for public health purposes, is practiced almost entirely by public agencies—Federal, State, County, or Municipal. Most of these operations are directed or influenced by Federal or State agencies which prescribe standards and supervise methods.

The application of pesticides for the control of mosquitoes is usually limited to areas in and around centers of population. Areas involved are in many cases normally dry, but become suitable breeding habitat for mosquitoes when wet

with high tides, floods, or rainfall. Permanently wet areas often are controlled by water-management methods which keep mosquitoes in check. Some water courses polluted by domestic or industrial wastes are major sources of mosquitoes, yet unproductive to wildlife. On the other hand, many treated areas, even those close to cities and their suburbs, contain a wealth of wildlife. In such areas any losses from whatever cause may be readily seen by the public, and the reaction is frequently vehement.

In more remote breeding areas, such as the open salt marshes or extensive fresh-water marshes, pesticides are seldom used except to control adult mosquitoes, and then at low rates. In some cases, applications to destroy larvae are made to extensive wet areas near population centers. When applied as recommended, these treatments have caused little known damage to birds and mammals, but due to application problems have killed varying numbers of crabs, shrimp, and lower forms of aquatic life with some loss to fish and amphibians. In the extensive irrigated areas in the West, pesticide applications have rarely resulted in any extensive damage to wildlife.

Due to concern that there might be damage to wildlife, the U. S. Public Health Service has since 1944 conducted an extensive series of laboratory and field investigations on pesticides for mosquito control. Similar research has been carried on by the U. S. Department of Agriculture and many State Agricultural Experiment Stations. In general, this work has indicated that damage to sensitive crustaceans and other invertebrates in open salt marshes is caused by applications of DDT in oil at a dosage of above 0.2 pound per acre. Little is known of the long-time cumulative effects. The use of pesticides in mosquito and fly-control has resulted in little known damage to wildlife when application was in accordance with recommendations. Even though it may be exceptional, there is one instance where serious damage to wildlife has been documented. A gnat-control program involving the use of DDD at Clear Lake, California, resulted in significant loss of fish-eating birds.

It should be noted that a national committee is now at work attempting to coordinate the efforts of mosquito control and fish and wildlife management. It is commonly agreed that extensive research is of immediate importance to determine whether or not pesticide usage in the mosquito-control field might contribute to unknown damage to fish, wildlife, or organisms related to their food supply.

It is recognized by those responsible for the planning and execution of mosquito and fly-control programs that damage to private property and to wildlife must be avoided. To this end, governmental agencies at various levels and some professional societies are working together, through committees, to search out areas of possible wildlife damage and to establish safe procedures.

Control of Unwanted Fish and Wildlife by Pesticides

Rodenticides of various types are used for controlling rodents in or about buildings, in fields, on range lands, and in forests. In the open, wild animals other than those requiring control may be subjected to treatment unless the specificity of the pesticide, season of the year, placement of the chemical, or other factors rule out such hazards. Most rodenticides are applied on a spot-by-spot basis rather than over broad areas, as is the case with insecticidal sprays. Also, rodenticides usually are applied to a limited quantity of the rodents' preferred food as bait. As a result, rodenticidal baits have more specificity for designated rodents than do aerial applications of insecticides for insect control. Moreover, the use of baits is further enhanced by controllable techniques of placement.

Anticoagulants are available commercially as rodenticides, either as chemicals or in prepared ready-to-use baits. To be effective, these chemicals must be taken daily over a period of several days. Rodents, apparently not associating the cumulative effect of internal bleeding with their food supply, return to feed on treated baits again and again. Hazards to other animals from single accidental feedings are minimal.

Compound 1080 (sodium fluoroacetate) is sometimes used in the control of domestic rodents, field rodents, and carnivores such as the coyote. Its high toxicity requires that

it be used with utmost caution and that it be handled only by qualified personnel. Minimal hazard depends on proper placement and inspection of bait stations. Properly applied grain baits put out for ground squirrels, although toxic to birds and deer, have resulted in relatively little loss to valuable wildlife species. Magpies sometimes take meat baits, yet their populations do not seem severely affected in treated areas.

Zinc phosphide is used widely for field-rodent control. Most incidents involving the poisoning of birds following use of this material have been found, upon investigation, to be the result of careless application.

The use of endrin in orchard mouse control continues to increase. Despite the high toxicity of the substance, no comprehensive studies have been conducted on its effect on orchard-inhabiting wildlife.

Rotenone and toxaphene are used to control unwanted populations of fish. Other aquatic forms, such as tadpoles, water snakes, and fish-food organisms may be killed in such operations. The use of toxaphene has caused some loss to waterfowl.

The problem of controlling the sea lamprey in the upper Great Lakes has received considerable attention in recent years. After extensive screening tests, lamprey larvicides have been developed which appear to be quite specific and effective in the control of this pest. Better methods are needed for the control of drilling snails, starfish, and other injurious species.

SUMMARY AND CONCLUSIONS

Destructive pests make the production of food, fiber, and timber needed for man's survival difficult while still other organisms threaten his health or comfort.

Through years of research, the use of chemical pesticides has evolved as one of the several pest-control practices essential to the adequate production of farm crops, forests, and livestock, and in the control of pests detrimental to man's health, comfort, and general welfare. On the other hand, there have been instances where pesticides under certain conditions of use have brought about a reduction in numbers of desirable forms of life.

Because of these conflicts of interest and the importance of the problem, an interdisciplinary committee under the auspices of the National Academy of Sciences—National Research Council has been established to evaluate pest-control and wildlife relationships.

There is broad public interest in wildlife, representing individuals from all walks of life. Wildlife ownership is vested in the State, despite the fact that a high percentage of the birds and mammals are now produced on privately owned land, largely agricultural in character. Although the Indians and early settlers relied upon wildlife to meet a substantial portion of their essential food requirements, today's emphasis, excluding commercial fisheries, is placed largely upon recreational and aesthetic values. Because of the increase in population, individual wealth, and leisure time, the number of people interested in the conservation of wildlife is increasing steadily.

While biologists generally regard the use of pesticides as an emergency measure, it seems obvious that their use will continue until such time as suitable substitutes can be developed. Efforts to hold pests in check through biological, cultural, and ecological measures have been and are being made, but such efforts alone are not enough. Increases in the population, modern trends in automation, and rising labor costs which demand increased efficiency preclude the continuing practice of sharing crops with pests.

Pesticide use imposes certain hazards on wildlife not shared by man and his domestic animals, which are afforded considerable protection by the observance of specified intervals between pesticide application, the occupation of treated areas, and the consumption of treated produce. Wildlife receives no such protection.

Sweeping generalizations must be avoided in drawing conclusions regarding the danger from use of pesticidal chemicals. Pesticides are used in many ways, for many purposes, and in many situations. Thus, as would be expected, many valuable uses for pesticides are practically devoid of any pronounced hazard to wildlife, while certain other practices pose very real hazards that at times have caused serious damage.

Four general conclusions stand out: (1) Because they were developed as toxicants for certain species of animals, insecticides and rodenticides tend to pose greater hazards to wildlife than do other classes of pesticides; (2) although wildlife may at times be adversely affected by the normal use of pesticides, it is the misuse of those pesticides highly toxic to specific plants or animals that poses the greatest hazards to wildlife; (3) greater damage to wildlife may occur in eradication and other programs requiring pesticide dosage application rates considerably higher than those used in the routine agricultural, forest, and public health pest-control programs; and (4) heavy losses in aquatic life, especially fish, often can be traced to lack of proper safeguards to prevent unintended spread of the chemical over water areas.

In order to hold wildlife losses to a minimum, scientists representing all of the disciplines involved should unite forces in an all-out effort to identify and evaluate specific hazards and to develop corrective measures for objectionable practices.