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Brief Submitted

By

Environment Canada

to the

BRITISH COLUMBIA ROYAL COMMISSION

^{2nd} OF INQUIRY INTO THE USE OF

PESTICIDES AND HERBICIDES

Environmental Protection Service

Environmental Management Service

Canadian Forestry Service

Canadian Wildlife Service

Inland Waters Directorate

Atmospheric Environment Service

Fisheries and Marine Service

Fisheries Operations

Fisheries Research and Development

Marine Sciences Directorate

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1. INTRODUCTION

Canada's new Department of the Environment came into being on June 11, 1971 and amalgamated those elements within the federal government involved in work related to the environment and renewable resources. "Environment Canada" comprises five mission-oriented services:

Atmospheric Environment Service

Environmental Management Service

Environmental Protection Service

Fisheries and Marine Service

Planning and Finance Service

Six main goals were listed by Environment Minister Jack Davis following the creation of the new Department:

- (a) Carry on established resource programs and services
- (b) Clean up and control pollution
- (c) Assess and control the environmental impact of major development
- (d) Initiate long-term environmental programs. Promote and support international environmental initiatives
- (e) Develop an environmental information and education program.

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The federal environmental role is prescriptive (objectives, criteria, standards), descriptive (state of the environment) and punitive (prosecution).

The general policy of Environment Canada is to control any contaminant (pesticide) which, upon release or escape into the

environment, may have a harmful effect on living resources, and[^] which poses a threat to human health. The basic steps involved in a pesticide (i.e., insecticide or herbicide) hazard control program are:

- (a) to gather the necessary information on the kinds, quantities and locations of the release of a pesticide.
- (b) to undertake certain tests on suspected contaminants to the environment, or require the producer to undertake these (i.e., toxicity to non-target organisms, sublethal effects etc.).
- (c) to restrict the release of certain pesticides, partially or totally as the tests indicate, by ^{No}regulations [?] under new and existing legislation, or by employing the regulations of others.
- (d) to conduct an appropriate program of research and monitoring of the effects of the pesticide on the environment. Of fundamental importance to the entire strategy are pathway determination and mass-balance studies of pesticides and potentially adverse changes in biota from contamination by toxic substances including pesticides.

A number of Acts and Regulations assist Environment Canada to fulfill its mandate. The five Acts utilized most frequently in relation to pesticides are:

Canada Water Act
Clean Air Act
Fisheries Act

Migratory Birds Convention Act

Forestry, Development and Research Act

~~In addition, a new Act, The Contaminants Act, is presently being formulated by Environment Canada.~~

It is appreciated that the use of some chemicals to control the impact of pests on man's food, health and general welfare justifies their use and that, furthermore, their use in the future is necessary to ensure a sufficient supply of food ^{in the} in a finite land space with a rapidly increasing human population. The problem therefore becomes one of the wise and carefully controlled use of such chemicals, backed by a sound program of research and control to define and minimize the potential for trouble involved in their use.

2. ROLE, INVOLVEMENT AND CONCERNS --

2.1. Atmospheric Environment Service:

The Atmospheric Environment Service is not directly involved with pesticide and herbicide application, but has available a fund of information and expertise on the meteorological parameters which directly effect the dirft and deposition rate of emitted chemical treatments. To produce the correct dosage and planned spatial coverage requires the advance knowledge of the local wind field and turbulence structure which will be present during application. Further, it is essential to have advance knowledge of the local wind field and turbulence structure which will be present during application. Further, it is essential to have advance knowledge of the probability of precipitation occurring after application and before the chemicals have had their desired effect.

Meteorological advice may be inserted into the planning at a number of stages. For example:

- (a) Long-term climatological data may be analysed to isolate periods of time in which the correct meteorological parameters are likely.
- (b) An operational outlook may be made available up to a week before planned application at which time the probability of the selected climatological events occurring may be decided.

(c) In the period 12 hours to 48 hours before application an operational weather forecast may be made, based on the synoptic situation and the effects of the local topography on the larger scale weather.

(d) On site meteorological advice may be necessary during application in particularly complex terrain.

This type of weather advisory assistance was applied with evident success in June, 1973, when the Canadian Forestry Service conducted aerial spraying of the Sprucewoods Forest Reserve near Carberry, Manitoba.

Research relative to the transport of particulate matter provides an excellent basis for the assessment of large-scale transport of pesticides. Because of their size, pesticide sprays, dusts and their residues can be readily picked up by the atmosphere through turbulence, and transported great distances by wind.

The pesticide is returned to the earth mainly through the processes of turbulence, sedimentation, impaction, and rain-out. Depending on the nature of the particle and atmospheric conditions, pesticide residues from a single source area can travel vast distances or remain suspended in the air for hundreds of days. While the deposition may be extremely widespread, local subsidence, rain-out and/or persistent synoptic-scale patterns may cause certain regions to receive more substantial accumulations than others.

(Mukammal and McKay, 1971).

3. ROLE, INVOLVEMENT AND CONCERNS --

3.1. Environmental Protection Service:

- (a) The primary role of the Environmental Protection Service, (EPS), as the name implies, is to safeguard the ecosystems from the effects of deleterious chemicals or substances. This includes pesticides, whether they be in the form of solids, liquids, or gases, dissolved or otherwise, and irrespective of the method by which they are discharged. In April, 1972, the Environmental Protection Service in Vancouver was formed and has since assumed those pesticide control responsibilities that were previously administered by the Fisheries Service.

E.P.S. is also responsible for the coordination of all matters relating to pesticides within the Department of the Environment. Pest control programs submitted to the British Columbia Interdepartmental Pesticide Committee are forwarded to E.P.S. for comment. E.P.S., in turn, forwards details of these programs to appropriate services within Environment Canada for review and comment. A final coordinated reply on behalf of Environment Canada is provided to the program sponsor and to the Chairman of British Columbia Interdepartmental Pesticide Committee.

Furthermore E.P.S. conducts surveillance and monitoring of selected pest control programs to evaluate the impact of pesticides on the environment, particularly non-target species, under British Columbia conditions.

Additionally liaison with Federal and Provincial government departments, universities, industry and the public is maintained.

- (b) E.P.S. Pacific Region (comprises B.C. and the Yukon Territory) participates in numerous control programs. A strict examination and assessment is carried out with respect to:
 - (i) The type of pesticide used,
 - (ii) Formulation,
 - (iii) Rate, method, concentration, number of, timing and location of application, etc.,
 - (iv) Possible hazards of each toxicant and/or its metabolites on the environment, especially non-target flora and fauna,
 - (v) Monitoring of spray drifts and their effects on non-target aquatic and terrestrial invertebrates, fishes, birds, mammals, etc.,
 - (vi) Establishing whether detrimental pesticide effects, if any, are temporary or permanent.
- (c) The major programs we have been involved with in the past year are:
 - (i) Mosquito Abatement Projects
 - Lower Fraser Valley Mosquito Control Program
 - Interior of Southern British Columbia Mosquito Abatement
 - Yukon Territory Mosquito Control Project
 - (ii) Blackheaded Budworm Operation of Western Hemlock near Port Alice and Port McNeill of Northern

Vancouver Island. E.P.S. and other Environment Canada Services were involved in this program from the initial stages through the auspices of the Pest Control Committee of the Council of Forest Industries.

(iii) Rights-of Way Programs of B.C. Hydro and Dept. of Highways.

These involve the use of several herbicides, chiefly triazines and phenoxy compounds.

(iv) Alder Control Programs of B.C. Forest Industries.

A number of herbicides are used for alder suppression, mainly the phenoxy and triazine toxicants. E.P.S. is presently engaged in a pesticide project involving the use of phenoxy compounds for roadside control of alder. The principal object of this study is to obtain data regarding the influence of phenoxy compounds on British Columbia ecosystems, with emphasis on the following observations:

- Impacts on non-target organisms, especially aerial arthropods, birds, plants, and wild-life;
- Forests pesticide spray drifts and their influence on non-target flora and fauna, including fish and fish food organisms;
- Minimum dosage required to suppress target species;

-- Timing of application to achieve satisfactory control with minimum environmental damage.

(d) The E.P.S. main concern is the potential hazards of pesticide contamination of the environment, particularly non-target aquatic and terrestrial species. Certain pesticides, their residues, metabolites and/or contaminants have been reported to have adverse effects on some segments of the ecosystem. Their introduction to such systems could initiate a number of reactions, which invariably have a detrimental effect on man. For example:

(i) Reduction of species number

The direct application of pesticides to crop lands, forests, and other habitats may reduce and sometimes temporarily exterminate not only the pest, but also non-target organisms in the treated area.

(ii) Alteration of habitats

Pesticides are effective in altering habitats.

Herbicide destruction of plants on which animals depend for food and shelter, may cause significant reduction in their numbers in the treated area. Changes in vegetation are usually detrimental to dependant species, but may also be favourable for other species. For instance, when the tops of mature forest trees

were killed with herbicides, the trees sprouted from their bases, thus improving browse for some animals, e.g. deer, (Pimental, 1971).

(iii) Pesticide persistence, movement and residues in the Environment.

Persistent pesticides remain in the environment and are biologically effective over long periods of time. The obvious disadvantage is that the longer the chemical persists in the environment the greater are the risks involved. Residues can result in prolonged hazards to organisms in the treated area. Furthermore transport of the chemicals and/or residues by soil, water, air, or organisms far removed from the point of application. Persistent chemical residues, for example, DDT are widespread in nature. Some degradation products are more stable and toxic to certain segments of the environment than the parent compound. The methylation of mercury and epoxidation of certain of the cyclodiene pesticides are additional examples illustrating these phenomena.

(iv) Biochemical, behavioural, physiological and reproductive changes in species.

The chronic effects of sublethal concentrations of pesticides are often difficult to recognize and diagnose

but may be more hazardous than acute toxicity: For example, long-term exposure to minute amounts of pesticide and or their metabolites have been reported to adversely affect normal functions of some organisms. In some instances insects, mites and some mammals have acquired resistance to certain pesticides.

(v) Biological magnification

The ability of some living organisms to accumulate certain pesticides in their body tissues appears to be a common physiological phenomenon. The organochlorine insecticides are most often involved in this process. The capability for concentrating pesticides is best illustrated by oysters and waterfleas. Oysters exposed to 1 ppb of DDT have been reported to concentrate it 70,000 times in their bodies. (Butler, 1964; and Pimental 1971). Waterfleas are even more efficient; they were able to concentrate 0.5 ppb of DDT by a factor of 100,000, (Priester 1965; and Pimental 1971). Normally, the capability for biological magnification is not as great as this, but when the event is repeated through several links in the food chain, extremely high concentrations of pesticide residues can occur in the species at the top of the food chain. An example is the simple food chain involving soil, earthworms and

robins: An initial DDT level in the soil of 9.9 ppm, reached 141 ppm in the earthworms, and about 444 ppm in robins, (Hunt, 1965; and Pimental, 1971). This high concentration in the robins was toxic to some birds.

4. ROLE, INVOLVEMENT AND CONCERNS -- Environmental Management Service

This Service of Environment Canada comprises the following:

Canadian Forestry Service

Canadian Wildlife Service

Inland Waters Directorate

Lands Directorate

4.1. The Canadian Forestry Service (CFS):

CFS is the largest forestry research agency in Canada. Its prime function is one of forestry and forest products research rather than forest management which is conducted largely by the various provincial governments. The Minister of the Environment administers the Forestry, Development and Research Act, which provides "for the conduct of research relating to the protection, management, and the better utilization of forest products". The Act also stipulates that the Minister may undertake, promote or recommend measures to encourage public cooperation in the wise use of the country's forest resources, and that he may enter into agreements with the provinces or any person in connection with the forest protection, management, utilization, and related research, or for forestry publicity or education. This responsibility is channelled through the Director General of the Canadian Forestry Service.

Research activities are conducted at six regional centres across Canada, including the Pacific Forest Research Centre, Victoria, and at six specialized institutes, the Petawawa Forest Experiment Station, and at the Eastern and Western Forest Products Laboratories in Ottawa and Vancouver. All the regional centres are concerned to some extent with pest problems, although priorities vary, as each establishment pursues the forestry problems of most immediate concern to the areas served. Two institutes, the Insect Pathology Research Institute, Sault Ste. Marie, Ontario, and the Chemical Control Research Institute, Ottawa, are exclusively concerned with pests and pest-related research, whereas most of the other institutes have, on occasion, investigated aspects of pest problems related to their fields of specialization. The activities of all these establishments are coordinated through the Directorate of Operations in the Canadian Forestry Service Headquarters, Ottawa.

In addition to the primary activities of pest research and services, the Canadian Forestry Service participates in the review of pesticide regulation and use through representation on various committees of the federal government, including:

1. Federal Interdepartmental Committee on Pesticides.

2. The N.R.C. Associate Committee on Scientific Criteria for Environmental Monitoring.
3. The N.R.C. Associate Committee on Agriculture and Forestry Aviation.
4. The Interdepartmental Committee on Forest Spraying Operations.
5. The Annual Forest Pest Control Forum.
6. Canadian Forest Pest Control Committee.

Brief descriptions of committees 1, 2 and 3 follow below. Committees 4,5 and 6 are described in more detail as they relate more directly to forest pest problems.

Federal Interdepartmental Committee on Pesticides

This Committee was formed in 1964. Current official representation is as follows: Agriculture (2 members), Consumer and Corporate Affairs (1), Environment (5 members: Environmental Protection, Wildlife, Forestry, Fisheries, and Water), Indian Affairs and Northern Development (1), National Research Council (1), and National Health and Welfare (2).

Briefly, the terms of reference for this Committee are as follows: to assess the adequacy of the overall Canadian program on pesticide use; to take appropriate action on recommendations flowing from the Health and Drug Directorates of the Department of National Health and Welfare; to provide the liaison with appropriate provincial authorities;

and finally, to advise the federal government on international developments affecting insecticides. This Committee, chaired by the Assistant Deputy Minister of Agriculture, meets twice annually and reports to the Minister of Agriculture; copies of reports going to Ministers of other Departments represented on the Committee.

N.R.C. Associate Committee on Scientific Criteria for Environmental Monitoring

This Committee was formed in 1970, with representation from the National Research Council, Department of Agriculture, Department of the Environment, Department of National Health and Welfare, Cyanamid of Canada and York University. The terms of reference for the Committee are basically to prepare and publish criteria for pollutants in air, water and soil, and to this end three sub-committees have been established, one dealing with pesticides.

This sub-committee is just beginning to operate and is directing its attention initially to developing procedures for measuring pesticides within the human sphere of protection, as well as within the environment in general.

N.R.C. Associate Committee on Agriculture and Forestry Aviation

This Committee was formed in 1966, with representation from the National Research Council, Canadian Transport

Commission, Departments of the Environment, Agriculture, National Health and Welfare, the Ministry of Transport, and 13 members from industry. It is a national committee, with the following objectives: to promote and advise on the design and performance of spray aircraft equipment; to promote development and improvement in spray aircraft operational techniques, and to advise on chemical safety and flight during operational spray programs.

The committee encourages close liaison and cooperation with any agency dealing with large-scale aerial spray programs, and it should be kept fully informed on operational spray programs undertaken by a province with federal financial assistance.

Interdepartmental Committee on Forest Spraying Operations

This Committee has been superseded by the two described below, but since it has been mentioned in other briefs, its history is summarized for the record. It was formed in 1958 following a meeting called to discuss the conflicts between fisheries and forestry resources, which had been brought into focus by DDT spraying operations in eastern and western Canada. The Committee was originally comprised of representatives of the Fisheries Research Board, the Department of Fisheries, the Canadian Wildlife Service, and the Canadian Forestry Service. Additional representation has since been provided by the Departments of Agriculture, National Health and Welfare and other federal

agencies. Throughout the life of the Committee, the meetings were regularly attended by representatives of provincial Forestry Services, including British Columbia, and industrial agencies such as the Council of Forest Industries of B.C. The aims of the Committee included:

- (a) Review of forest insect outbreaks, probability of damage to the forest, and hazards to other forms of life that would result from chemical control operations.
- (b) Coordination of recommendations for control action and safeguards to be taken.
- (c) Support of additional research to develop less hazardous insecticide formulations and improved methods of application.

During the period 1969-1972 the federal government withdrew financial support to forest spraying operations, but the Interdepartmental Committee on Forest Spraying Operations remained a viable forum for the exchange of information. In 1973 federal support for selected control operations in cooperation with Provincial agencies was renewed under the authority of the Minister of the Environment, and the Interdepartmental Committee on Forest Spraying Operations was dismissed. The following forum and committee were formed in its place.

Annual Forest Pest Control Forum

This meeting, organized by the Canadian Forestry Service, will replace the communication function of the above Committee and encourage the exchange of information between province, industry and research agencies on forest pest control problems.

Canadian Forest Pest Control Committee

This Committee was formed in 1973 to enter into agreements with the provinces for the sharing of costs involved in certain pest control operations. At present, financial assistance is limited to control operations against spruce budworm, hemlock looper, the pine sawflies, and accidentally introduced pests.

The Committee consists of representatives of the Departments of the Environment, Agriculture, National Health and Welfare and other Departments as required. It will review requests from the provinces from the standpoint of controlling forest pest outbreaks, which, if unchecked, would have:

- deleterious effects on the environment over large areas;
- adverse economic consequences on the forest industry;

- significant sociological consequences such as reduced employment or loss of recreational use of forest land; or
- serious risk of spread across interprovincial or international boundaries.

The Committee will also consider proposed control methods to be employed, and health and environmental hazards. It will recommend to the Minister of the Environment control projects which, in its opinion, warrant federal financial assistance.

A variable threshold deductible, to be paid wholly by the province, has been set for each province. It is based on provincial forestry revenues at national average provincial rates, per capita. Above the threshold there is an escalating rate of federal financial support, ranging from 25 per cent for the first \$25,000 above the threshold to 50 per cent of costs in excess of \$1,250,000.

Pest Control Committee - Council of Forest Industries

In British Columbia, the Canadian Forestry Service participates as an active adviser to the Pest Control Committee of the Council of Forest Industries. The purpose and functions of this Committee are described in the Council of Forest Industries brief.

The existing forum for discussion of forest pest problems has been an invaluable committee; however, its limitations should be recognized. It does not permit a province-wide review of the forest pest situation, nor is it concerned with pest problems in amenity or recreation areas unless they coincide with the interest of production forestry.

Forest Resources
4.1.1. Research and Services in Pest Control in the Canadian Forestry Service.

(a) Pesticides:

No attempt has been made to develop or maintain an accurate estimate of losses as a result of insects and diseases in the forest of British Columbia; however, they are usually considered to approximate the losses from wildfire. Many pests are involved and all tree species are susceptible. The destructive action may be sudden and dramatic, (e.g., outbreaks of bark beetles, defoliators), or slow and prolonged, (e.g., stem diseases, wood borers). Frequently pests do not kill trees, but render them unsuitable as a forest product or reduce their amenity values, e.g. tip weevils. All stages from seed to over-mature relics are subject to attack by these organisms; this is a natural biological process and, in fact most of the forests of British Columbia are the result of the natural ecological processes of insects,

disease and fire, acting separately or in concert through time.

CFS scientists have recognised this for many decades and the investigations on major pests, which began in the early 1920's, have been directed toward determining the ecological, sociological and economic factors, to formulate forest management guidelines designed to prevent conditions that increase the risk of pest outbreaks.

The current program at the Pacific Forest Research Centre, prepared in consultation with the Provincial Forest Service, industry and the University of British Columbia, reflects to a large extent, the areas of major concern and priority in the forests of British Columbia.

There are major projects on:

- bark and wood-boring insects
- defoliators
- the balsam woolly aphid
- tip and shoot mining insects
- stem diseases
- root diseases
- forest nursery pests
- the biological control of decay and root fungi
- detection and appraisal of tree pests and damage
- seed and cone insects

Twenty-seven scientists are involved in these studies.

In addition to foresters, forest entomologists and pathologists, this group includes insect physiologists, tree physiologists, taxonomists, mycologist, a nematologist and an insect toxicologist. Other disciplines, including chemistry, climatology, hydrology, mathematics, soil science, silviculture, plant ecology, economics, etc., are available in the Centre and actively cooperate as required.

Some Canadian Forestry Service Accomplishments in Reducing the Need For Pesticides in British Columbia

- The aim of the Canadian Forestry Service research program is to develop forest management guidelines that will reduce losses and the need for direct control action. A few examples follow.
- The attractiveness of cut logs to the ambrosia beetle is directly related to the time of year when the tree was felled; thus, by adjusting log movements from the forest, the risk of ambrosia beetle attack can be considerably reduced.
- The balsam woolly aphid, which has defied direct control, has been contained within a static area since 1967. This may be due to a quarantine on all balsam fir seedlings and voluntary restrictions on log movements agreed to by the forest companies. Considerable research on the climatological and dispersal characteristics of this pest formed the basis of these guidelines.

- Several management practices have been recommended to control bark beetles, all aimed at reducing the availability of breeding material. These include removal of low-vigor, high-risk trees through selective cutting; sanitation through cleaning up material such as logging slash, windfall and fire-killed timber; and reduced stump heights. Another practice is to log attacked trees before the beetles emerge to infest other trees. These practices are feasible and effective in situations where the outbreaks are relatively small. Many of the 1973 timber sales in the interior of the province are stands of beetle-killed trees.
- The hemlock dwarf mistletoe problem can be resolved largely by sanitation cutting, where all hemlock are felled during the logging operation to ensure that a mistletoe infection source is not left on residual standing trees to infect future stands.
- The impact of root rot diseases, which are difficult to control, can be reduced through silvicultural manipulation of infected stands, such as early removal of infected trees, clear-cutting of infected stands followed by planting of resistant species, and removal of infected stumps and roots in high-value sites.

-- In forest tree nurseries, it is imperative to control forest pest damage in order to preserve the continuity of sustained yield management from year to year.

Pesticides are frequently used in these nurseries, but there has not been the same degree of concern because their use is confined to relatively small areas.

Nevertheless, the nurseryman is able to employ several cultural practices that reduce the amount of pesticide required.

Research programs have shown that the following practices can reduce the need for pesticides: controlling soil moisture, temperature, nitrogen level and pH; time of planting; summer fallowing; sanitation practices, such as burning infected material; removing alternate hosts for certain fungus diseases; inspection of imported plant stock; and growing species (e.g., pine) outside the natural range of its major pest (e.g., European pine shoot moth).

Role of Canadian Forestry Service Institutes in Pest Control in B.C.

The experience and consultative services of other regional Centres are readily available to the Pacific Forest Research Centre.

The Institute, Sault St. Marie, Ontario, with a staff of 19 scientists is directed to the study of insect pathogens, (bacteria, viruses, fungi and protozoans).

pheromones and insect reproduction physiology. There have been some notable successes in the field of insect pathology, e.g., control of certain sawflies by the use of viruses; more will be said later about biological control.

The program of the Chemical Control Research Institute, Ottawa, with 13 scientists, is directed toward insecticide testing and application trials, studies of environmental impact of pesticides, and the integrated use of biological and chemical control.

The general procedures of the Chemical Control Research Institute serve as a model for the Canadian Forestry Service protocol for dealing with pesticide investigations across Canada. Briefly, this Institute reviews the data on new pesticide compounds submitted to it as candidates for forestry use. Those satisfying certain criteria, including low toxicity to non-target organisms, are tested in the laboratory for effectiveness against various forest pests. The most promising materials are tested more rigorously in the laboratory and, if warranted, small-scale field trials are carried out to assess effectiveness under natural conditions. If the material is still promising, large-scale field trials are carried out to assess effectiveness under natural conditions. If the material is still promising,

large-scale experimental trials will be conducted with operational application equipment and techniques. Effects on non-target organisms are monitored and checked by wildlife ecologists and residue chemists, who collaborate with scientists in other missions of the Department of the Environment and other government agencies or with universities through contractual arrangements. If the candidate chemical survives the testing procedure, it can be used on an operational scale, where monitoring is continued. If the chemical is still acceptable, it can be recommended for registration and general forestry use against the target species. Registration for use against other species of insects is not granted until additional testing is done. The insecticide, fenitrothion, which the Canadian Forestry Service recommended this year for use against the blackheaded budworm in northern Vancouver Island, is a major example of an insecticide that has been subjected to this rigorous screening program. Two reports (Krehm 1973; Yule 1971) illustrating the comprehensive information available are submitted separately to the Commission.

Role of Canadian Forestry Service in Major Pest Control Projects

Where outbreaks of destructive forest insects are extensive, the forest manager is faced with the risk of widespread and severe losses of timber. In British Columbia, outbreaks of

the hemlock looper and the blackheaded budworm have extended over hundreds of thousands of acres and killed hundreds of millions of board feet of prime timber. In Central B.C., over one-billion cubic feet of spruce was lost to the spruce bark beetle in the major outbreak between 1956 and 1965. Destructions of this magnitude can have a long-term effect on the forest ecosystem and on the socio-economic structure of a region.

Aerial spraying with pesticides has been used extensively to protect large areas of forest from severe defoliation. The most notable examples are the spraying operations against eastern hemlock looper in Newfoundland. Most of the spraying operations in British Columbia were reported in the Council of Forest Industries brief.

At present, direct control techniques are not practical for the bark beetles, although significant advances are being made in developing procedures that may have application in the future. For defoliators, there are several insecticides that can be sprayed from the air, and this technique has proved to be effective on many occasions. The Canadian Forestry Service role in these operations is to provide advice and guidance to the resource manager in the decision-making process and the conduct of the operations, and in the assessment and reporting of the results. Costs may also be shared according to the formula described earlier.

Procedures and the rationale employed in the decision-making process in these large-scale operations are described below.

The CFS conducts an annual survey of forest insect and disease conditions throughout Canada. Specially trained scientists and technicians are in the field throughout the summer, collecting samples in pre-selected areas and where insect outbreaks occur or are suspected. They collaborate closely with industry and other government forestry staffs to survey, map and report promptly on pest conditions. Serious pest outbreak conditions are reported in detail to the B.C. Forest Service and to the coordinating and action committees, such as the Pest Control Committee of the Council of Forest Industries or the Kootenay Pest Control Committee. In situations where there is a potential for significant tree mortality, special surveys are made in collaboration with industry and the B.C. Forest Service to collect detailed data on the conditions of the outbreak area. This information is analyzed and presented to special meetings where representatives of industry, B.C. Forest Service and other provincial and federal agencies responsible for the several aspects of resource and environmental management can evaluate the situation and determine an appropriate course of action. In

most instances, no control action is warranted; in a few cases, preparation for control with the option to abort may be necessary (e.g., hemlock needle miner outbreak on North Vancouver Island, 1965). On rare occasions, it is necessary to conduct a protective control operation; however, only a portion of the infestation area is considered for protective action. Eradication of a pest, or control of epidemic populations, is not regarded as feasible or desirable.

In arriving at the decision, the forest managers will consider:

- (i) The forecasted population density and its effect on tree condition.
- (ii) The present condition of the forest in terms of recent defoliation history, vigor and age of stands, species composition and susceptibility to the pest.
- (iii) Alternatives to direct control action and their consequences. These include: salvage logging, in which the capability to salvage must be assessed along with the cost of altering logging plans through decadence of unharvested stands which must be left while the salvage operation is undertaken, and no action, resulting in extensive mortality and loss of timber and increased fire hazard over large areas for many years.

- (iv) The overall forest management plans for the area and the region.
- (v) The alternative objectives of the proposed operation that must be considered. These can range from:
 - (a) simply keeping trees alive that would die if defoliated the next year, to (b) preventing reductions in annual increment and risk of loss to decay by top killing or accelerated decadence in old-growth stands, to (c) protecting amenity, recreational, property and other non production forestry related values.
- (vi) The economic and social consequences of inaction and various levels of action. Some form of cost benefit analysis is usually required. For relatively small operations, where the benefits are obviously high, the analysis may be cursory and highly subjective, but it is mandatory for the larger programs, where federal financial support is expected.

The Canadian Forestry Service also advises on the choice of insecticide, the dosage and method of application. Regional centres usually consult with the operational manager concerning the boundaries of the area to be treated, and advise on the development of the insect throughout the area and when to commence and cease operational spraying. The Service also assesses the effectiveness of the operation in

terms of insect population reduction and foliage protection. Special studies are usually carried out by CFS staff to determine effects on potentially sensitive non-target organisms. For example, in the operation this year on North Vancouver Island, the Chemical Control Research Institute conducted a special study to monitor the effects of fenitrothion on birds and small mammals in the coastal B.C. forest ecosystem. Special studies are also made on spray application equipment and procedures, coverage and drift.

Current Trends in Pesticide Use in Forestry

The nature and manner of pesticide use in forestry has changed significantly in the past decade. This is most evident in eastern Canada, where large-scale aerial spraying programs are still required to prevent extensive losses to the spruce budworm in the forests of Quebec and New Brunswick. A decade ago DDT and Phosphamidon were widely used at dosages of 1/2 to 1/4 lb. per acre. Today a more selective insecticide, fenitrothion, is used in these programs along with Zectran and Metacil. Application technology has improved considerably and dosages are in the order of 1 to 3 ounces per acre, with spray droplet sizes and frequency across the swath approaching that achieved with sophisticated Ultra Low Volum (ULV) apparatus.

Large 4 motor aircraft (DC-6B) equipped with electronic navigational instruments for guidance were used in Quebec this year and demonstrated the advantages and disadvantages of this new system in contrast to the more conventional spray aircraft (Grumman TBM Avenger) guided by observers flying above them in "bird-dog" aircraft. It was originally planned to spray at night with the DC-6 system and, although not approved this year, the concept of nighttime forest spraying will undoubtedly be thoroughly tested in the next few years.

An apparently successful attempt was made to control a developing outbreak of the spruce budworm in northwestern Ontario in 1968 and 1969. In this case an apparent epicentre was sprayed thoroughly before the epidemic spread into the surrounding forest. This approach has much to commend it and should be tested elsewhere.

Experiments were carried out in New Brunswick in 1972 and again in 1973 to spray adult moths of the spruce budworm. Massive moth flights into sprayed areas had often reduced the effectiveness of the spray conditions in the past and these trials were conducted after laboratory studies had shown that the adults were very sensitive to light dosages of Dimecron. Tracking of moth flights with radar was also successfully tested there in 1973.

In other areas of forestry, emphasis is being placed on the use of systemic chemicals which are absorbed or injected into the root system. While the cost factor is high, the technique may be practical in the protection of valuable shade and park trees.

Future Need for Pesticides

After a decade of relatively low forest pest activity, we have experienced a dramatic increase in the number of defoliator outbreaks in this province in 1972 and 1973 (Table 1). Most will probably collapse before control is required but, on the basis of past experience, we expect that some outbreaks will require protective action if extensive tree mortality is to be prevented. Each case will have to be considered on its merits, but it is obvious that there is a continuing requirement for pesticides in forest protection. In our opinion, the safeguards incorporated into the registration procedures and in the reviews of proposals by federal and provincial agencies are adequate to ensure that proposed pest control operations are necessary and that they will be conducted with minimal risk throughout the forest environment.

~~4.1.1.~~ (b) Biological Control of Forest Insects:

*info
on success*

To the casual observer of ecological problems, biological control is an attractive alternative to pesticides. Unfortunately, like most biological processes, it is an extremely complex and highly detailed subject which, within the limitations of our present knowledge and limited financial resources, only rarely provides a solution to current pest problems. Rather than review the progress and theory, we are attaching to the brief a recent review of biological control programs against insects and weeds in Canada for the period 1959-1968. This review summarizes the current situation in both forestry and agriculture, and includes many valuable recommendations which we endorse. We recommend Parts III and IV of this document for the consideration of this Royal Commission.

Current efforts in the introduction of parasites and predators to control pests in B.C. include programs on the larch casebearer and the balsam woolly aphid. We also plan to introduce a promising parasite of the larch sawfly into B.C. in 1974-75. Successful control of the larch casebearer has been achieved elsewhere in North America and we are optimistic of good results in B.C. in the next few years. Although many species of predators of the balsam woolly aphid have been introduced into British Columbia and elsewhere in North America, biological control

with introduced predators of this pest has not succeeded.

With regard to native biological control organisms, we recovered a fungus disease, Cordyceps militaris, from the green-striped forest looper during the recent outbreak on Northern Vancouver Island. Techniques have been developed to propagate this fungus and it has been tested in the laboratory and in the field against several defoliators, with promising results in some cases. Development work is continuing.

A few strains of the bacterium Bacillus thuringiensis Berliner are available commercially. Effectiveness of B.t. varies with the strain used, the target species, application time and dosage and many environmental factors. In many ways this bacterium appears to act more as a chemical insecticide than a pathogen, since its effect depends largely on the toxicity of a protein crystal that accompanies the bacterium spore. Susceptibility varies between orders and families of insects, but the Lepidoptera are among the more susceptible. Since B.t. acts selectively with little risk of adverse environmental effects, it is generally desirable for widespread application, provided an adequate degree of pest reduction can be achieved.

Insect pathologists in the Canadian Forestry Service have experimented with various strains of B.t. for many years and have been active in its development. Recent experiments

have shown that the effect of B.t. on spruce budworm can be enhanced with the addition of the enzyme chitinase. Several trials were conducted in Eastern Canada in 1973 to compare the effectiveness of two strains of B.t. (with and without chitinase) with the insecticide fenitrothion. One strain of B.t. was also tested against the false hemlock looper near Salmon Arm in 1973. This trial was conducted by the British Columbia Forest Service, Abbott Laboratories Inc. and the Canadian Forestry Service to determine the susceptibility of the looper through a range of dosages from 1/4 lb. to 1 lb. per acre. It is our expectation that the use of B.t. will increase considerably. We encourage its use against lepidopterous defoliators in parks and other recreation areas, and near lakes and streams. Further testing and development may be required before it can be recommended or becomes practical for general use in production forests.

4.1.1. (c) Development of Alternative Control Techniques:

The development and implementation of forest management guidelines to reduce the risks and magnitude of pesticide outbreaks is a long-term aim of most Canadian Forestry Service pest research projects. For many insects and some diseases, pesticides offer an immediate relief in a crisis situation. Fortunately, the technology of pesticide use and application has been refined and the risk of wide-spread

ecosystem catastrophies ^{is low} has been reduced in a well-managed operation. Outbreaks of major pests cannot be controlled by insecticides without causing unreasonable damage to the forest ecosystem, and thus, chemical control action is not warranted (e.g., bark beetles and balsam woolly aphid). However, alternative approaches are being investigated, some of which appear promising for pests that cannot be controlled at present and for those that can be controlled by pesticides.

Pheromones:

Synthetic pheromones that attract certain forest insects have been produced and are being tested. In this region, we are testing attractants for the spruce budworm and the spruce beetle in cooperation with scientists in other Canadian Forestry Service establishments and in the United States. Both pheromones are proving to be valuable aids in surveying and estimating population densities. The bark beetle pheromone, frontalin, is being used to aggregate spruce beetles and induce them to attack pre-selected trees, which is a major advance in the manipulation of the behavior of a population.

Fertilizers:

Laboratory studies with the balsam woolly aphid have shown

that significant population increases and decreases occur when the host tree is treated with different forms of nitrogenous fertilizer. An extensive study to test this hypothesis under field conditions is being carried out in a balsam woolly aphid infested forest near Duncan.

Insect Hormones:

Extracts with juvenile hormone-like properties have been taken from western red cedar, Douglas-fir and the balsams in B.C. by scientists at the Western Forest Products Laboratory and the Pacific Forest Research Centre. These extracts, and natural and synthetic juvenile hormone compounds, have been tested in the laboratory at the PFRC and at the Insect Pathology Research Institute. A small field test against the eastern hemlock looper, using a commercially produced juvenile hormone analogue, was conducted this year by staff of the Laurentian Forest Research Centre in Quebec, however, results are not yet available. These compounds hold some promise for insect control but considerable investigation will be required to establish specificity, since this group of hormones is associated with the moulting process, which is common to many arthropods.

All of these techniques interfere with biological processes and hence with ecosystem stability, and it should be recognized that their use will disrupt some components of

the ecosystem. For example, the bark beetle pheromone, frontalin also attracts an important predator which is caught with the beetles. As with pesticides, these techniques will be refined, but they will always have an undesirable effect on some component of the ecosystem.

Forest Resource
4.1.1. (d) Herbicides:

The use and extent of herbicide treatments in British Columbia forests has been outlined in other briefs to the Commission (Council of Forest Industries of British Columbia and the British Columbia Forest Service). The Canadian Forestry Service has received few requests for research in the use of herbicides in forestry or their effects in the forest ecosystem. Consequently, this type of work has a low priority in our research program.

The Chemical Control Research Institute has no active investigations in herbicides, but it maintains a file and bibliography on properties and side effects. The institute also maintains an active liaison with those engaged in research and regulation of herbicides, principally in the Canada Department of Agriculture and in industry, and has been able to answer questions referred to them at short notice.

The Canadian Forestry Service has not conducted any research on the use or effects of herbicides in British Columbia, but in recognition of the increasing forestry use of these compounds, particularly in the western United States and Canada, it has contracted to have an annotated bibliography of herbicides in forest ecosystems prepared. This report, to be available shortly, forms the basis for a critical review to be completed during 1974-75. The prerequisites and priorities of herbicide research will be examined in the light of this review and reports of the findings of this Royal Commission and other hearings on this subject that are scheduled in the near future (e.g., United States Environmental Protection Agency hearings on 2,4,5-Trichlorophenoxyacetic acid, April, 1974).

TABLE I: Damage Potential and Current Status of Some Common Forest Insect Pests in British Columbia.

COMMON NAME	DAMAGE POTENTIAL MORTALITY	SEVERE GROWTH LOSS	BEGINNING OF CURRENT OUTBREAK	LAST MAJOR OUTBREAK PERIOD	CURRENT TREND	REMARKS
Blackheaded budworm	Occasional	Frequent	1969	1953 to 1957	Decreasing on Vancouver Is. Increasing on North Coast	Frequent large outbreaks
Spruce budworm	Frequent	Frequent	1969	1953 to 1959	Increasing in Fraser Canyon Low in Prince George	Frequent large outbreaks in three different forests
Hemlock looper	Frequent	Occasional	1971	1941 to 1946	Increasing in Columbia R. - Arrow Lakes Valley	Severe killer on coast, occasional growth loss in interior
Hemlock sawfly	Rare	Occasional	1973-	1955 to 1957	Increasing	Associated with blackheaded budworm outbreaks
Douglas-fir tussock moth	Frequent	Frequent	1971-	1961 to 1963	Decreasing	Important in amenity forests of Okanagan
Forest tent caterpillar	Rare	Frequent	1972-	1960 to 1964 1966 to 1969	Increasing	Large spectacular outbreaks on aspen
Larch budmoth	Rare	Occasional	1973-	1965 to 1967	Increasing	Sporadic, at high elevations

TABLE I: Damage Potential and Current Status of Some Common Forest Insect Pests in British Columbia. (Cont'd.)

COMMON NAME	DAMAGE POTENTIAL MORTALITY	SEVERE GROWTH LOSS	BEGINNING OF CURRENT OUTBREAK	LAST MAJOR OUTBREAK PERIOD	CURRENT TREND	REMARKS
Black army cutworm	Frequent	Frequent	1973-	none reported in forested areas	Increasing	First time reported in plantations. Large regenerated areas completely defoliated
Cooley spruce aphid	None	Rare	N.A.	N.A.	Increasing	Deforms spruce, important in nurseries Christmas trees
Larch casebearer	Occasional	Frequent	1966-	new pest	Static at high level, spreading	New pest, spread from U.S., continuously high populations
False hemlock looper	Occasional	Occasional	1972-	1947 to 1948	Increasing	Sporadic localized outbreaks
Phantom hemlock looper						
Filament bearer looper	Frequent	Occasional	1971-	1956 to 1957	Increasing	Associated with hemlock looper. Damage inseparable
Green-striped forest looper				1969 to 1970	Low	
Saddle-back forest looper	Occasional	Rare	N.A.	1959 to 1962		Sporadic severe local outbreaks

TABLE I: Damage Potential and Current Status of Some Common Forest Insect Pests in British Columbia. (Cont'd.)

COMMON NAME	DAMAGE POTENTIAL MORTALITY	SEVERE GROWTH LOSS	BEGINNING OF CURRENT OUTBREAK	LAST MAJOR OUTBREAK PERIOD	CURRENT TREND	REMARKS
Mountain pine beetle	Frequent	--	1970-	1964 to 1969	Increasing	Tens of Thousands of trees being killed annually
Douglas-fir beetle	Frequent	--	1973-	1954 to 1966	Increasing	Currently low, but often kills thousands of trees
Spruce beetle	Frequent	--	--	1968 to 1970	Low	Currently low, but often kills all
Balsam woolly aphid	Frequent	Frequent	--	1963 to 1969	Static	New pest, destroying Abies in S.W. British Columbia
Sitka spruce weevil	Nil	Frequent	N.A.	N.A.	Continuously high	Deforms tree, makes planting Sitka spruce uneconomical

4.1.2. Canadian Forestry Service -- Western Forest Products Laboratory.

Because of the value of forests in the Canadian economy, the Western Forest Products Laboratory was established to study means to utilize more effectively Western Canadian forest resources. Research effort is concerned with the physical, chemical and anatomical properties of wood, wood processing technology and wood pathology and preservation. These relate to the use of wood as building material, engineered components, plywood, fibre products, fuel, and as a source of chemicals.

Wood as a biological material is subject to deterioration by fungi, insects and marine animals that utilize it for shelter and food. Because of the latter factors, wood may deteriorate, eventually becoming valueless as a structural material or as a source of fibre or chemicals. To prevent this loss and to extend the useful life of wood, protection against attack by organisms is a necessary consideration in the utilization of wood. Studies of this aspect form a basic part of the Laboratory research effort.

The presence of moisture and air in wood favors its attack by organisms. These conditions exist in wood in the tree and in the freshly manufactured product, and the most practical means of preservation is to remove moisture. However, to

produce a dry product is both time-consuming and expensive in terms of equipment, production and storage, hence pesticide treatment is a much used alternative.

Treatment of lumber and timbers with pesticides falls into two categories: (1) temporary protection of green lumber with anti-stain and mould preventives during water-borne shipment to overseas markets, and (2) the more permanent preservative treatment of utility poles, railway ties, marine piling, bridge timbers, wharves and bridge decking, etc. These categories will be discussed separately.

(a) Temporary Protection:

About 4,000 million board feet of lumber is shipped annually by sea, mostly in packages in the green condition. To protect against stain and mould formation during shipment, this lumber is treated by dipping or by spraying with a dilute solution of mainly tetra and trichlorinated phenols. This treatment has been successfully used for some years. It is applied to about 80 per cent of the production of coastal mills and to about 7 per cent of the interior production when unseasoned lumber is moved to the Coast for transshipment to overseas markets. An amount in excess of 250 tons of prepared concentrates is required annually for this purpose.

Research at the Western Forest Products Laboratory, which formerly concentrated on adequate treatment, measurement of retentions, etc., is now mainly concerned with studies of degradation of chlorinated phenols by microorganisms where it has been shown that certain common fungal strains can detoxify these compounds. Other work is concerned with testing newly developed fungicides of low mammalian toxicity for this purpose. In cooperation with industry, application methods are under surveillance, and recent changes in sawmills, for example, have seen a reduction in leakage of chemicals through greater use of enclosed lumber dipping tanks, instead of broadcast spray units.

It is intended that the Laboratory prepare a handbook of correct procedures for handling anti-stain chemicals, including techniques for waste disposal, to ensure that all personnel concerned with operation and management are aware of environmental hazards.

(b) Permanent Preservative Treatment:

The second major area of chemical treatment is concerned with pressure processes where larger loadings are required to protect wood in biologically ^{As before} hazardous environments, such as ground contact areas of high humidity or in marine uses (pilings, wharves, etc.).

After pressure preservative treatment, products, such as poles, railway posts, ties and bridge timbers, can be expected to serve for 30 years or more. Without treatment, they would fail in 6-10 years. Untreated piling for wharves has been known to fail within 3 years. Some 600,000 poles and piles, one million railway ties and 13 million board feet of lumber are treated annually in plants in the lower mainland, the Prince George area, the Kootenays and Dawson Creek. Over 300 tons of pentachlorophenol, 3000 tons of creosote and 140 tons of copper-chrome arsenate salts are applied annually.

It is our opinion that in the wood-production industry, there is an ^{growing} ~~acute~~ awareness of the environmental hazards of using wood preservatives. In particular, pressure treating plants are making greater efforts to recover excess treating solutions that may spill during the process, and also to destroy toxic residues in high-temperature furnaces rather than through use of waste pits.

Preservation research at the Western Forest Products Laboratory has been mainly concerned with improving penetration, quality control methods, and ^{and developing} ~~means of~~ ^{new agents} identifying the preservative retention potential of individual trees of species used for poles and marine piling.

The laboratory has technical personnel in wood pathology and wood preservation, as well as an Environmental Quality Officer available for consultation on all facets of the use of pesticides of a wood preservative nature.

4.2. Canadian Wildlife Service (CWS):

The Canadian Wildlife Service is another component of the environmental Management Service. Studies have been carried out to assess hazards of mercury and organochlorine insecticides in terrestrial and aquatic wildlife (Keith and Reynolds, 1971; Vermeer, 1971; Fimreite, Fyfe and Keith, 1970), the effects on wildlife of prolonged, large-scale chemical spray operations using phosphamidon and fenitrothion in New Brunswick, (Pearce, 1971), organochlorine residues in prairie falcons (Fyfe, et al, 1969) and ecological considerations of herbicide use in Alberta (Patterson, 1973). On the Pacific coast preliminary studies are currently being conducted to determine the effects of petroleum hydrocarbons on aquatic ecosystems and their sublethal effects on marine seabird populations.

About 27 million acres of cropland in the Canadian prairies are sprayed annually with ^{chloro}phenoxy herbicides (about 20 million pounds of 2,4,-D and MCPA) (Maybank and Yoshida, 1969). In British Columbia the field crop acreage treated in 1972 amounted to 3,500 acres (14,000 lb. 2,4,-D and MCPA).

35,000

Maybank and Yoshida (1969) demonstrated that in Saskatchewan, up to 30% of the ground sprayed, 2,4-D is subject to drift. As a result of spray drift and atmospheric contamination, one of the serious side effects is the impact on non-target ecosystems and habitat damage. ~~Evaluation~~ of herbicide spray programs on rights-of-way for roads, railroads, pipelines, utility transmission lines and irrigation projects comprising about one million acres (Oetting, 1971) and the ecological ^{effects} ~~evaluation~~ of picloram on non-cropland vegetation are being evaluated (Patterson, 1973).

Some effects on wildlife of prolonged large-scale chemical spray operations to protect New Brunswick forests against defoliation by the spruce budworm have been reviewed by Pearce (1971). The short-lived organophosphate insecticides, phosphamidon and fenitrothion, which replaced DDT, damaged bird populations at dosages used initially. The hazard was reduced when application rates were lowered. Currently, fenitrothion is used to control forest insects in B.C. In 1973, 29,000 acres in the Port Alice area was sprayed. No biological studies comparable to those conducted by Canadian Wildlife Service personnel in New Brunswick were carried out.

Organochlorine insecticides, such as DDT and dieldrin, have

TABLE II: DDE, AND TOTAL MERCURY LEVELS IN FISH-EATING BIRDS, 1963-72 -- EUROPE AND ATLANTIC COAST:

SPECIES	SITE (Author)	N	TISSUE	mean ppm wet weight	
				DDE	Hg
Gannet (<i>Sula bassana</i>)	GULF OF ST. LAWRENCE				
	Bonaventure I. P.Q. (36)	9	E	29.60	--
	" (36)	10	E	14.90	--
	" (36)	10	B	3.30	--
	Janeville NB (49)	1*	B,B,L	49.50	3.20
Double-crested Cormorant (<i>Phalacrocorax auritus</i>)	Bathurst NB (49)	1*	B	1.76	--
	Magdalen Is. P.Q. (49)	1*	B	19.10	--
	Riorden NB (49)	5	E	9.91	.50
	Heron I. NB (49)	10	E	7.84	.31
	Dalhousie NB (15)	3	L	--	3.51
Wing-billed Gull (<i>Larus delawarensis</i>)	Bathurst NB (15)	1	L	--	11.30
	Bathurst NB (49)	7	E	1.45	.08
Common Tern (<i>Sterna hirundo</i>)	Bathurst NB (51)	10	E	.91	.12
	" (49)	10	E	.64	.13
	" (15)	4	E	--	.58
	" (15)	4	L	--	2.50
	ELSEWHERE				
Gannet	Funk I. Nfld. (36)	10	B	1.48	--
Double-crested Cormorant	Bay of Fundy				
	-Manawagonish I. NB (49)	10	E	7.46	.23
	-Fatpot I. NB (65)	11	E	29.40	--
	-Hospital I. NB (65)	4	E	8.63	--
	Gulf of Maine				
Gannet	-Muscongus Bay Me. (42)	24	E	6.20	--
	-Duck I. Me. (42)	11	E	7.60	--
	Great Lakes (2)	3	E	30.00	--

TABLE II: DDE, AND TOTAL MERCURY LEVELS IN FISH-EATING BIRDS, 1963-72 -- EUROPE AND ATLANTIC COAST:

SPECIES	SITE (Author)	N	TISSUE	mean ppm wet weight	
				DDE	Hg
Shag (Phalacrocorax aristotelis)	Ireland SE Coast (45)	5	E	.30-.70	--
	Scotland NW Coast (47)	5	E	.36	--
	Scotland SW Coast (53)	6	E	2.20	--
	England NE Coast (53)	5	E	1.60	--
	" (45)	2	E	3.70	--
Herring Gull (Larus argentatus)	Britain NE Coast (9)	302	E	1.93	--
	Bay of Fundy				
	-Fatpot I. NB (65)	10	E	5.67	--
	-Hospital I. NB (65)	3	E	2.83	--
	Lake Michigan (37)	36	E	71.00	--
Common Tern	England NE Coast (44, 53)	6,1	E	.55	--
	Norway W Coast (4)	80	E	1.53	--
	Britain E Coast (45, 53)	8,14	E	.20-.70	--
	Lake Ontario (51)	10	E	23.10	.87
	Long I. NY (8)	9	E	--	.073***
Common Puffin (Fratercula arctica)	" (24)	5	M(ch)	2.05	.81
	" (24)	4	M(imm)	1.25	--
	Avalon Pen. Nfld. (37)	20	E	.67	--
	" (36)	5	WB(imm)	.25	--
	Labrador (36)	10	M	.29	--
	England NE Coast (45)	1	E	1.00	--
	Scotland NW Coast (47)	5	E	.18	.43**
	" (47)	1	WB(ad)	.47	.74**

TABLE II: DDE, AND TOTAL MERCURY LEVELS IN FISH-EATING BIRDS, 1963-72 -- EUROPE AND ATLANTIC COAST:

SPECIES	SITE (Author)	N	TISSUE	mean ppm wet weight	
				DDE	Hg
Common Murre (Uria aalge)	Labrador (36)	10	M	.30	--
	" (36)	9	E	.77	--
	Scotland SW Coast (53)	7	E	2.00	--
	England NE Coast (44)	4	E	2.30	--
	" (53)	8	E	.70	--
	Baltic Sea (35)	9	E	38.80	--

*bird found dead or dying, **calculated from dry weight, ***geometric mean

E = whole egg, M = muscle, WB = whole body, B = brain, L = liver

ch = chick, imm = immature, ad = adult.

been used extensively in agriculture, forestry, and industry for the control of disease vectors for more than 20 years. This type of substance persists in the environment much longer than most pesticides and also shows the feature of fat solubility which causes it to be stored in lipids. This in turn enables it to be transferred from one organism to another. From a model to predict the global distribution and accumulation of DDT, Cramer (1973) suggested that the time required to return to equilibrium after the termination of DDT usage lies somewhere between 25 and 110 years. The concentration of DDT in marine life is already near its equilibrium value and should not increase significantly in the future. In recent years, experimental studies have shown that persistent organochlorine insecticides have a wide range of subacute effects at doses considerably below the acute ones. These include effects on enzyme induction, fine structure, metabolism, reproduction and behaviour.

The Canadian Wildlife Service is concerned about the sublethal effects of the widespread distribution of organochlorine insecticides in the food-chain and the concentration of these residues in marine seabird populations. Eggshell thinning and egg breakage associated with large residues of organochlorine insecticides have been reported in heron, golden eagle, peregrine and sparrowhawk.

TABLE III: DDE, AND TOTAL MERCURY LEVELS IN FISH-EATING BIRDS -- PACIFIC COAST:

SPECIES	SITE	TISSUE	N	Mean ppm.	
				DDE	Hg
Pelagic Cormorant	Nanimo	Liver	5	--	2.060
Pelagic Cormorant	Mandarte	Eggs	10	0.819	0.350
Pelagic Cormorant	Mittlenatch Is.	Eggs	10	0.549	0.160
Double-Crested Cormorant	Mandarte Is.	Eggs	3	4.070	0.360
White Pelican	Stum Lake	Eggs	10	2.800	0.376
Sooty Shearwater	Masset/71	Carcas Whole	1	0.116	0.080
Fork-tailed Petrel	Skedans Is./70	Eggs	2	4.080	0.280
Leach's Petrel	Cleland Is./70	Eggs	10	2.160	0.380
Glaucous winged gull	Boundary Bay	Muscle	6	0.120	--
		Brain	6	0.038	--
Glaucous winged gull	Port Alberni	Liver	3	--	0.039
Glaucous winged gull	Nanimo	Liver	1	--	0.100
Glaucous winged gull	Horseshoe Bay	Liver	4	--	0.500
Glaucous winged gull	Cleland Is./70	Eggs	10	1.590	0.130
Glaucous winged gull	Mandarte Is./70	Eggs	10	0.750	0.130
Glaucous winged gull	Mittlenatch Is./70	Eggs	10	0.456	0.210
Glaucous winged gull	Stevenson Islets	Eggs	10	1.430	0.170
Glaucous winged gull	Lucy Is./70	Eggs	10	0.282	0.160
Glaucous winged gull	Skedans Is./70	Eggs	10	0.342	0.080
Glaucous winged gull	Bonilla Is./70 (Northwest Rocks)	Eggs	10	0.224	0.050

TABLE III: DDE, AND TOTAL MERCURY LEVELS IN FISH-EATING BIRDS -- PACIFIC COAST:

SPECIES	SITE	TISSUE	N	Mean ppm.	
				DDE	Hg
Western gull	Nanaimo/68	Liver	3	--	0.250
Bonaparte gull	Horseshoe Bay	--	-	--	0.190
Osprey	Kootenay R./69	Egg	1	6.110	--
Osprey	Kootenay R./69	Egg	1	3.370	--
Common Murre	Q.C.	Whole Bird	1	1.210	--
Common Murre	Samiahmoo Bay	Liver	1	0.580	0.410
Common Murre	Samiahmoo Bay	Liver	1	0.630	0.230
Pigeon Guillemot	Skedans Is./70	Eggs	2	1.640	0.330
Pigeon Guillemot	Cleland Is./70	Egg	1	1.260	0.450
Pigeon Guillemot	Mittlenatch Is./70	Eggs	10	0.604	0.470
Tufted Puffin	Cleland Is./70	Egg	1	0.424	0.110
Tufted Puffin	Cox Is. (Q.C.)/71	Whole Carcas	1	0.259	0.340
Tufted Puffine	Cox Is. (Q.C.)/71	Whole Carcas	1	0.480	0.260
Rhinoceros Auklet	Explorer Bay Langara	Muscle	1	0.232	--
		Fat	1	17.700	--
			1	--	--
		Liver	1	0.551	--
		Brain	-	0.143	--
		Muscle	1	0.115	--

TABLE III: DDE, AND TOTAL MERCURY LEVELS IN FISH-EATING BIRDS -- PACIFIC COAST:

SPECIES	SITE	TISSUE	N	Mean ppm.	
				DDE	Hg
Rhinoceros Auklet	Explorer Bay Langara	Fat	1	6.420	--
		--	1	--	--
		Liver	1	0.381	--
		Brain	1	0.067	--
Rhinoceros Auklet	Lucy Is./70	Eggs	10	2.840	0.320
Rhinoceros Auklet	Moore Is./70	Egg	1	2.090	0.130
Rhinoceros Auklet	W.Q.C. Is.	Whole Bird	1	3.510	0.430
Rhinoceros Auklet	W.Q.C. Is.	--	1	9.840	0.310
Cassin's Auklet	Q.C.	Whole Bird	1	0.174	0.180
		--	1	1.260	0.130
Cassin's Auklet	Moore Is.	Eggs	3	2.920	0.050
Ancient Murrelet	Langara Is./68	Eggs	5	0.900	--
Ancient Murrelet	Langara Is./68	Muscle	7	0.150	--
Ancient Murrelet	Langara Is./68	Fat	7	5.270	--
Ancient Murrelet	Langara Is./68	Liver	7	0.128	--
Ancient Murrelet	Langara Is./68	Brain	6	0.046	--
Ancient Murrelet	Langara Is./68	Chick	2	5.740	--
Ancient Murrelet	Langara Is./68	Whole Bird	2	1.320	0.230
Marbled Murrelet	Port Alberni	Liver	3	--	0.380
Marbled Murrelet	Horseshoe Bay	Liver	3	--	2.220 (4.9)
Marbled Murrelet	Egeria Bay (Q.C.)/67	Muscle	3	0.310	--
		Fat	3	1.510	--
		Liver	3	0.147	--
		Brain	3	0.048	--

Bogan and Banine (1972) reported that the ratio of organochlorine (pp'-DDE) levels in the Kittiwake was at least 60 compared with ratios of 2 to 10 in other Atlantic seabirds. The total organochlorine content in muscle and liver was generally low in auks and shearwaters (0.1 - 1.0 ppm). DDE levels were higher in the kittiwake, fulmar and storm petrels, 1 - 10 ppm. The highest levels were found in glaucous gulls breeding above seabird colonies. The levels in normal birds amounted to 17 ppm DDE in the liver. In others, the levels were 67 ppm DDE in fat. DDE concentrations of fish-eating birds were reported by Pearce et al. (1973). He suggested that North American species were appreciably more contaminated than closely-related species in Europe (Table II). DDE levels in fish-eating species on the Pacific coast (Table III) tended to be lower than levels found in gannets, double crested cormorant (Gulf of St. Lawrence) (Table III) and were similar to levels reported in British seabirds.

4.3. Inland Waters Directorate (IWD):

The role of the Water Quality Branch of the Inland Waters Directorate is largely described by the terms of the Canada Water Act. When there is a significant national interest in the management of a water resource, the IWD is required to assess the quality and use of the water

and to initiate and implement programs to restore, preserve, or enhance the water quality. Our role as it relates to pesticides is thus to measure the level in inland waters of national interest and to recommend action required to reduce or maintain these levels of pesticides.

Our major concerns are:

- (a) The accessibility of pesticides used on land areas to the aquatic environment;
- (b) the direct use of pesticides on or in the aquatic environment;
- (c) the degradation rate of pesticides in the aquatic environment;
- (d) the impact of the pesticide and its degradation products on the aquatic environment.

5. ROLE, INVOLVEMENT AND CONCERNS -- Fisheries and Marine Service:

 This service consists of three components:

 Fisheries Operations

 Fisheries Research and Development

 Marine Sciences Directorate

5.1. Fisheries Operations:

 Fisheries Operations, (formerly the Department of Fisheries) is primarily responsible for all aspects of the management of the fisheries resource and other aquatic organisms.

 Section 33 (2) of the Fisheries Act prohibits the deposit of substances deleterious to fish into waters frequented by them. All chemical base pesticides are demonstrably toxic to fish under experimental conditions so that pesticide applications must be kept under careful surveillance and control if deleterious effects are not to ensue as a consequence of pesticide use near fish-bearing waters (McKee and Wolf, 1971; Richmond and Ilnytzky, 1972; Rudd and Genelly, 1956).

 Historically, the Department of Fisheries first became deeply involved with large scale pesticide application in 1956-57 when 155,000 acres of forest were treated with DDT at the rate of 1 lb. per acre to control a serious outbreak of blackheaded budworms on Northern Vancouver Island.

The consequences of the decision to treat the infested forest without due regard to its impact on the fisheries resource became shockingly evident in four major streams (the Keogh, Benson, Klashkish and Waakaas Rivers).

The progeny from an estimated 43,000 coho salmon spawners and several thousand steelhead and trout were almost totally eliminated (Crouter and Vernon, 1959). The coho was the only salmon species affected because only their progeny were present in the stream at the time of spraying.


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The 1956 coho salmon spawning escapement to the affected streams have not yet returned to the pre-spray population levels and the estimated direct cost to the fishing industry is in the order of millions of dollars. Indeed, the immediate effects on the fisheries resource and the resulting public outcry became so apparent that the Pest Control Committee became the first resource use body to adopt the concepts of multiple resource management in British Columbia.

Since that initial, disastrous exposure to the hazards of large scale pesticide application, forest spraying for pest control has not been the cause of a fish kill in British Columbia. Referral systems were developed, the advice of fisheries representatives to the Pest Control Committee fell on receptive ears, dosages were modified, the leave strip concept was almost universally applied, timing of applications to coincide with non-critical

periods was adopted when possible, on-the-spot surveillance was increased to stop pesticide applications when unforeseen hazards developed, alternative pesticides less hazardous to fish were tested and utilized and the application rates required to control insect infestations were subjected to more intense scrutiny so that the likelihood of applying pesticides at dosages three or four times greater than required ultimately became extremely remote, (Jackson, 1960; Todd and Jackson, 1961; Schouwenburg, 1964; Schouwenburg and Jackson, 1966; Jackson, 1966).

In 1963 another major fish kill occurred from the application of DDT in the Shuswap Lake area to control mosquitos. An estimated three million juvenile sockeye and chinook salmon were killed. These mortalities imposed a direct cost on the fishing industry of approximately \$250,000. The applicator was successfully prosecuted under Section 33 (2) of the Fisheries Act -- the first such prosecution under this legislation for pesticide misuse in British Columbia. From that time on, Fisheries Operations was represented on boards or associations known to sponsor mosquito control programs so that fisheries concerns were recognized during the planning stages of future control operations.

Following the Shuswap incident, Fisheries Operations also undertook a substantial public education program in which members of our technical staff would participate in training

programs for spray applicators and citizen groups which were sponsored by the Provincial Department of Agriculture. In these sessions the environmental hazards of pesticide usage were explained and illustrated, as was the methodology of hazard assessment and hazard avoidance. 

Presently our concern is the chronic or sublethal effect many pesticides may have on fish life. (It is interesting to note that DDT was withdrawn from the market when some of its subtle detrimental effects became known.) Conventional safe practises will reduce the chance of chemicals entering the waters and thereby the probability of experiencing sublethal effects. However, little information is available on the effects that low dosages of water borne pesticides may have on fish food organisms.

Monitoring of the 1973 fenitrothion program on Northern Vancouver Island showed that no acute fish toxicities occurred but the 600 foot leave strips did not prevent a massive killing of terrestrial streamside invertebrates upon which rearing fish depend for a large portion of their food supply. (In addition these contaminated invertebrates fell into the streams in large quantities where rearing fish fed upon them.) No immediate or direct fish mortalities were documented but due to a reduction of food supply the survival of fish in the stream could be reduced (Taylor and Langer 1973).

5.1.1. Vegetation Control.

The volume of applications for the use of herbicides in the forest has increased approximately five times since 1965. Extensive use of 2,4,-D, 2,4,5-T, picloram, borates and related compounds is made in a wide range of forestry programs including road maintenance, alder and maple control, conifer thinning, and other reforestation techniques (brown & burn). These programs involve hundreds of acres, many of which are adjacent to fish-bearing streams and their tributaries.

Close cooperation between the forest companies and the government has discouraged the use of the more acutely toxic herbicides and has maintained buffer strips between streams and the treatment areas.

In general we try to keep all non-aerial spray applicator equipment 50 feet from streams; but a minimum of 30 foot untreated area should be left between stream and spray deposition areas. However, selective hand application may be undertaken to within 10 feet of the stream bank. A 10 foot bankside green strip is necessary to provide erosion control, shade and protection for rearing fish, habitat for terrestrial insect forms that serve as fish food organisms, and to provide deciduous litter that

contributes to the aquatic nutrients necessary for stream invertebrate population which again serve as fish food organisms.

Our main concerns with herbicide usage are basically related to sublethal effects. Sublethal effects could be catagorized as (a) the removal of streamside vegetation and the effect this produces on aquatic life and (b) the reaction of aquatic organisms to sublethal doses of chemical that may enter the stream. There is little information available on the sublethal effect of herbicides on fish although herbicides have been shown to adversely affect fish growth at concentrations as little as 3% of their commonly referred to toxicity (LC_{50} or TL_m) level (Webb and Brett, 1973).

Routine forestry usage of herbicides carries with it the problems of adequate applicator education, and adequate monitoring and inspection to ensure guidelines are effective and are being adhered to. Considering the large number of individuals involved in forestry pesticide application, continual applicator upgrading seems a prime requisite.

5.1.2. Industrial Weed Control.

Industrial weed control usually involves the treatment of areas with herbicides where unwanted plants become a nuisance. Such areas include powerline and telephone right-of-ways, ditches, yards and other general equipment areas where no ground cover is preferred.

Our concerns for these types of programs are very similar to those mentioned in the previously discussed forestry programs involving herbicides. The only difference is that in industrial weed control programs larger dosage rates of more persistent herbicides are used to sterilize the ground for as long a time period as possible. Since most large scale programs (e.g., road, railroad, powerline right-of-ways) usually cross streams and runoff channels, the probability of herbicides entering fish frequented waters is fairly great.

Fortunately most such large scale programs are forwarded to Fisheries Operations for review. We have insisted ^{on} ~~on~~ ^{dosage reduction where such possible} ~~dosage rates that do not exceed those recommended by the~~ manufacturer and that generous leave strips be left around fish frequented water bodies or drainages leading to such waters. The programs of greatest concern are those where ^{in drift by Road side broadcasting} ~~herbicides are applied by helicopter or railroad cars.~~

This type of dispensing equipment usually does not enable the applicator to respect streams because the sprayer is over the stream before it is noticed. ^{can be shut off,} ~~is noticed.~~

Most spray programs involving vegetation control around industrial installations such as pipelines, refineries, yard drainage ditches, etc. rarely are forwarded to our Service for review. Many of these programs are known to involve commercial applicators.

Other than the acute toxicity problems inherent in such programs one must consider unknown sublethal effects such as physiological stress, and the removal of bankside cover, and the promotion of erosion by ^{removing} ~~disallow-~~ing good ground cover.

5.1.3. Agricultural Pesticide Use.

The agriculture industry is one of the largest pesticide users in this province in terms of volumes used and areas treated. Since most agricultural activities are restricted to valley bottoms, most agricultural pest control programs are adjacent to water bodies frequented by living organisms. Non-commercial farm applicators are relatively uncontrolled in this province and this area of pesticide use is of an extreme concern to Fisheries Operations.

The industry uses agricultural chemicals for biting insect control, crop insect control, seed treatment, crop weed control, grazing land pest control and parasite control. A broad spectrum of pesticides are used that can be extremely toxic. Farmer applicators do not have to

attend applicator courses and their programs have harmed aquatic life in the past. For example, a farm in the Chilliwack area is presently being prosecuted for indiscriminately storing large volumes of chemicals, including deadly Dinitrophenol, alongside a fish stream and allowing spillage of herbicide into the stream where it is alledged to have caused a substantial fish kill.

In 1970 another fish kill occured in the same area. The dead fish had quantities of herbicide in their body tissues when analysed. The adjoining field had recently been sprayed with a boom sprayer which could have easily extended over the stream.

Grasshopper control programs cover hundreds of acres of Interior crop and rangeland. In 1972 an unexplained fish kill occurred in the Nicola River immediately adjacent to such a program conducted by an inexperienced summer student employee.

These are a few examples of some of the acute effects uncontrolled agricultural pesticide use may have on fish bearing waters. It is our belief that this uncontrolled use is doing widespread damage through direct kills and numerous undocumented sublethal effects. These sublethal effects can include the lowering of the physiological resistance of fish to various other environmental stresses,

the destruction of fish food organisms, and the lowering of primary production in streams.

5.1.4. Mosquito Control.

One form or another of mosquito control is practiced in most well populated areas of British Columbia. Unfortunately improper mosquito control can clash with the fishery resource because often mosquito larvae develop in waters frequented by fish. Chemicals have become the most convenient method of controlling mosquitos in this province.

It is our policy that chemicals must only be used as a last resort. Presently not enough emphasis is placed on the physical control of mosquitos on their breeding grounds. For example stagnant pools can be drained as a permanent solution and pools that cannot be drained can be treated with light oils to kill the larvae. If these methods are impractical chemical larval control with 'Abate' is acceptable. Once the mosquitos have emerged, no adult control program can be effective and chemical adulticiding poses the greatest threat to the fishery resource. Therefore it must be considered a last resort measure.

Since the discontinuation of 'DDT', 'malathion' has been

introduced which is much more acceptable because of its rapid breakdown. However, it is still very toxic to all aquatic life. Most mosquito control programs depend upon adulticiding with 'malathion' as an important part of their programs activities. Usually the 'malathion' is dispensed by fixed wing aircraft and such programs must be well controlled not to harm other resources. Organized control programs such as in Kamloops and the Fraser Valley are well controlled but little effort is made to monitor each program on a continuing basis. This is necessary because the applicators and control officers continually change over a period of years.

Little is known about the attempts of mosquito control by unorganized areas or the homeowner, ~~but~~ usually where they have attempted a program and not sought advice, the program has been a failure or a disaster such as ~~in~~ ^{the case} the massive Shuswap Lake fish kill. The chemicals for mosquito control are readily available and many users of these chemicals do not know how to use them properly to take other environmental considerations into account or use alternate and possibly more effective methods of mosquito control.

5.1.5. Industrial Pesticide Discharges.

(a) Growth Control Agents:

This category of pesticide releases may contain chemicals that are not often thought of as pesticides. Included are toxic chemicals used to control algae growth in water systems and fungus and slime growths in industrial processes including pulpmills, sewage treatment plants, hatcheries, etc.

The very toxic and the persistent chemicals should be avoided. In the past growth controlling agents have included mercury, copper, arsenic and cadmium compounds. Such elements are extremely lethal to fish life and have accumulated in food chains to such a degree that they can make fish unsafe for human consumption. For this reason most mercury and cadmium compounds have been removed from the market.

Chlorine is used extensively to control aquatic plant populations where they interfere with intake screens and water systems. Chlorine treatment is also used to control bacterial growth in sewage releases. Residual chlorine and chlorine by-products are extremely toxic to fish life (Environment Canada 1973). *Brief to P.C.B. on municipal wastes*

(b) Pesticide Formulators and Distributors:

British Columbia's pesticide supply is formulated and distributed by a variety of commercial companies. The process of formulation puts the technical grade chemical into its usable form. The process usually produces an effluent that is contaminated with pesticides. In 1972 the effluent of one such company was analyzed and a variety of pesticides were detected including 'malathion' at a concentration of 11 ppm. This effluent flowed directly into the Fraser River.

(c) Lumber and Miscellaneous Forest Industries:

Presently sawmills and pole ^{treatment plants} mills in B.C. use vast quantities of wood preservatives to protect the finished ^{and for in service treatment of poles in the ground} product from disease prior to export. Hundreds of tons of ^{chlorinated phenols} Pentachlorophenol are used for this purpose every year. PCP is one of the most broad spectrum pesticides on the market and is extremely toxic to all aquatic life (McKee, 1971). ^{Three} (Two) documented fish kills have been caused by its use during the last two years ^{were}

Sawmills using PCP are located immediately adjacent to the tidal portions of large salmon streams. It is in such areas as in the Fraser River where each year 10's of millions of adult and young salmon congregate on their respective upstream and downstream migrations. The mills

*chlorinated
phenol solutions*

use thousands of gallons of ~~PP~~ and losses often were large at certain operations because little attempt has been made in the past to contain losses of the chemical *chemical*

5.1.6. Miscellaneous Pesticide Use.

(a) Aquatic Weed Control:

It has come to our attention during the past year that large quantities of chemical aquatic weed control agents are used in this province. Some are used in drainage ditches but the bulk are used to control excessive aquatic plant growth in recreational waters such as in marinas and beach areas in Shuswap Lake.

Unfortunately areas of lakes that have good weed growth are very important as fish rearing areas. *Aquatic weeds offer* ~~They offer~~ fish protection and serve as a substrate for the growth of fish food. Their total removal by any method destroys a vital portion of the fish habitat. The addition of a chemical to water to remove such weeds can also cause acute fish toxicities and will have a direct sublethal effect by the poisoning of aquatic invertebrates and algae upon which fish must depend for food.

In the past such aquatic herbicide programs have not been referred to our Service and it has been impossible to identify the applicators -- most of which are probably

non-licensed. The use of such chemicals are a threat to the fishery resource and are totally uncontrolled. Limited physical removal of excessive aquatic weeds is an obvious alternative to chemical removal.

(b) Mollusk Control:

Swimmers' itch can be controlled by the destruction of freshwater snails which are the vectors of the blood fluke of aquatic birds. This can be accomplished by the spreading of copper sulphate over the breeding grounds of snails on an annual basis. The only annual program is carried out at Cultus Lake by B.C. Research (Howard, Halverson, and Walden 1964) but numerous resort centres are interested in ridding their beaches of the problem, especially in the B.C. interior.

Copper sulphate, the chemical used to control "swimmer's itch", is extremely toxic to aquatic life and can cause fish mortality at concentrations of 25 parts per billion. At the effective dosage rates it can easily cause fish kills and greatly reduce the productivity of treated waters by destroying invertebrate and plant life in treated areas. In fact, the early treatment programs at Cultus Lake resulted in extensive fish kills. Continuous use could also give rise to a copper accumulation in the biota and the

use of this toxic agent should be discouraged.

Sodium arsenite and arsenate compounds have been used to control ~~to~~redo activity in marine wood structures. This activity has been discouraged in recent years because the arsenic compounds are toxic and will accumulate in the tissues of edible fish. The actual treatment of ~~existing~~ ~~wood structures~~ usually took place in water and therefore its spillage was difficult to control.

(c) Household Pesticides:

Many manufactured pesticides are available to any home owner through retail outlets. Most British Columbia households have an adequate supply of pesticides to cause a substantial fish kill if a portion of this supply was disposed of in a storm drain, ditch etc. leading to a fish-frequented stream. Such was the case in the Campbell River when someone in the Surrey area disposed of their garbage into the stream. A fish kill resulted because the garbage contained two cartons of flea powder, a common household pesticide.

5.1.7. Assessment.

Currently the main thrust of Fisheries Operations assessment of the hazards of pesticide usage involves the utilization of information pertaining to short-term fish toxicity. Little

is known about sublethal or genetic effects or about impacts of fish food supply reduction following pesticide utilization. Little information concerning the basic chemical reactions which take place following the introduction of pesticides into water or the bio-chemical responses brought on by breakdown products exists. These are areas requiring further basic research and it is anticipated that Fisheries Operations will, in the future undertake or sponsor investigations in this sphere.

5.2. Fisheries Research and Development:

5.2.1. Pacific Biological Station:

Activities at the Pacific Biological Station involve a number of different research disciplines which are directly concerned with the ecology of living resources. Through these activities, most Station biologists encounter and become keenly aware of the results of man's impact on his environment. Professionally, they are concerned about environmental modification and contamination, resulting perturbations occurring in ecosystems, and attendant damage to populations of resource organisms. Many uses of pesticides and herbicides contribute to problems of the nature indicated.

*Used as
reference to
only by Nanaimo*

From 1953 to 1963 a limited amount of research was conducted on biocides at the Nanaimo Station. In 1971-72 a specific programme was conducted on sublethal effects of sodium pentachlorophenate. Such work had as its objectives (a) a search for insecticides for use in forest spray operations which would be less hazardous ecologically than DDT, the initially preferred control agent, and (b) development of methodology for investigating the environmental impact of pollutants, including biocides, on young salmon. We remain highly concerned about degradation and contamination of the aquatic environment, we have done some work on pesticides and herbicides but we are not currently highly involved in studies of such problems.

As mentioned, a major concern of aquatic ecologists is the potential disruption of ecosystems which can occur when pesticides or herbicides are introduced into the environment.

The plants and animals of an ecosystem generally form complex associations and may be highly interdependent. Plants and animals occupy positions in food webs through which energy is transported from sunlight, through a succession of intermediate organisms, to organisms of direct use to man.

The removal of one or more elements of the food web forces a revision in the relations between the remaining elements. Such revisions may have subtle, unsuspected and, too

frequently, damaging side-effects. Too frequently damage is done to the organisms near the top of the food web, such as trout and salmon -- those of direct social and economic benefit to man.

Testing of chemical control agents prior to their introduction or use may lead to direct but very limited appreciation of potential hazards. Nevertheless, the complexity of ecosystems and their component organisms is such that the full impact of control chemicals often may not be fully appreciated until they have been put to actual field use. Too often in the past follow-up investigations of biological effects have been insufficient to identify deleterious side-effects at an early stage of damage. Sometimes side-effects are very subtle and develop slowly over an extended period of time. Once side-effects are recognized, there has often been considerable resistance on the part of users of control agents against modification of their activities. One reason for this is the fact that opponents of ecological damage often have been sorely pressed to evaluate the economics of environmental damage, compared with the obvious, accountable, and real but narrow benefits obtained by the user.

It is worth pointing out that some sectors of natural

resource utilization traditionally appear to compete with one another (e.g., forestry and fisheries), when in fact they really interact with one another. If both sectors of resource utilization are desirable, some form of managerial compromise must be reached in which each resource can be self-sustaining. It is almost a certainty that ^{maximum} ~~manimum~~ utilization rates of interacting resources would be below those levels set on the basis of the false assumption that such resources exist independently. Often the extent of such compromises arrived at in the past have been based on short-term economic criteria. These criteria may be totally at variance with the longer term biological needs in a real economic-ecological compromise. Unilateral decisions on utilization of interacting resources are certain to create both economic and resource imbalances.

There is no question that pesticides and herbicides have been of major value to man in agriculture, human health and forestry. However, there is now abundant evidence to show that benefits of chemical control have not been achieved without appreciable costs arising from environmental contamination. Control chemicals should and will continue to be used. As ecologists, we conclude that they must be used with a profound and growing respect for their ability to create highly deleterious side effects among ecosystems and resource organisms.

Recognition of the potential hazards of chemical control agents should, if anything, force a concerted effort to develop other, more specific control methods. Chemical control methods can no longer be viewed as a panacea; research should strive to make biocides unnecessary through the development of less hazardous alternatives.

5.2.2. Pacific Environment Institute:

During its brief history the Pacific Environment Institute has not become involved in studies of pesticide levels in waters or biota of the Pacific Coast. It is agreed that a paucity of information exists concerning these levels in seawater, and how much is being added, year by year, by rainfall, by freshwater systems carrying runoff from agricultural, forestry and industrial operations is completely unknown.

The many commercial pesticides (biocides) registered for sale in this country, display a wide variety of chemical structures. Many of these will contain "unfamiliar" types of chemical groupings in terms of types of material which normally are degraded by bacteria or other microorganisms. An example of these are chlorinated hydrocarbons ~~such as~~ ~~DDT~~ which are extremely persistent in the environment. One major concern therefore is that many of these per-

sistent pesticides are probably being added to the environment at rates greatly in excess of their removal rate. Furthermore, manifestations of toxicity of these biocides are not readily detectable except in spectacular cases where high local concentrations may result in fish kills and massive deaths of shore birds. Although the technical capability to measure the levels of such compounds in water or biological samples is good, our ability to assess the likely impact on fish and wildlife of existing and future levels of biocides remains poor. We do not know what some of the sublethal effects may be on various trophic levels in freshwater or marine food chains, which trophic levels are involved in bioaccumulation, or what "safe" levels might be in selected organisms. Safe should be defined in this context to include ability to function and reproduce without impairment. Other unknown factors include the possibility of mutagenic, teratogenic or carcinogenic effects on fish and molluscs and the possibility that some of these agents may have appreciable toxicity to invertebrates (larvae) and phytoplankton.

There is undoubtedly an impulse on the part of regulatory agencies, in response to public pressure, to ban the use of selected biocides without a proper and complete evaluation of the ecological impact of their substitutes. One can refer here to the use of Methoxychlor as a substitute for

DDT. Although this material was tested against rats and found to be non-toxic, subsequent usage in the field has uncovered toxic effects on fish populations.

These various concerns would indicate that not enough research is currently being done to define adequately what are the dangerous levels of biocides and what biological impact they are having in our land today.

5.2.3. Vancouver Laboratory:

The activities of the Vancouver Laboratory, Fisheries *Development* and *Research Board*, are primarily concerned with various aspects of fish technology and a limited effort is directed to problems related to water pollution, mainly in areas requiring expertise in biochemistry and analytical chemistry. There is an obvious need for an adequate assessment of sublethal effects of pesticides on fish and to emphasize the significance of biochemical investigations in this field.

(a) Lethal Action:

The lethal potency of pesticides and other chemicals on fish is measured by acute toxicity bioassays in which the mortality of experimental animals is determined as a function of concentration of the toxic agent and time of

exposure. As indicated below this technique presents serious limitations for establishing the levels of water pollutants that can be considered safe to fish. However, it must be stressed that the acute toxicity bioassays will continue to play a major role in monitoring water pollution, since in absence of other information they provide useful comparative data on the toxicity of chemicals to fish. The chief shortcomings of the acute toxicity bioassays are that they are of short duration (usually 1 to 4 days), not beginning to approach the life span of fish or the time of exposure to pollutants that would take place in natural conditions. Also, they give no information on the sublethal physiological damage or ecological side effects which may ultimately result in a pronounced decrease in fish population or the elimination of some species.

(b) Sublethal Action:

The sublethal action of pesticides on fish may lead to an impairment of normal functions (slowed reactions to external stimuli, physical weakness, lowered resistance to diseases, etc.) which make the animal unfit to survive under competitive conditions in the natural environment. A reduced reproductive capacity, high mortality in early stages of development and diminished abundance of animals or plants serving as food, are among the other factors contributing

to a decrease in fish population in polluted waters. In addition to these biological effects some water pollutants can reduce the value of species utilized in commercial or recreational fisheries, due to the accumulation in the body of fish of compounds that alter the flavour or are hazardous to human health.

Biochemical and physiological investigations on the effects of pesticides and other water pollutants on fish have as primary objective the detection of toxic manifestations that are more sensitive than mere survival. Toxic chemicals are known to interfere with various vital processes in the animal, such as growth and reproduction of cells, utilization of energy reserves, response of the nervous system, mechanism of excretion and osmoregulation, hormonal balance etc. The methods developed in clinical chemistry and human toxicology have often been adapted to detect the departure from normal activity pattern in fish exposed to water pollutants. The approaches which showed promising results involve the investigation of the changes in blood chemistry, histopathological damage to various tissues (gills, liver, reproductive organs, etc.), inhibition of specific enzyme systems and metabolic indicators of stress. In more general terms, the deterioration of physiological conditions of fish exposed to pesticides can be assessed by measuring the swimming performance (speed,

endurance), respiration (rate of oxygen uptake or gill ventilation), food conversion efficiency and growth rate.

It might be concluded that the detection of sublethal effects of pesticides through the use of biochemical and physiological techniques represents an important aspect of water pollution control.

5.3. Marine Sciences Directorate:

Marine Sciences Directorate of the Fisheries & Marine Service has an interest in the physics and chemistry of the oceanic environment. The Ocean Chemistry Division of the Directorate, has been involved in studies on the chemical properties of sea water, the budget and routes of chemicals in the marine environment and problems of marine environmental quality in general. Its on-going marine hydrocarbons program encompasses studies of petroleum-based, natural and chlorinated hydrocarbons in the marine environment. However, due to overall program priorities, effort has been limited to aspects of petroleum-based hydrocarbons only. In future, Ocean Chemistry may look into chlorinated hydrocarbons, especially the monitoring of the persistent types, in the marine environment.

Our main concern is the lack of critical and quantitative data on the occurrence of pesticides in the marine environment.

Even for the much investigated pesticide, such as DDT and its degraded products, actual quantitative data in the marine environment are few. Furthermore, the reliability of these few results is severely hampered by analytical and contamination problems arising from high concentrations of interfering materials, such as PCB and from the very low concentrations of the pesticide.

The inorganic pesticide compounds used include toxic metallic compounds of copper, mercury, arsenic and lead. Their typical natural concentrations in sea water are: 1 ppb. (part per billion, or microgram per liter) of copper, 0.1 ppb. of mercury, 2 ppb. of arsenic and 0.02 ppb. of lead. (Dryssenetal 1971). The contributions of such inorganic pesticidal compounds to sea water concentrations are unknown. Investigations of the occurrence of pesticides in the marine environment have been made on DDT and its metabolites mainly. Very few measurements for halogenated hydrocarbons in sea water have been made. DDT residue concentrations in sea water were reported (Cox, J.L., 1971) to be 2.3 - 2.7 pp trillion (10^{12}) from Vancouver to San Fransisco and 3.0 - 5.6 pp trillion off the Californian coast. This agrees with a predicted DDT concentration in the surface sea water of 5 pp trillion, based on rainfall statistics and calculated DDT residue concentrations in rainwater. The level of DDT residue in surface marine sediments has not been investigated much: levels of 0.04 - 0.61 ppb of DDE

were found in the top few centimeters of surface marine sediments near the U.S. northwest coast, (Claeys, pers. comm., 1972).

This oceanic value of 5 pp trillion is significant if the measurements were valid. Fresh water concentrations of 1-3 pp trillion in Lake Michigan, (Reinert, 1970), were associated with fish tissue concentrations of 3 ppm. and evidence of environmental degradation.

The distribution in the biota of the marine environment is little investigated, and the scant results available show it to be highly variable, even at the same locality.

The concentrations of DDT residues in the marine biota were estimated (Woodwell, et.al., 1971) in Table IV.

TABLE IV: ESTIMATES OF DDT RESIDUES IN MARINE BIOTA IN THE LATE 1960's:

	<u>DDT Content (ppm.)</u>	<u>Total DDT ($\times 10^8$ g.)</u>
Open ocean algae	0.1	1.0
Continental shelf algae	1.0	3.0
Attached algae	1.0	20.0
Total oceanic algae	---	24.0
Fish	1.0	6.5
Mammals	1.0	0.55
Others (protozia, coelenterates, annelids, nematodes, mollusks, echinoderms, arthropods)	0.1	3.2
Total oceanic animals	---	10.25

The concentrations in a polluted estuary (Carmans River

estuary, Long Island, N.Y.) (Woodwell, et.al. , 1967) for marine biota are shown in Table V.

TABLE V: DDT RESIDUES IN MARINE BIOTA OF A LONG ISLAND, N.Y. POLLUTED ESTUARY:

Sample	DDT residues (ppm.)
Water	0.00005
Plankton, mostly zooplankton	0.040
Shrimp	0.16
Opsanus tau, oyster toadfish (immature)	0.17
Gasterosteus aculeatus, threespine stickleback	0.26
Spartina patens, shoots	0.33
Fundulus heteroclitus, mummichog	1.24
Strongylura marina, Atlantic needlefish	2.07
Spartina patens, roots	2.80
Sterna hirundo, common tern	3.42
Butorides virescens, green heron	3.57
Larus argentatus, herring gull (immature)	5.43
Sterna hirundo, common tern (five abandoned eggs)	7.13
Larus argentatus, herring gull	9.60
Pandion haliaetus, osprey (one abandoned egg)	13.80
Larus argentatus, herring gull	18.50
Mergus serrator, red-breasted merganser	22.80
Phalacrocorax auritus, double-crested cormorant (immature)	26.40
Larus delawarensis, ring-billed gull (immature)	75.50

Due to this lack of data, it is impossible to ascertain the amount of pesticides, and in particular DDT residues, in sea water and the fraction retained by marine biota.

5.3.1. Routes of Entry of Pesticides into the Marine Environment:

Paths of entry into the ocean include atmospheric fallout, agriculture runoffs and sewage outfalls.

The atmosphere has a tropospheric saturation capacity of 10^{12} g. of DDT (Woodwill, et.al. 1971) and constitutes a major reservoir of airborne pesticides. Rainfall is suggested to be the main removal mechanism for DDT in the atmosphere: the amount removable by rain has been estimated to be 2.4×10^{10} g. per year (Natl. Acad. Sciences, Washington, D.C. 1971) into the ocean, estimated to be 25% of the annual production of DDT/? Amount transported by river into the ocean was minor, estimated to be only 10^8 g. per year, or 0.1% of the annual DDT production. Contributions through sewage outfalls are unknown quantitatively.

5.3.2. Removal Mechanism from the Ocean:

DDT residues in sea water are removed by incorporation into marine organisms and with organic matter as suspended particulates or dissolved organics. Surface film on the ocean, with high fatty acids and alcohols, tends to concentrate the residues. There is a lack of data on direct measurements of sedimentation of DDT residues incorporated with organic matter.

5.3.3. Persistency and Toxicity:

DDT compounds are characterised by high volatility, low solubility in water and high affinity for organic matter, silt particles and soil (Risebrough, 1971. Although the longevity of chlorinated hydrocarbons in soils is known to be 10-40 years after application, (Rudd, 1971), a similar study in the oceanic environment is lacking. Based on carbon dioxide transfer rate in the surface mixed layer, a mean transport rate of 4 years (Woodwell et. al. 1971) for DDT from the surface mixed layer of the ocean into deep waters is indicated. A residence time of 5 years was estimated by the U.S. National Academy of Sciences Panel. Another aspect of the persistency is the retention and magnification of the chlorinated hydrocarbons up the marine food chain, as evident in Table IV.

There are few investigations on the toxicity, or more appropriately the sublethal effects, of chlorinated hydrocarbons on marine organisms. Species difference would be expected in their response, as shown in the case of marine phytoplankton (Menzel et. al. 1970): a green estuarine flagellate Dunaliella tertiolecta would be insensitive to 1 ppm. while an open ocean diatom Cyclotella nana was sensitive to 0.1 ppb. of DDT. Chlorinated

hydrocarbons have also been shown to inhibit photosynthesis in marine phytoplankton cultures at 1 ppb. level (Wurster, 1968). Thus, the effects of chlorinated hydrocarbons on total photosynthesis of the ocean would not be expected to be significant but there should be concern on the species-dependent effects, at the sublethal concentrations.

6. RECOMMENDATIONS

1. It is recommended that the use of persistent toxic pesticides be reduced wherever possible and practical.
2. Increased research efforts should be directed to the development of:
 - (a) selectively toxic chemicals,
 - (b) non-persistent toxicants,
 - (c) less toxic solvents, adjuvants, diluents, etc. for pesticide,
 - (d) selective methods of application,
 - (e) non-chemical control methods such as use of attractants, sterilization, cultural and physical controls, etc.,
 - (f) integrated control methods,
 - (g) measures and guidelines to protect the environment from known harmful biocides,
 - (h) information on the chemical reactions which take place following the introduction of pesticides into the environment and the biochemical responses that occur as a result of breakdown products.
 - (i) information on chronic and sublethal effects of pesticides and their degradation products on all segments of the environment.
3. Research relevant to British Columbia should be conducted on all aspects of pest control. Emphasis should be placed on pesticide monitoring to establish baseline data and contamination, particularly at sublethal levels to non-target aquatic

and terrestrial species, and on techniques for prediction of environmental effects.

4. More effort should be made to quantify, through statistics and data collection, the input, budget, and removal rate of pesticides, especially the persistent ones, in all segments of British Columbia environment - land, air, marine, freshwater, etc.
5. In cases of large scale pesticide programs, contingency plans should be available ^{with proposal} to rapidly deal with spillage of chemicals. These plans should include safe methods for disposal of surplus product as well as "empty" packages and/or containers.
6. Additionally, a program should be initiated for the appropriate disposal of unwanted pesticide products as well as their containers or packages that would be applicable to the commercial and domestic user.
7. An informational program on the benefits and hazards of proper pesticide use should be extended. In addition, a program on control by means other than the use of chemicals should be provided to the public.
8. A more stringent continual upgrading of all licensed applicators and dispensers should take place to insure that only the most qualified will handle pesticides. This would enable applicators to be career men and would reduce the overall number of applicators. (The dispensers of pesticides should have the equivalent education of a pharmacist and all pesticides should be dis-

pensed by such qualified people.)

9. All current uses of persistent chemicals should be fully reviewed in the light of recent advances in understanding the undesired effects of some pesticides. (The acceptable uses should be selected and agreed to unanimously by the appropriate departments. Such uses should be restricted for essential purposes, limited to the lowest effective dosage required for the production of essential foods and fibre, and replaced by safer alternatives wherever possible.)
10. An independent body should be created to set pest control policy, guidelines, and regulations. It would also direct education, license applicators, coordinate research, and generally control pesticide use to insure an unbiased approach so as no further environmental degradation will occur in this province.
11. A forest Pest Control Committee should be formed by the B.C. Forest Service to review the forest pest situation annually and to determine a course of action regarding these pests. this committee should have representation from the B.C. Forest Service, other provincial government agencies and the forest industry, as well as advisory representation from the Canada Department of the Environment, similar to the present Pest Control Committee of the Council of Forest Industries of British Columbia. It would differ from the latter committee in that it would be responsible to the Minister of Lands,

*Under
C.D.A.
jurisdiction*

Forests and Water Resources and/or other ministers of the Government of British Columbia. The Committee should have the authority to form sub-committees to consider in detail pest problems on a district or on a problem basis as they occur. It should recommend control action when necessary and should be allocated the means to conduct these operations, including special surveys, public information and discussion, etc., in cooperation with industry and other agencies.

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