PEST CONTROL AND
WILDLIFE RELATIONSHIPS

PART II

Policy and Procedures for Pest Control

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A Report by the
Subcommittee on
Policy and Procedures for Pest Control,
of the Committee on
Pest Control and Wildlife Relationships

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FOREWORD

This is the second 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 (Part II) was assembled, evaluated, and compiled by the Subcommittee on Policy and Procedures for Pest Control. Part I is a Report on Evaluation of Pesticide and Wildlife Problems, and Part III a Report on Research: Past, Present, Future Needs.

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 which appears on the cover was generously furnished by the State of Maine Forest Service—Joel W. Marsh, Photographer. The planes spray in pairs, each emitting a 350-foot swath of fine mist and applies one gallon per acre (one pound of DDT).

CONTENTS

INTRODUCTION

The purpose of this publication is to outline policies and procedures designed to attain effective pest control with minimum damage to wildlife.

While covering the basic procedures that apply to all forms of pest control, the material is directed chiefly to large-scale operations involving the use of chemicals. Primarily, the report concerns itself with insecticides. Herbicides and fungicides, despite their importance in the control of pest plants and diseases, are less toxic than insecticides, and current methods of application cause little or no direct damage to fish and wildlife.

Unfortunately, pest control operations employing insecticides frequently create wildlife problems of varying gravity. The very fact that many programs cover extensive areas and affect a number of wildlife habitats carries with it the possibility of heavy and widespread damage.

Chemical pesticides by their very nature involve hazards, for few of them are specifically selective in their action. Under certain conditions some may kill a certain proportion of beneficial organisms; some are known to affect wildlife adversely.

Pesticide use, of course, is only one of the many hazards that beset wildlife. Highways, urban developments, water pollution, dams, drainage of wet lands, hunting, fire, and many other factors, adversely affect them.

For whatever types of control the future may evolve, there can be no doubt that today chemical control performs indispensable services to agriculture, to forest crops, and to public health. Accepting, then, the present necessity for their use in the national economy, the problem becomes one of adopting procedures designed for more effective control and greater safety to wildlife.

GROWTH OF CHEMICAL PESTICIDES

Pest control in the United States has been practiced for well over 100 years. By the early 1800's, pesticides had already found limited use in agriculture, but for many decades biological and cultural methods dominated all other control techniques, since chemicals—insecticides, fungicides, etc.—were relatively ineffective and so costly their use could be justified only for crops of highest values.

The use of chemical pesticides was of minor importance until well into the later half of the 19th century. About that time Paris green was developed as a control for the Colorado potato beetle. The use of various pesticides including arsenicals, mercuric and copper compounds, sulphur, cryolite, pyrethrum, nicotine, and quantities of other lesser products increased gradually, so that by 1948 the total reached some 250 thousand tons plus millions of gallons of petroleum oils, other oils, and similar products.

With the advent of DDT in 1945, followed in quick succession by other chlorinated hydrocarbons and organic phosphates, many of the older materials have been replaced. These newer compounds are effective at much lower rates of application resulting in an increase of several fold in acreage treated with very little change in the actual tonnage of primary insecticidal chemicals produced. The use of herbicides has increased many fold both in tonnage and acreage treated. At the same time, due to reduced costs and improved methods of application, it is now considered practical to use pesticides to protect general farm and forest crops as well as to control pests injurious to public health.

Since World War II, the production of pesticides in the United States, including herbicides, fungicides and insecticides, has reached a total of approximately one billion pounds annually.

IMPORTANCE OF CONTROL PROGRAMS

The importance of pest control to our national economy would be difficult to exaggerate, for in spite of chemical and all other methods of control, losses through pest attack are

staggering. The actual amount of these losses is unknown, but in 1954 the Department of Agriculture estimated the annual agricultural crop loss from plant diseases at 2.8 billion dollars, and from insects at two billion dollars. More definitive assessments made in 1959 indicate that these figures may be conservative and that current losses are considerably greater. In forested areas insect damage is several times that wrought by fire. In 1952 the Forest Service estimated that in addition to growth losses of over 21 billion board feet, forest insects annually destroyed more than seven billion board feet of timber valued at over one hundred million dollars.

For the prevention of illness and the protection of recreation and land values the total cost of controlling mosquitoes and other arthropods amounts to many millions of dollars each year. The States of Florida and California alone are now spending a combined total of over ten million dollars annually for this purpose.

Pest-control programs are based upon the assumption that benefits will exceed costs. Those carried out by farmers and homeowners generally are for the protection of agricultural crops, livestock, or other commodities produced for personal income or enjoyment. Publicly supported pest-control programs, administered and financed by Federal, State, or local agencies of government, are conducted at the request of one or more segments of the community whose health or economic welfare is affected by a pest which cannot be adequately controlled by individual effort. In either situation, the private citizen and the public officials responsible for these activities must face decisions as to whether control is feasible, economically justified and of minimum hazard to other values.

The private citizen, be he farmer or homeowner confronted by a pest control problem on his farm or flower or vegetable garden, makes his own decisions as to what steps to take. If he elects to use a pesticide he should realize that he is dealing with highly toxic materials and has a moral responsibility to follow carefully the directions on the pesticide label and to apply no more and no less than directed. If he does this he may expect to obtain satisfactory results and produce no undesirable effects.

Public responsibility for safe and effective pest control cannot be the sole responsibility of public officials or agencies of government, but must be shared by the entire community. The control operators themselves must bear certain responsibilities, especially in large-scale applications of chemical pesticides. For here errors of judgment, carelessness, or inexperience can cause widespread damage. The resulting destruction of values and the public condemnation that follows may readily create a hostile atmosphere toward all pest control.

To avoid such misadventures, adequate training is an indispensable safeguard for all those engaged in actual control operations, for regardless of the type of program, there is no substitute for well-trained, experienced and responsible personnel. Too often inexperienced or ill-equipped operators, having made unrealistically low bids, will omit necessary precautions in order to cut expenses. Lack of experience, poor equipment, and inadequate supervision, are sources not only of poor control and disastrous side effects, but constitute a very grave danger to the operators themselves.

Unfortunately some states still have failed to require licensing of control operators. Neither have they established minimum standards for equipment and proficiency of companies and individuals engaged in the large-scale application of chemical pesticides.

One of the more difficult problems frequently confronting administrators of pest-control programs is the inadequacy of finances to carry out effective operations and provide proper safeguards. Except in emergencies pest control should not even be attempted unless there is assurance that it can be planned and properly executed with the funds available.

Large-scale control programs present the greatest difficulties in planning, procedure and administration, and it is to the problems likely to be met in operations of this size that the report is primarily directed. Greater emphasis has been placed upon insecticide use since it is the insecticide that is more likely to cause wildlife losses. The

report makes no attempt to cover wildlife control programs, i.e., predators, jack rabbits, lamprey eels, etc. Neither does it deal with animal diseases caused by bacteria, viruses and protozoa.

RESEARCH NEEDS

Many agencies seeking to diminish the serious and mounting losses from pests have developed impressive research programs, and accumulated extensive basic knowledge of pest control by cultural, biological and ecological means, and more recently by chemicals. But in the broad interrelationship between pest control and wildlife survival there still exist many unanswered questions and unsolved problems.

For example, research has not yet fully traced the effects of chemical pesticides on wildlife or on plant life or on the soil. Knowledge of the long-term effects of chemicals on the environment is still fragmentary; nor has research developed satisfactory techniques for measuring the ecological effects of chemicals already in use. Yet despite the incompleteness of reliable information regarding the long and even the short-term effects of pesticides on wildlife or on the environment, there are time-tested procedures that if followed will go far toward minimizing the dangers. Meanwhile much needed information can be obtained by cooperation between research and control agencies.

WILDLIFE VALUES

Abundant leisure and expanding urbanization have brought about a heightened awareness of the diverse values that wildlife contributes to the American pattern of living. Those values are often difficult to define, and more difficult still to assess in dollar terms, but they are undeniably real and becoming increasingly precious. Wherever they are involved they must be weighed together with other values in arriving at pest-control decisions.

In most large-scale control programs one is dealing basically with a complex of values. One must be aware of what these values consist in, for failure to assess wildlife values fully can seriously impair the validity of action decisions in pest control. It is important, then, in the early

steps of planning, to seek out all groups and interests likely to be affected, and wherever possible to strive for joint decisions. One must face the fact, too, that for benefits gained there may be benefits lost, and that in protecting what seem to be the higher values there is still much to be learned about the long-range effects of chemical control measures on the total environment.

To minimize the dangers to wildlife and the wildlife habitat one cannot afford to ignore the guidance of time-tested procedures and established precautions. A major objective of this report is to bring these procedures and precautions to the attention of the control operator.

Intended primarily to be of direct practical use to the operator, the report first outlines the general principles that apply to all forms of large-scale pest control. It then describes in detail the procedures of control programs. Here, since control methods differ with the type of pest, a procedural program is given for each of three major groups—Agricultural Pests, Forest Pests, Pests Injurious to Public Health.

This treatment necessarily results in some duplication, but has the practical advantage of providing the operator in each group with a complete step-by-step program for the type of pest he seeks to control.

LEGAL AUTHORITY

In all phases of pest control precautions should be taken to assure legal authority adequate to cover all necessary action.

No one piece of overall Federal legislation exists that provides for every aspect of the control of agricultural and related pests. The Department of Agriculture Organic Act of 1944, as amended (7 U.S.C. 148-148e), the Plant Quarantine Act of 1912, as amended (7 U.S.C. 151-167), and the Joint Resolution approved May 9, 1938 (7 U.S.C. 1848-148e), pertaining to emergency outbreaks of insect pests, contain the greater part of the basic Federal authority required for cooperation with the states in the control, eradication, or confinement of agricultural plant pests. Other legislation such as the Federal Plant Pest Act of 1957 (7 U.S.C. 150aa-150jj), the Federal Insecticide, Fungicide, and Rodenticide Act of 1947 (7 U.S.C. 135-135k), and others pertain to special problems in the plant-protection field that through the years have required specific legislation. The states have enacted similar laws which authorize them either individually or in cooperation with the Federal Government to take action to abate serious pest problems occurring within their jurisdictions.

In the case of forest pests effective control requires action by both public forestry agencies and private forest land owners. The Forest Pest Control Act of June 25, 1947, (16 U.S.C.: 594-1—594-5) recognizes the national concern and Federal acceptance of shared responsibility in the control of forest pests on Federal, State, and private lands. State laws vary from state to state but in general provide the authority necessary to complement Federal legislation.

Public Health Service activities relating to control of animal reservoirs or vectors of human diseases are conducted through Federal-State cooperative efforts. Legal

authority for such activities is contained, in a broad sense, in the Public Health Service Act of 1944, as amended (Public Law 410, 78th Congress). In many vector-control programs including those which are organized for public health disaster relief, the Federal personnel at the local operational level may be under supervision or close guidance of State personnel, in which case they become "loaned servants."

State health departments are uniformly clothed with legal authority to suppress communicable diseases, and about one-half of the States have local "district" organizations with legal authority to control or suppress various pests, particularly mosquitoes. In the field of public health, courts have rather generally upheld the right of organized boards of health to suppress nuisances which may result in health hazards. One or more courts have expressed the opinion that the public health power "is the most important of police powers and may be exercised whether conferred by express grant or otherwise."

The Public Health Service Act also provides basic authority in Federal quarantine and inspection activities relating to control of communicable diseases. By this Act the Surgeon General is authorized to inspect, fumigate, disinfect, sanitate, exterminate pests, destroy animals or articles found to be infested or contaminated, and employ other measures in preventing the introduction, transmission, or spread of communicable diseases.

Certain agencies of the Federal Government, including the Public Health Service, may provide assistance to States during disasters and epidemics under provisions of the Federal Disaster Act of 1950 (Public Law 875, 81st Congress). A prerequisite to such assistance is a Presidential order declaring a disaster or epidemic and specifying the affected area.

Since pesticides and the other regulated chemicals are recognized as essential to food production, the Federal Food, Drug and Cosmetic Act, as amended, provides machinery for establishing non-hazardous tolerances for these chemicals, and for enforcing compliance.

The introduction of new pesticides demands adequate program planning, care in actual use, and field evaluation of long and short-term results. Before any pesticide definable as an economic poison or a regulated chemical can be marketed in interstate commerce, it must be properly labeled and registered with the Pesticides Regulation Branch of the U.S. Department of Agriculture under the provisions of the Federal Insecticide, Fungicide and Rodenticide Act as amended. Under this Act, any new or unfamiliar uses of pesticides or other regulated chemicals must be supported by substantial evidence as to the practical performance values of the product. There must also be evidence that the product when used as directed will not be injurious to persons, useful plants, or beneficial animals that may be intentionally or accidentally exposed, either at the time of treatment or thereafter. Compliance with Federal regulations often means that five years and at least a million dollars are required of the chemical manufacturer to place a new pesticide or other regulated chemical on the market with a sufficient number of residue tolerances and usages on food and feed crops to permit the product to be marketable.

The possible effect of widespread commercial usage of the chemical on fish and wildlife is reviewed by the Pesticides Regulation Branch. Additional data may be requested on these matters, and consultations arranged with the Fish and Wildlife Service, Department of the Interior, and such other Government agencies as may be interested. Label warnings regarding the prevention of adverse effects, or warnings as to their possibility, are sometimes necessary. Any labeling on the package of the pesticide or other regulated chemical accompanying these products or referred to in the literature accompanying these products must be registered with the Pesticides Regulation Branch. If any hazards accompany the use of these products, necessary warnings and precautions must be given on the label. When important public health questions are involved, or when usage in or around human habitation is under study, it is the practice of the Pesticides Regulation Branch to consult with the Public Health Service as to the adequacy of the proposed directions and precautions.

Legal restrictions on the labeling directions for the use of pesticides and certain other regulated chemicals are

generally applicable under the Federal Insecticide, Fungicide and Rodenticide Act as amended by the Nematocide, Defoliant, Desiccant, Plant Growth Regulator Amendment of 1959.

Broadly speaking the existing body of legislative authority, Federal and State, has been designed to perform a dual function. It authorizes the use of approved chemicals in the interest of protecting health and producing needed food and fibers, while defining limitations of such use and establishing practices designed to minimize possible detrimental effects.

Special conditions together with rapidly developing materials and techniques may make further legislation desirable. It is suggested that proposals for any future legislation be carefully scrutinized to assure authorization adequate to meet the demands of control operations and to provide all necessary safeguards.

PUBLIC RELATIONS

In planning control programs that involve the use of chemical pesticides, a vital factor to consider is the reaction of the public. This is true whether the program is designed to protect forest values, agricultural values, or health. It is especially true of large-scale programs. Here public acceptance of the need for control and support of the program itself are indispensable, for the attitude of the public can mean all the difference between active support and violent opposition.

The average layman is neither forester, entomologist, nor wildlife manager, but he wants to know—he has a right to know—what is going on, and any withholding of information arouses his suspicion and antagonism. So, with every pesticide program he should be given the information he deserves. He should know about the program before it starts. He should understand its purpose, techniques, difficulties, and expected results. If spraying is involved, it is essential that he know why it is necessary, why and how it will affect him, his economic security, or food supply. Throughout the progress of the operation he should be kept abreast of what is happening, and at the end he should be frankly informed of results—how completely the objectives were attained, what if any were the undesirable effects and when they may be expected to be corrected.

Unfortunately, public relations is probably given less thought in planning control programs than any other single factor. Too often it is looked on as an irksome necessity, yet no one factor in the entire control program carries a greater potential for good or evil, since ordinarily the public will support a program it understands, and vigorously oppose the same program if its purposes and methods are not understood.

Initial support is best gained by public participation in the early deliberations before control decisions have been

made. This should be followed by a thorough and candid information program, both during the planning stages and throughout the actual control period. Final decisions as to the conduct of the control program must necessarily rest with the agencies responsible for the protection of the threatened resource, but every effort should be made to forestall conflicts, and when they do occur complaints should be handled promptly and reasonably.

It is especially important to keep the public fully informed of the need for control, the possible hazards, and the balance of values. The public should be made aware that for the values saved there may be some values lost, and that the justification lies in preserving the higher values. Wherever there is a possibility of wildlife mortality, this should be frankly discussed in relation to overall benefits, and a clear idea given as to the possible extent of damage and the expected lapse of time before wildlife populations may return to normal.

Many effective means of communication exist for bringing this information to the public—news items, press conferences, radio, television, public gatherings, and hearings. All interested groups should be consulted and kept informed. Educational leaflets are especially useful if well prepared and wisely distributed. Every available technique should be used.

In the field of public health especially, the public aspects of any control program demand careful advance planning. During outbreaks of disease fear frequently develops, and ill-conceived news reports or information withheld can easily change fear to hysteria. All this may be avoided if the authorities prepare factual news releases giving the exact status of disease outbreaks and what is being done to combat them. A well-informed public can do much in actually carrying out health programs; for example, in mosquito control individuals may learn to adopt measures applicable to their own property.

To sum up: Administrators of control programs cannot safely neglect their responsibilities and opportunities in planning for a well-informed public. Almost invariably when

the facts are known public support follows, and may have potentialities far beyond the approval of any single program. Regardless of techniques employed, the information should be straightforward and objective—certainly not defensive. The carefully planned use of chemical pesticides needs no apology. For nearly a century pesticides have helped safeguard our economy and maintain our way of life at its present high level. To broaden the knowledge of their protective role is an essential function of public relations.

TECHNIQUES OF CONTROL

Preliminary to any pest-control program is an analysis to determine whether an actual problem exists, whether the public will benefit materially from control efforts, whether detrimental side effects may be expected, and if so how they can be kept to a minimum. In short, a problem analysis provides the fundamental data upon which control decisions are based.

Control decisions and the resultant action vary with the objectives of ownership, and primary responsibility for pest-control rests normally with the land owners involved. In the case of most agricultural pests it is considered the responsibility of the individual grower to take whatever steps are necessary to protect his crops. However, where introduced plant or animal pests are concerned, organized cooperative effort may be required. Thus Federal and State quarantines are often necessary to prevent an introduced pest from spreading into areas where it would seriously interfere with the production of agricultural commodities. Occasionally native pests such as grasshoppers on low-unit-value range land reach explosive numbers and cannot be handled by individual action. These situations require the intervention of local, State, and Federal governments.

State and Federal pest-control laws often define responsibility in pest control, and authorize the expenditure of public funds to protect public interests. Forest-pest projects usually cover many ownerships, and responsibility for the program must be jointly determined. Often, too, the benefits following the control of forest pests involve an entire timber type or other large forest area, and so broaden the responsibility far beyond that of the actual owner of the infested timber.

A proven control procedure is a prerequisite to control action. Proof of its feasibility comes through research

and operational testing prior to undertaking large-scale programs. Until such proof is established, the hands of management are tied. For example, not until the advent of aerial spraying with DDT as a practical procedure could effective measures be taken to combat extensive outbreaks of forest defoliators. Similarly, the concept of malaria eradication from the world was held impractical before the discovery that residual applications of DDT retained their lethal action against Anopheles mosquitoes for long periods. Residual insecticides have also made it possible to permit more effective control and eradication of Aedes aegypti and have enhanced the control of other arthropod disease vectors.

The procedures for identifying pest problems, evaluating the need for control, and actual control measures, vary widely with the kind of pest and damage caused. Because of these fundamental differences the material that follows has been divided into three broad fields—agriculture, forest, and public health.

I. AGRICULTURAL PESTS

A. Problem Analysis

It has been estimated that at least 3,000 insect species are destructive crop pests throughout North America, and the inclusion of plant diseases, nematodes, and weeds would increase this several fold.

Agricultural pests cause losses in many ways. Occasionally they destroy crops outright, but more often they reduce yields and quality. The great majority require annual control in order to produce a marketable product, and treatments to prevent damage tend to become routine procedures adjusted to the pest, crop and local conditions, although at times pests may become abnormally abundant and require additional measures. Most agricultural pests permit effective suppressive action by individual farmers and growers, but some, like grasshoppers, occur periodically over large areas and require the cooperative action of many owners coordinated by State and Federal agencies. All these considerations influence the amount and nature of the control effort.

Nearly half of our common insect pests were introduced from foreign countries. The diversity of climate and the variety of agricultural crops grown in the United States provide exceptionally favorable environments for many of these foreign invaders and when a new plant pest, whether it be insect, plant disease, nematode, or weed, becomes established here, it is rarely accompanied by natural enemies which may help keep it under control in its native land.

In general, there are three types of agricultural pests requiring action, (1) native pests which, in spite of natural enemies, cause endemic or epidemic damage to crops, (2) introduced pests that have become widely distributed and behave like those of native origin, and (3) introduced pests occupying only a part of their potential ecological range and susceptible of being eliminated or denied further spread into additional major agricultural areas.

1. Determination of the Problem

The need for pest control in agriculture is usually obvious to growers wishing to market a quality crop. Annual depredations of the cotton boll weevil, Mexican bean beetle, Colorado potato beetle, codling moth, as well as many destructive plant diseases are examples of pests which create problems year after year. With serious introduced pests that have not been permitted to disperse throughout their host ranges, such as the golden nematode of potato, witchweed of corn, pink bollworm of cotton, the white-fringed beetle, and others, the need for control and regulatory action is clear. From time to time research workers develop new means of suppressing other less obvious but often equally serious pests which permit further increases in crop yield or quality. These control measures are often eagerly adopted by producers in order to compete in the highly competitive agricultural market.

The countrywide cooperative survey and detection program of the U.S. Department of Agriculture which operates in conjunction with State Departments of Agriculture, Experiment Stations, county agents, industry, and others, provides information on the current status of insect pests. National survey information is released each week and draws

attention to areas with actual or potential pest problems. This service provides both growers and industry with the information they need concerning many agricultural pests throughout the United States.

For a number of epidemic pests, such as grasshoppers, more detailed surveys provide information on the exact status and probable limits of the impending outbreak areas. While grasshoppers in croplands are regarded as a grower's individual problem, provision is made to cooperatively control those occurring in the vast low-value rangeland areas in the West where private and public lands are interspersed.

2. Biological Evaluation

Biological evaluations are limited to crop pests suspected of requiring control action. Two broad categories are of concern, (1) introduced pests, and (2) native pests, or those of foreign origin which through the passage of time now behave as natives.

a. Introduced Pests. In determining the course to take with pests of foreign origin that may be curbed by governmental action, many factors must be considered. Following detection, the multiple judgment of State and Federal research agencies, and often of industry, must be obtained to determine if the pest is capable of inflicting severe crop damage. Determinations must be made as to its biology in the new environment, the commodities subject to attack, and available safe methods of control. In considering a regulatory or eradication effort, information with respect to detection of low population densities, means of dissemination over long distances, and possible action to interrupt this spread with the least disruption of orderly commodity movement is important. The probable cost to the States and Federal Government of confinement or possible eradication must be compared to the estimated losses and annual costs of control that might accrue if the pest is permitted to spread throughout its ecological range.

b. Native Pests. For native pests which are normally controlled by individuals, it is important that information be

available with respect to abundance potentials, when and where control may be necessary, and the availability of safe methods of suppression. This information is usually provided by the Department of Agriculture, State Experiment Stations, the Extension Service, and Agricultural Colleges.

3. Available Methods of Control

In agricultural pest control three courses of action are available: (1) quarantine, (2) eradication, and (3) suppression.

a. Quarantine. The current system of foreign plant quarantines has been quite successful in excluding many foreign agricultural pests. Despite this protection, however, some serious pests have become established, and these require evaluation and possible action. Following a determination that a new invader is likely to cause serious economic crop losses if permitted to spread through channels of trade, it may be necessary to invoke State or Federal plant quarantines which if enforced will prevent or retard its spread. But regulatory procedures are often made difficult by the fact that many plant pests are carried over long distances by means which may not be closely associated with host plants. For example, the gypsy moth can be transported on quarry stones, junk, and other articles; the Japanese beetle often hitchhikes on aircraft.

b. Eradication. Because of the tremendous losses to agriculture many of these introduced pests can inflict, it is usually desirable to take regulatory action to confine them within the smallest area possible and, if safe effective means are at hand, to eradicate them. In the long run, eradication, whenever possible, may be desirable since it eliminates future damage and annual costs of control.

c. Suppression. Here four types of control measures are available: (1) cultural, (2) biological, (3) chemical, and (4) integrated.

(1) Cultural control, properly directed may contribute greatly to man's attack on agricultural pests. To be effective, however, this

type of procedure must usually be a community undertaking.

One form of cultural control is the development of plants resistant to the invasions of certain pests. Thus, resistant varieties of alfalfa withstand invasions of the spotted alfalfa aphid, and resistant varieties of wheat reduce the depredations of a number of races of stem rust. These measures, however, only remain effective until new strains of the pest evolve which will reproduce normally on previously resistant host varieties. Other examples of cultural control include optimum planting dates, as for wheat in areas where the Hessian fly occurs.

Crop rotation, quality seed of pest resistant strains, proper soil preparation, adequate fertilizers, are among the practices that assist in pest control, and good farming has long demonstrated that cultural practices can do much to keep some pests to a minimum. But while many problems can be helped by these means, they can not be considered cure-alls in coping with the wide variety of agricultural pests.

(2) Biological control, using insect parasites, predators, and diseases, provides a long-term approach designed to assist nature in keeping pest populations at low levels. The importation and colonization of insect parasites and predators over many years has helped to hold many introduced pests in balance. In California the mass propagation of insect parasites has saved the citrus industry millions of dollars in its battle against scale insects. On the other hand, many more costly attempts involving other pests have been fruitless. For many years organized efforts have been under way to introduce parasites and predators from abroad to combat high populations of such insects as the European corn borer and Japanese beetle.

The mass production of microbiological diseases, such as the milky disease of Japanese beetles and European chafer, has been quite effective in reducing high populations of these insects. But milky disease is of little value in the control of low populations, and has no place in the eradication of incipient infestations. The use of diseases to combat agricultural pests is increasing in importance. In general, however, biological control, whether produced by parasites, predators, or diseases, can be expected to result only in the reduction of pest populations in a cyclical pattern. Years of low populations are followed by a progressive buildup to a new peak which in turn is followed by a general population reduction. Much remains to be done to work out satisfactory methods of employing biological control measures as a solution to the plant pest problems.

(3) Chemical. Many effective, safe, low-cost chemicals are available to farmers to combat practically every damaging pest attacking the wide variety of food, feed and fiber crops grown in this country. Some are highly specific; others may control a wide variety of pests, and the choice of material must often be determined by the complex of pests to be controlled. Chemical control is usually not an annual necessity, although cotton, most vegetables, and practically all fruits must be sprayed year after year as a routine farming practice. Other groups may require chemicals only as fluctuations in pest populations rise to damaging proportions. Repeated sprayings may constitute a danger to wildlife, and it is important that care be taken to select the proper chemical, formulated in proper form, and applied at the proper time in order that the crop be protected and undesirable residues avoided. In many instances application techniques have been standardized to the point where they are essentially routine for any crop grown extensively for market.

Chemical control presents two principal problems: (1) pest resistance to some pesticides as a result of repeated applications, and (2) undesirable effects. The first has led to an intensified search for new and more effective chemicals devoid of residue hazards and, in some cases, to heavier and more frequent applications of existing materials. The possibility of undesirable side effects has aroused increased alarm over chemical residues in food and feed crops, and the possible long-range effects on man, domestic animals, fish and wildlife.

(4) Integrated control is the combining of chemical control with biological or cultural control, a procedure often practiced. This method is used to eliminate the pink bollworm from the large, highly productive, cotton producing area in the vicinity of Phoenix, Arizona. Here, repeated insecticide applications reduce summertime generations to extremely low population levels, followed by approved cultural practices during the winter months, which are not favorable to pink bollworm survival.

4. Cost-Benefit Evaluation

The successful producer of marketable food, feed and fiber crops has learned through the years of the importance of keeping the commodities he raises free from pests. Under current consumer standards, fruits and vegetables must be insect free before they can be processed or are acceptable to the modern housewife. The producer further realizes that commodity grades and quantity may be considerably reduced due to pest attack. It thus becomes important to him to include pest control procedures in his operations. In some cases biological or cultural control may be indicated, but in others he must rely heavily on chemicals in order to receive the greatest dollar return for his efforts. State agricultural experiment stations, the U. S. Department of Agriculture, and others provide him with guidelines for getting the greatest return for his work. Thus, in individual control cost benefit evaluations may be fairly simple.

In publicly sponsored programs, however, a determination of the cost benefit ratio may be more complicated. Obviously, it is important that the benefits from control exceed operational costs either in suppressing immediate emergency conditions or in the long-term benefits that may accrue to the community. Here many factors must be taken into consideration—the value of the crop or commodity being protected; the destructive capacity of the pest; the likelihood that its depredations may be transitory or recurring; the availability of safe, inexpensive methods of control lacking seriously harmful side effects; and sufficient public interest and financial support to undertake a program. These and other factors must be carefully weighed before a decision is reached.

5. Conclusions

The conclusion whether to undertake quarantine, eradication, or suppression programs should follow a complete assessment of the problem. This will be arrived at after a thorough study and evaluation of all the literature, both foreign and domestic, describing identical or similar problems; a complete evaluation of the infestation based on detailed surveys to ascertain extent of spread and intensity; a review of all available methods of control; and a careful analysis of the benefits to be derived.

B. Control Action

Control action against agricultural pests varies widely. In general, control of most agricultural pests is an individual responsibility and determination as to the action required rests with the producers of agricultural commodities. Their decision will be influenced greatly by agricultural advisers such as agricultural extension service representatives who are in a position to relay up-to-date information on acceptable procedures as developed by research agencies. The safety of their choice of pesticides will be assured by careful observance of the provisions set forth in the Federally accepted label.

When organized control by governmental agencies is required, a joint determination should be made by the

official agencies involved, together with the affected industry and the public.

1. Control Recommendations

Where Federal or State governments cooperate in the suppression or eradication of a plant pest in the public interest—either in support of quarantine action or to suppress outbreaks—multiple judgment should determine the steps to be taken. This will involve a thorough discussion of the problem, together with possible approaches to its solution, in consultation with advisory and cooperating organizations and other official agencies. Among these are the National and Regional Plant Boards which represent the segment of State Departments of Agriculture, or their equivalents, having a principal interest in plant protection problems of a regulatory or control nature. In addition, the affected industry, whether it be associated with citrus, cotton, or other agricultural commodities, should contribute to the decision making, together with representatives of all related agencies and public groups.

2. Decision on Action to be Taken

When agreement is reached with respect to the need for and the advisability of taking action against a pest problem of the type requiring State or Federal assistance, details must be worked out concerning its programming. In most cases where regulatory action is necessary to prevent spread of a new pest, further legal consideration is required. While State laws vary considerably with respect to imposing plant quarantine regulations, Federal legislation pertaining to plant pests requires a public hearing to determine the need for such action. Announcements of these hearings together with a notice of the proposed rule making must be published in the Federal Register and in other newspapers and periodicals well in advance of the required hearing. These announcements invite interested parties to appear or to be represented either personally or in writing at a specific time and place to present their views as individuals or as a representative of responsible organizations for or against the proposed action. Based on the testimony received at these public hearings, the Department of Agriculture will

make a decision. If it decides to promulgate a quarantine, it will publish its findings in the Federal Register together with the quarantine document and such administrative instructions as are necessary to implement it, along with the effective date of the action. It also notifies the numerous transportation agencies and segments of industry that may be involved.

3. Planning the Project

Careful planning is essential to successful pest control. In operations for which the grower is responsible guidance is furnished by official agricultural agencies. The Economic Insect Survey Report of the Department of Agriculture, and corresponding State reports distributed by State agencies, provide farmers and agricultural advisers with timely information relative to the presence and abundance of serious pests on a variety of food and feed crops as they develop during the year. Usually this provides advance information as a guide to planning for an outbreak. Some crop pests will cause damage somewhere each year and experience has taught farmers the need for annually protecting their crops. The recommendations of agricultural advisers and official research agencies provide a plan for growers to follow. Similarly, advice from research workers, wildlife specialists, and method-improvement scientists largely determines the plan of operations for official pest-control programs.

Growers have assurance that agricultural chemicals registered by the Department of Agriculture or by the numerous States having similar labeling legislation are safe to use and are effective in suppressing the plant pest involved, provided the directions on the label are strictly followed. They need have little fear that the commodities produced will contain pesticide residues over and above the levels permitted by regulations under the Federal or other food and drug laws. Under the same conditions of use, damage to wildlife and the wildlife habitat should be minimal.

The approaches to each program, whether privately or publicly sponsored, must be worked out individually for there is no single method of control which will cover the diversity of biological factors associated with plant-pest

problems. In some, aerial spraying is effective, in others it would have little value. Cultural control combined with chemical methods may be effective in suppressing or eradicating such insects as the pink bollworm, but a similar approach would be useless against pests such as Hall scale. Mediterranean fruit fly, or the gypsy moth, which requires methods other than cultural.

a. Participation, Cooperation, and Coordination. Programs in which the Department of Agriculture cooperates with appropriate State agencies are operated under State authority. Thus, State laws and not Federal laws authorize access to private property, and while Federal quarantines regulate the movement of commodities capable of carrying infestation from one state to another, corresponding State quarantines are necessary to regulate intrastate spread. In control or eradication efforts associated with regulatory problems, the Federal Government, affected States, industry, and individuals should cooperate in the financing and in the coordination of the various aspects of the program. Usually the Department of Agriculture will be in a better position to take the lead in organizing and administering programs since most of them involve operations in several States.

b. Basis of Financing. Sources of funds to finance cooperative programs will vary considerably according to the circumstances surrounding particular problems. Sometimes foreign pests appear first at points in the United States, where their preferred hosts are not economically important crops, yet in other areas are of high economic consequence. In such cases programs to prevent the spread of serious, introduced pests are designed to protect those areas of the country where the pest is nonexistent. Under these conditions Federal authorities should assume a greater share of the financing to protect those States where pest infestations would inflict serious economic loss. In grasshopper or similar control operations, in the vast low-value rangeland areas of the West, it is reasonable to expect ranchers, the State, and the Federal Government to share the cost of control equally on private lands or on public lands under long-term leases to private individuals. On lands in the public domain the cost must be borne principally by the Federal Government.

c. Program Organization and Assignment of Responsibility. Following the development of a plant-pest-control or quarantine program, the routine operations should be undertaken within the organizational pattern of Federal and State agencies having responsibility for plant protection. Within each State operational plans must be developed and job assignments made to those in the best position to execute them. All segments of the operation, including seasonal time schedules, need to be coordinated with other pest-control or regulatory responsibilities of the cooperative personnel within the area of operation. In order that all phases of the action program may be carried on effectively, experts in various fields such as aircraft application and wildlife biology should be called upon to advise and assist.

d. Development of Action Plans. Plans covering (1) safety, (2) training, (3) operation, (4) technical supervision, and (5) public relations are necessary to the successful completion of a pest-control program. Preparation of these plans often requires the aid of experts. While specific action plans must be prepared cooperatively between State and Federal workers at the local level, regional and national officials should approve and coordinate the program in order that it can be uniformly administered.

e. Protection of Other Values. In large-scale programs where pesticides are essential to success, operations should normally be designed as single-treatment procedures, in which one application, or one series of applications, will eradicate the pest or effectively suppress it for extended periods. Annual pesticide applications with all their disadvantages are thus avoided, but limited retreatments may be necessary on a small percentage of the area where suppression or eradication has not been achieved. Even in the control of rangeland grasshoppers where suppression of high populations is the objective, results with low levels of chemicals have been exceptionally successful in maintaining control over large areas for five and even ten years. This contrasts sharply with conditions surrounding the abatement of many agricultural pests where treatments must be made each year without any foreseeable end.

Extreme care must be taken in the selection of methods and materials used to combat pests. Where chemicals are

involved, the probable effect on fish and wildlife populations on the public health and on other values should never be lost sight of. The appropriate formulation, method of application, and comparative costs are factors to be carefully considered. For soil inhabiting insects, such as the imported fire ant or Japanese beetle, granular formulations are normally indicated in order that the chemical may reach the ground without undue interference by plants and plant parts. For defoliating insects, such as the gypsy moth and grasshopper, pesticides are usually applied as liquids.

Close liaison is required with Federal and State conservation officials at all levels of operation during the course of these programs. When wildlife biologists are available, their assignment to make observations during operations is highly desirable. Research biologists in various disciplines such as water pollution, apiculture, and others, should be urged to make observations or collect experimental data in conjunction with program operations.

Methods-improvement work and research become an integral part of the operations, making it possible for those administering the program to take advantage of any developments which provide additional safeguards and more economical or effective work.

4. Control Operations

Adequate supervision is essential to successful operations. Supervisors should be thoroughly trained for their specific responsibilities, either by years of experience or through a complete understanding of the principles of pest control as outlined in training and operational manuals. Any deviation from the accepted principles of plant-pest control should not be tolerated.

Contract operators must be thoroughly oriented concerning the details of their job, and their equipment carefully checked to see that it meets contract specifications and is in acceptable condition. Contractors should be well briefed with respect to safety measures and fully acquainted with critical areas where special care must be exercised.

In all pest-control undertakings the timing of application is extremely important. While approximate scheduling can be arranged in advance of operation, weather conditions often necessitate adjustments.

Supervisors must be adequately trained to recognize the biological factors that govern the optimum time to apply treatments. They should be prompt in responding to complaints during the course of the program and in taking appropriate action. Good communication is extremely important in order to keep operators and supervisory personnel constantly aware of all phases of the program as it progresses, and prepared to adjust the operation as conditions demand.

5. Appraisal of Results

A constant check should be maintained to determine the effectiveness of control and regulatory actions. This makes it possible to judge the efficiency of the operations and to determine the success of the work in relation to current circumstances. The technical aspects of control work require the attention of experts in specific fields, such as aeronautics, ground machinery, and other phases of methods work to assure that the day-to-day activity closely follows specifications, and that uniformity is maintained in various areas of operation. The chemicals used in these undertakings, together with the means of application, should be constantly checked to assure that they meet contract specifications.

6. Report of Accomplishments and Recommendations

Periodic formal reports and reviews should be required to provide a basis for administrative review and guidance and for the information of others interested in the problem.

II. FOREST PESTS

A. Problem Analysis

Forest-pest outbreaks are sporadic and likely to extend over wide areas, effecting many ownerships. Thus only a few pests warrant or permit effective action by individual effort, and for the most part surveys and control actions are carried on cooperatively by many owners and coordinated by Federal and State agencies. The necessity for control varies with time and place. Control may not be needed for years and then overnight become an urgent necessity. All outbreaks ultimately subside, some with relatively little damage, others only after catastrophic loss. Relatively inconsequential outbreaks far outnumber the catastrophic ones, and the problem is to determine which are serious enough to warrant action while control possibilities are still within practical limits.

Many kinds of pests are continually present in the forests. Collectively, they cause great losses—estimated at about one-fourth the annual production of forest products in the United States. Most losses are the result of normal infestations, and while it is important that they be reduced through improved management practices, direct control generally is impractical. But at times pests become epidemic; that is, they become abnormally abundant and, unless controlled, occasion widespread destruction.

1. Determination of the Problem

The first step in problem analysis is to decide whether or not there is a pest situation requiring action. This is determined by periodic surveys, usually annual, in which the status of the pests is recorded over wide areas. These surveys are made on the basis either of damage or of insect populations. In the former case, the emphasis is placed on determining the immediate economic need for control, and in the latter on the long-term biological status of the pest population. In either case these general surveys are followed by more intensive ones to learn the exact status of the more acute pest problems. Survey findings from all sources are normally assembled and summarized in a

central forestry organization, then reported to timberland owners and forest-management agencies.

2. Biological Evaluation

Biological evaluations generally are limited to pests suspected of requiring control action. These pests fall into two broad categories: (a) introduced, and (b) native.

(a) Introduced Pests. In considering an introduced pest, an evaluation must take into account its extent of establishment, its demonstrated or potential destructiveness in the new environment, its destructiveness in its native land and other lands where it has become established, and whether the new environment in which it is now found is likely to favor its spread and destructiveness. Since early action is usually the key to success, a considerable degree of speculation is inherent in the biological evaluation of introduced pests, for once a foreign pest becomes thoroughly established and its destructiveness demonstrated, eradication may be extremely difficult. Unless eradicated, most introduced pests ultimately assume the role of native pests, though some, like the chestnut blight, continue rampant until the host itself is eliminated.

(b) Native Pests. Biological evaluation of native pests is still on a short-term basis; that is, from generation to generation or from year to year, but gradually information is being assembled through surveys on the nature and amount of damage caused by the principal native species. Biological evaluation of these native pests hinges on many determinations such as past destructiveness, present abundance, status of natural control by predators, parasites and diseases, condition of host trees, trend and duration of the outbreak, and climatic conditions. Considerable progress has been made in developing evaluation procedures for some of the major insect pests, such as spruce budworm and some bark beetles. But they require complex and time-consuming procedures that must be applied by skilled technicians and adapted to specific situations.

3. Available Methods of Control

In forest-pest control, three courses of action are available: (a) quarantine, (b) eradication, and (c) suppression.

(a) Quarantine. Quarantine provides an important tool in preventing foreign pests from becoming established in the United States, or, once established, in preventing their spread to new areas.

(b) Eradication. This means the total elimination of a pest and is not only very difficult but time-consuming and costly. Eradication is primarily aimed at foreign invaders and is least expensive and most likely to succeed during the early stages of invasion. Seldom has it been attempted against pests of commercial forests, nor is it considered practical against native forest pests or against introduced pests that have become well established over extensive areas.

(c) Suppression. Most native pest outbreaks subside naturally without causing serious damage, and to treat all potentially serious outbreaks would be wasteful and probably impossible, for extensive forests grow to merchantable age without ever being subjected to epidemic pest losses. The usual policy is to postpone direct control until extensive tree killing is imminent and nature has been given ample opportunity to exert control. Under this type of program the status of natural control must be carefully checked and weighed each year.

When suppression is decided upon, four main types of control are available.

(1) Cultural control frequently depends on forest management and is sometimes called indirect control because it is applied to the host trees. It includes such procedures as regulating standage and composition so as to discourage harmful insects, and developing strains of trees that are genetically resistant to insect attack. A high degree of success has been attained against such insects as the Western pine beetle by

learning how to recognize trees susceptible to attack and logging them, thus reducing host material for potential outbreaks and at the same time utilizing trees that otherwise would be lost.

Frequently cultural control can be combined with other management practices. It is largely a preventive measure designed to create forest conditions unfavorable for insect outbreaks. It also is a long-term measure. But cultural control is not a cure-all, nor is it equally effective against all pests.

(2) Biological control employs agents such as insect parasites, predators, diseases and biologicals, most of which have been used for years. Other types of biological control, as yet largely in experimental stages, include the use of viruses and bacteria, and the controlling of life processes by hormones.

Characteristically biological control is a long-term process directed toward keeping pest-caused losses at a low level; however, to suppress certain outbreaks, some biological-control agents may be applied in much the same manner as are chemicals. Usually biological control is one of the first steps taken against introduced pests, but it is also useful against native species.

(3) Chemical, sometimes called direct control, involves the application of chemicals in a variety of ways, as in aerial spraying with DDT against defoliators. It is an emergency measure usually undertaken as a last resort to avert major losses, and it reduces the pest population with little change in the conditions that lead to the outbreak. The ideal chemical for control would destroy the pest at minimum cost without harm to the host tree or to other forms of life in and near the forest, but this ideal pesticide does not

yet exist. Meanwhile, chemical attractants and repellants for some kinds of pests offer promise of reducing harmful side-effects of those pesticides now in use. So far chemical control is the principal method available for quickly halting epidemics of forest pests in full progress.

(4) Integrated control is a combination of chemical, biological and cultural control and is commonly used in forest-pest-control practice. The objective is to use chemical control to supplement the other methods by combining the quick action of chemicals with the more lasting effects of biological and cultural control. Another goal is to reduce the amount and frequency of chemical applications and so minimize harmful side-effects.

All these measures are still being improved through research and on-the-job development. Since costs, effectiveness, and detrimental effects are variable the problem is to decide upon the measure best suited to a particular situation.

4. Cost-Benefit Evaluation

Cost-benefit information is essential to management. The forest owner, private or public, must meet many financial demands in growing a crop, and some of these demands are of an emergency nature. Pest control is one of these emergency operations; nevertheless an attempt must be made to define the limits of the emergency so that costs of control can be weighed against the benefits. The benefits can then be gauged by the owner in relation to other management needs, although the procedures in making this determination are difficult and as yet only partially defined.

There is no exact formula for determining an acceptable cost-benefit ratio, for no two owners will agree precisely on the relative values of benefits and damages. Obviously it is necessary that benefits exceed costs; usually they should exceed costs many times. Here, too, possible damage to wildlife must be evaluated in arriving at a cost-benefit decision.

In determining whether control expenditures will pay, it is necessary to consider present and future values at stake, the savings that may be expected, and how the control fits into long-term forest management. The actual destructive capacity of the pest must be determined as accurately as possible, taking into account opportunities for reducing losses by such methods as salvage.

This involves more than simply placing dollar values on theoretical timber volumes that may be killed outright or lost through growth-reduction. For the probable effects of forest destruction upon health, recreation, watershed management, and protection against fire must also be evaluated, as well as the unique role of forests as habitats for wildlife. In forested areas, wildlife values are often of major importance and call for careful assessment.

In addition, the possible detrimental effects must be weighed against the damage to the primary resource being protected. Means of keeping these side-effects to the minimum must be developed and made part of the control plan. In actual practice, it may be necessary to accept some damage in the interest of the overall public good from the needed control.

It is well to remember that a project may be technically sound and still be beyond all practical limits of available funds, manpower, equipment, and necessary materials. Practical consideration frequently demands curtailment of activities to a partial control program in any one year, and a careful adjustment to existing limitations.

5. Conclusions

When the biological, economic, and all other factors have been fully assessed and the facts established, they should be presented to the timberland owners and managers for their consideration. The case for and against control should be developed objectively, uncertainties frankly faced, and final recommendations based on the preponderance of evidence.

B. Control Action

The great variety of forest pests and the correspondingly large number of control procedures make it difficult to outline practices that apply to all situations. Once the problem-analysis has been made, however, there are certain principles that are basic to the plan-wise development of pest-control action.

1. Control Recommendations

Since for the most part only public agencies and the larger forest owners can carry on control independently—and even they must often work in conjunction—forest-pest control is characteristically a cooperative venture. Because of this cooperative need, Pest Action Councils have been formed to provide a forum for consideration of control proposals by all forest interests and the public, and to provide a means for coordinated action. These councils, which are country-wide in coverage, assure realistic consideration of all the facts and bring many points of view to bear on the problem. Project-priorities and proposed alternative courses of action are weighed in open meetings, and members of the councils may make on-the-ground determination of matters at issue, such as ownership, administrative, and legal considerations. The councils have no formal membership. Anyone interested may participate. Although the council's decisions are wholly advisory, they have the force of public opinion.

2. Decision on Action to be Taken

Taking all facts into consideration, the council usually comes to full agreement on the needed actions. In cases of substantial disagreement, action is withheld until more convincing information is available. When a plan of action is finally recommended, it is publicized and given full support of the council.

3. Planning the Project

Thorough and intelligent planning is essential for successful pest control. Objectives and scope of the proposed

project must be defined, and a plan developed for effectively meeting the objectives. Since natural factors may suddenly and substantially change control needs, the plan must provide for any adjustments that biological considerations dictate.

Plans vary widely, depending upon the pest and nature of the outbreak. For example, aerial spraying against a defoliator differs considerably from a penetrating oil-spray project against a bark beetle. However, the general principles apply to all large-scale projects, and include the following major categories:

a. Participation, Cooperation, and Coordination. Participation in control efforts is determined by the nature of the forest ownership and the degree of public interest. Customarily on large projects, a Federal or State forest agency takes the lead in organizing and administering the control program. In most States the State forester has been given the responsibility under law to take action against damaging forest pests. The nature of the cooperation and arrangements for coordination are worked out directly by the groups involved.

b. Basis of Financing. It is universally accepted that forests contribute importantly to the national economy and that their protection against ravages by pests is a matter of public concern. It is also generally recognized that many valuable indirect economic and social benefits of private and public interest are involved in forest protection. A guiding principle in the financing of forest-pest control is that the cost should be shared in approximate proportion to the estimated benefits to be gained. In some control projects where the Federal Government owns the great bulk of an infested forest—85 per cent or more—the public interest in control is considered to represent close to 100 per cent, especially if the chief objective of the minority owner is other than tree-growing. As Federal land ownership decreases so does the public interest, and where Federal forest ownership is 15 per cent or less, public responsibility is usually considered to be 25 per cent, provided the pest is not subject to control by individual effort. In some States a general tax is levied annually against all forest lands to

handle pest control, but generally this applies only in those States where timber types, age classes, and other factors are quite similar.

It is commonly recognized that pests which may be controlled satisfactorily by an individual property owner are his full responsibility, whether the owner be public or private. In these cases the public, through Federal and State governments, redeems its responsibility to private ownership by giving information and advice on control measures producing the most effective results. Pest situations of this type are similar to those in which farm crops are involved and the farmer applies the needed treatment as a production cost.

c. Program Organization and Assignment of Responsibilities. Once the scope and objectives of the proposed project, the participation, cooperation, and financing have been decided on, administrative responsibilities are agreed upon and personnel assigned the task of preparing detailed plans. At this point the establishment of a realistic time schedule is all-important.

d. Development of Action Plans. The care with which the planning phase of a control operation is conceived and organized determines whether it will succeed or fail; whether it will enjoy public acceptance or suffer rejection and opposition. Actual control operations may take only a few days or weeks, but adequate planning often requires many months. Generally speaking, control programs require action plans covering (1) appraisal, (2) safety, (3) training, (4) operation, and (5) technical supervision. Organization charts, definite assignments of duties and responsibilities, contracts for pesticides, equipment, and services should be included. Publications relating to pest control may be sought from the U. S. Forest Service, Department of Agriculture, and from the State forestry or wildlife agencies where these exist.

c. Protection of Other Values. In forest spraying, low dosages are applied and usually only one treatment is made. The goal is to achieve a high degree of kill so that retreatment of a particular area will not be necessary. Many

years may elapse before another epidemic occurs on a treated area. Extensive forests may mature without a need for pest control. For these reasons the use of chemicals in forest protection generally does not create a difficult problem of protecting public health, wildlife, and other values. Since the forest crop is not consumed, the residue problem is not serious, but in those cases where contiguous or intermixed agricultural crops may be adversely affected, special precautions must be taken to protect the food crop.

In the case of wildlife, every feasible effort should be made to minimize any detrimental effects of chemicals by making full use of the experience developed on other control projects. Nor should it be forgotten that certain insecticides are more injurious to fish and other aquatic forms than to birds and mammals. State and Federal experts should be called upon for advice and guidance in protecting other values. Ideally, such experts should participate directly in the planning and conduct of control operations, particularly in those situations where new information is needed. Frequently the forest manager and wildlife manager are the same person, and even if different individuals are involved, they share a common interest in producing trees and wildlife. This relationship has been recognized in the original research by wildlife experts and forest entomologists for developing DDT application rates still in general use. Wildlife biologists and silviculturists should continue working together to develop and improve effective control of animal pests.

4. Control Operations

Control operations consist in the actual implementation of all the steps called for by the action plan. Careful supervision is necessary to assure that all steps are carried out thoroughly and efficiently, yet kept sufficiently flexible to meet changing conditions. The selection of responsible contracting companies and employing experienced operators will go far toward assuring a successful program. A key element throughout this stage is maintaining good public relations.

5. Appraisal of Results

The purpose of appraising control programs is to weigh the benefits derived and to discover possible means for improving future control projects. Such appraisals involve both the technical and operational aspects of control.

In appraising the operational aspects the principal points to consider are costs, operating efficiencies, difficulties encountered, and similar matters.

Checking the technical aspects is more involved. While the control is in progress, the application should be checked and the immediate effect on the pest determined, as well as any possible effects on resources. These appraisals permit modification in materials, equipment, and methods while the work is in progress. When control is completed, the total results of the program should be measured in terms of pest reduction, host recovery, and side-effects on the environment.

6. Report of Accomplishments and Recommendations

A formal report provides a documentary basis for administrative review and guidance and for the information of all others interested in the control accomplishments.

III. PESTS INJURIOUS TO PUBLIC HEALTH

A. Problem Analysis

Vector control is concerned with a vast array of insects, rodents, and other animals that have detrimental effects on man's health, comfort, and welfare. Important vectors in this country include mosquitoes, flies and midges, together with external parasites such as fleas, ticks, and mites. Vector-control programs that present the greatest potential hazard to wildlife are those directed at extensive mosquito sources in rural areas, especially freshwater and salt marshes. Rodent-control programs, particularly those involving field rodents or rats on farms, present only a limited hazard to wildlife, and emphasis will be given here to mosquito control.

In most populous areas where mosquitoes are a menace to health or comfort, control steps of some sort have been taken and, except in emergencies, the operations are more or less routine.

1. Determination of the Problem

Vector-abatement programs should be based on a demonstrated need for control. One of the fundamental items in the development of a sound control program is an adequate survey to determine the problem's source and extent, the vector species present, and their relative prevalence. Plotting the exact location of breeding sites on detailed maps is of particular significance, since it permits pinpointing control operations to the most important areas. To begin major control operations with inadequate information is highly wasteful, and may result in complete loss of public confidence in a worthwhile project.

2. Biological Evaluation

Biological evaluations of pests injurious to public health in the continental United States are concerned primarily with indigenous species.

Biological evaluations are particularly desirable whenever there are excessive numbers of either (a) transmitters of disease, such as vectors of encephalitis, or (b) aggressive biting insects, such as salt-marsh mosquitoes. The presence of large populations of vicious biting mosquitoes frequently gives rise to a public mandate that immediate action be taken. Control action should be held in abeyance, however, until the seriousness of the outbreak has been evaluated. This is determined by such factors as proximity of breeding sources to centers of population, abundance of the vector, level of endemicity of vector-borne disease in the area, time of year, and weather conditions.

3. Available Methods of Control

Three courses of control action are: (a) quarantine, (b) eradication, and (c) suppression.

(a) Quarantine. Surveillance stations of the U.S. Public Health Service are established at all ports of entry to prevent the introduction of vectors, reservoirs, or human diseases. The entry of exotic vectors has been further controlled through routine fumigation and other treatment of aircraft and ships.

(b) Eradication. In the event of failure of quarantine, eradication is the recommended course of action. This implies the complete elimination of a species and is aimed primarily at introduced foreign pests.

(c) Suppression. Mosquito abatement and rodent control call for diverse suppression techniques. In mosquito abatement there are four main methods:

(1) Naturalistic control may be defined as the purposeful manipulation by man of one or more natural factors, physical or biological, in order to prevent or discourage mosquito breeding. Examples include water-level management of impoundments, changing the salinity of a body of water, and the use of biological control techniques. The best known of the biological agents are the larva-eating fishes, particularly the top-water minnow (Gambusia). The success of tidal ditches is substantially due to making mosquito larvae accessible to native predaceous fishes. Other examples of biological control, as yet in experimental stages, are the use of blue-green algae (Anbaena) to control ricefield mosquitoes, and the release of sterile male mosquitoes to decrease natural populations progressively.

Naturalistic control is largely an unexplored field. A recently developed method that appears very promising is the creation of impoundments on salt marshes where the water level can be manipulated and controlled. This method not only suppresses production of Aedes mosquitoes but actually enhances wildlife values. It would be highly desirable for conservation and wildlife

agencies to foster and promote research on naturalistic control methods.

(2) Source Elimination. Where at all feasible, efforts should be made to eliminate the breeding places permanently by filling, drainage, impounding, sanitation (elimination of artificial water containers), or other means. These are widely known as permanent or primary control methods and are particularly well adapted for all areas of intense economic development. Such areas include those within and close to cities or resorts where a high degree of control is sought. In general, permanent control measures are the most effective, economical, and enduring, although limitations in their use may arise where costs are excessive for the size of the area to be protected, or where valuable wildlife resources must be preserved. In areas where these resources are of particular value, consideration should be given to modification of the permanent abatement techniques, such as the use of large water-management ditches that do not lower the water table.

(3) Chemical control is the use of pesticides for destroying both the immature and adult forms of mosquitoes. It includes space spraying and the use of temporary larvicides, residual larvicides, and residual adulticides. Control at the source, if at all possible, is the procedure of choice.

Prior to the advent of DDT, adulticides were rarely used; today their use is common. The global campaign against malaria vectors is based on the application of residual toxic coatings of chemicals to surfaces where mosquitoes rest.

The employment of chemicals is frequently termed a supplemental or secondary control method. Its limitations include the temporary effectiveness of the treatments, the high cost of

repeated applications, the hazards involved, and the development of insecticide-resitant strains of pests. One of the chief advantages of chemical control is the immediate and often spectacular relief from annoyance. Chemical control measures play an important role in suppressing epidemics of mosquito-borne diseases, and are also used where the more permanent methods for mosquito control are not feasible. Since chemical control may adversely affect fish and wildlife, it should be planned and executed with full consideration for their protection.

(4) Integrated control is the best vector abatement. It calls for a combination of source elimination, naturalistic, and chemical control methods.

In rodent-borne disease control, there are also four main kinds of suppression: (a) ectoparasite control with insecticides to prevent disease transmission by fleas and ticks which might bite man when their rodent hosts are killed; (b) use of traps and rodenticides to reduce rodent populations temporarily until more permanent measures can be put in force; (c) repellants and exclusion to keep rodents from specific limited areas; and (d) field sanitation to reduce rodent food and harborage.

Rodenticides are widely used by agricultural workers, pest-control operators, and health departments especially around farm buildings and in urban areas. Introduction of the relatively safe anticoagulant rodenticides (warfarin, fumarin, pival, pmp, and diphacin) has greatly curtailed the use of the highly dangerous poisons, such as arsenic, strychnine, and thallium.

Properly used, these anticoagulant rodenticides represent a very limited danger to wildlife other than the rodents they are employed to destroy.

4. Cost-Benefit Evaluation

The public usually recognizes mosquito control as one of the community services—to prevent disease, to abate a nuisance, and to protect economic developments such as resort and recreational areas. Mosquito control is largely tax-supported by public funds, and control operations are undertaken only when local communities desire mosquito control strongly enough to defray the cost.

Certain benefits are difficult to equate on a dollars-and-cents basis. For instance, what is the value of saving a human life from a devastating disease like Eastern encephalitis? Most would agree that the prevention of one death or one case of permanent brain damage would justify the amount of money proposed for vector-control work in any community.

Pest epidemics can have severe impacts on tourism and the utilization of resort areas. The 1959 outbreak of Eastern encephalitis in New Jersey involved 21 deaths during a two-month period, and is estimated to have caused a loss of two million dollars to Atlantic City hotels alone.

The increase in value of lands made available for economic development and recreation as a result of mosquito control often more than justifies the expenditures.

It must be recognized that wildlife areas also are valuable resources, and the decision whether or not to undertake control measures in such areas is to be determined by a balancing of values in terms of maximum benefits.

5. Conclusions

Decisions on mosquito-abatement programs should be based upon a demonstrated need established by field investigations. Adequate consideration should be given to fish and wildlife, i.e., to recognize the values associated with the mosquito-breeding wetlands.

Major vector control should not be begun until the problem has been adequately analyzed and the need demonstrated. All control programs should be contingent upon

field surveys to determine the source and extent of the problem; biological evaluations of the pests involved; and determinations that the proposed control actions will be effective, economically sound, and compatible with human safety and wildlife values.

B. Control Action

Vector control in the United States is normally performed by local governmental agencies. In general the States and the Federal Government do not engage in active vector-transmitted diseases.

1. Control Recommendations

In times of emergency it is essential immediately to identify and evaluate present and potential public health hazards and to determine the action necessary to control or eliminate them. This preliminary action is usually initiated by the State health officer or his representative. In many cases, he will request the services of specialists from outside sources such as local mosquito-abatement district officials and Federal epidemiologists, entomologists, wildlife biologists, and engineers. In a few States, advisory committees for vector control have been established, and these groups provide an excellent means for guidance and coordinated action. Preliminary data on the type, severity, and extent of the hazard are obtained, and estimates made of the resources available locally (or required from other agencies) to reduce or eliminate the hazard.

2. Decision on Action to be Taken

One or more conferences are usually held to develop plans for action and to assemble the necessary resources. All facts should be considered before final decisions are made. Public releases on recommended actions should be carefully worded in order to avoid "scare headlines" and similar forms of publicity.

3. Planning the Project

Good planning is essential for successfully coping with outbreaks of pests and vector-borne diseases. Objectives and scope of the proposed project must be clearly defined.

Emergency control activities vary widely depending upon the pest species, nature of the outbreak, and resources available. For instance, the application of residual toxicants to buildings is a sound procedure for the control of Anopheles quadrimaculatus (malaria mosquito), whereas space-spraying is the method of choice in combating an infestation of floodwater (Aedes) mosquitoes.

a. Participation, Cooperation, and Coordination. Participation in control efforts is determined by the extent of the outbreak and the degree of public interest. In general, a disaster is a local problem at the outset, and recovery begins with self-help. The purpose of Federal participation is to supplement, not to supplant, the State and local resources, and to insure that the resources necessary for the protection of health are fully provided.

b. Basis of Financing. Pests which may be controlled satisfactorily by individual property owners are the responsibility of the owner. Providing individual householders with information and advice on suitable control measures for their premises is a responsibility of the public health and mosquito-control agencies.

To cope with major outbreaks State emergency funds are frequently made available by the governor to the local or State agencies. Federal assistance in major disaster areas may include direct provisions of equipment, supplies, facilities, and personnel, or monetary loans and reimbursements for disaster-aid expenditures by local governments. Emergency control operations are designed to augment the resources of local mosquito-control agencies. Local governments should be encouraged to make funds available for an accelerated control program.

c. Program Organization and Assignment of Responsibilities. In the preceding paragraphs, some essential preliminary planning steps have been outlined: definition of objectives and scope of the project; provision for participation, cooperation, and coordination; provision for financing and determination of administrative responsibilities. The next step is to prepare detailed plans, an important element of which is the establishment of a time schedule.

d. Development of Action Plans. In developing control-program plans, the following items should be considered: operational guides, technical supervision, entomologic evaluation, reports and records, public relations, safety (precautions), training, public education, organizational charts, duties and responsibilities of various jobs, and contracts for pesticides, equipment, and services. The U.S. Department of Health has a number of publications available on vector-control programs and techniques of operation. These should be consulted in developing action plans.

e. Protection of Other Values. Mosquito control has had a good safety record for over 50 years, and insofar as the use of mosquito larvicides, adulticides, and rodenticides is concerned, the dangers to wildlife are largely potential rather than real. The amount of aerial spraying for mosquito control comprises only about two per cent of the total acreage (100 million acres) sprayed annually in the United States, and even under disaster conditions the dosages needed for mosquito control are generally lower than for most other insect-control operations.

Nevertheless, every feasible effort should be made to minimize possible detrimental effects of chemicals to wildlife.

4. Control Operations

In executing the steps outlined under the action plan, it is essential to provide for adequate supervision. The ability to organize a system of effective vector control stems largely from the background, experience, and training of the supervisor, qualifications that cannot be overemphasized.

Since the ultimate success of a control program is dependent upon public support, public enlightenment is of paramount importance. Education of the general populace will do much to prevent or reduce misunderstandings.

5. Appraisal of Results

Measurement of the effect of treatment upon the vector population is the first objective of an appraisal. In addition,

such aspects as collateral benefits, costs, damaging effects, and public reaction should receive consideration. In the control of vectors of disease, the effect upon incidence of the specific disease involved should be determined.

When control is completed, the total results of the program should be measured in terms of reduction of vector and disease incidence, along with occurrence of side-effects on the environment. One of the chief purposes in appraising control programs is to discover possible means for improving future projects.

6. Report of Accomplishments and Recommendations

A clear, concise report of accomplishments and recommendations should be a requirement in every control action.

SUMMARY OF RECOMMENDED PROCEDURES

Careful organization and conduct of pest-control programs will do much to insure effective results with minimum damage to wildlife. The tested procedures described in this report are recommended to all those responsible for pest-control programs. In summary, these procedures are:

1. Identify the Problem. Organize and make systematic surveys promptly to detect and specifically identify the damaging pests. Review the literature.

2. Make Biological Evaluation. Determine the status of each pest and its trend. Appraise probable damage.

3. Choose Control Method. Determine for each pest situation the possible course of action and evaluate their relative merits for controlling the pest with least adverse effect on wildlife and other values. Choose the most suitable from the following methods: (a) exclusion or confinement by quarantine, (b) eradication, or (c) suppression. If suppression is the course indicated, select from the following methods: (a) biological, (b) cultural (manipulation of host or environment), (c) chemical, and (d) integrated. Decide whether pilot operations are necessary to test feasibility of large-scale work.

4. Weigh Costs of Protection Against Values to be Protected. Weigh costs of control, including hazard to fish and wildlife, against the economic and social values threatened. Take into account alternative courses of action and the relative urgency of competing projects.

5. Recommend Course of Action. Make technical recommendations based on nature of the threat, available control measures, expected tangible benefits, and feasibility of control objectives.

6. Decide on Action. Review the technical recommendations with all affected groups participating. Decide (a) whether to undertake control, (b) how it will be done, (c) by whom it will be done, (d) whether legal authority and funds are adequate, and (e) what precautions are necessary.

7. Allocate Costs. Assign proportion of control costs on the basis of benefits to be derived.

8. Plan the Project. Define objectives clearly, determine the scope of the project and plan carefully and realistically. Integrate into the plan positive measures for protecting wildlife values. Draft contracts to insure administrative control at all times.

9. Carry out the Project. Insure adequate supervision of the control program, keep procedures flexible enough to adjust to changing conditions. Measure effectiveness of control and impact on wildlife as work progresses. Consistent with public interest, respect private property rights.

10. Appraise Results. Review and assess project accomplishments to devise means for increasing effectiveness and lessening harmful side-effects.

11. Keep People Informed. Let the public know at all stages what is being done and why it is being done.

12. Conduct Research. Establish an active program of research to develop new methods and increase effectiveness of control, yet minimizing harmful effects to wildlife.

PRECAUTIONS

In pesticide use the following precautions are indispensable in attaining effective and economical pest control with least harm to wildlife:

1. Do not apply pesticides unless it is definitely established that chemical control is clearly the method of choice.

2. Do not apply unless the pesticide is registered for the purpose intended and directions for its safe use are clearly understood.

3. Do not apply unless the selected chemical, its dosage, formulation, and manner of application are known to be effective against the pest and least harmful to wildlife.

4. Do not apply in a large-scale program until both the chemical and the method of application are thoroughly field-tested.

5. Do not apply on more than the minimum area required for control.

6. Do not apply in quantities greater than necessary to meet the control objective.

7. Do not apply without adequate supervision to insure that all precautionary measures are taken.