ENVIRONMENTAL EFFECTS OF THE SPRUCE BUDWORM SPRAY PROGRAM IN NEW BRUNSWICK, 1976

A preliminary report by the Committee for Environmental Monitoring of Forest Insect Control Operations

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FOREWORD

This report is anonymous because it is a compilation from fourteen contributors. The main authors were H.A. Hall, Dr. D.A. Lord, P.A. Pearce, Dr. P.E.K. Symons, Dr. I.W. Varty, J.P. Witteman and G.W. Wood. The editors were I.W. Varty, P.A. Pearce and J.C. Baird. The report has the distinction of being cross-disciplinary and cross-institutional, but the lead agency was the Atlantic Region's Environmental Management Service of Environment Canada. It is published in a Canadian Forestry Service Information Report series for library convenience, not to single out credit. Nevertheless the monitoring committee notes with appreciation the editorial contribution of Mrs. Margaret Cameron and the publication facilities of the Maritimes Forest Research Centre. The report was written for a target readership of federal and provincial government resource and environment departments, spray agencies, universities, lay environmental groups, the press, and the interested public. Its aim is to deliver the latest information on the ecological consequences of the budworm spray program in New Brunswick.

I.W. Varty, Chairman,
Atlantic Regional Committee for
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ABSTRACT

The persistence and distribution of four insecticides (fenitrothion, trichlorfon, aminocarb, and phosphamidon) and the ecological consequences of their use were monitored in the 10-million-acre aerial spray program against spruce budworm in New Brunswick in 1976. The population responses of various faunal groups were measured by extensive field surveys.

Birds: Spray operations were characterized by an uneven distribution of toxic effects on songbirds. Warblers and kinglets were especially vulnerable to phosphamidon, and a reduction in numbers sometimes occurred after application of fenitrothion. The type of spray aircraft and delivery system had a significant influence on the hazard to songbirds.

Mammals: Fenitrothion and phosphamidon had no deleterious influence on the fertility of voles and deermice, indicating little hazard to these small mammals. There were no cases of poisoning of livestock or game mammals attributable to the sprays.

Stream fauna: The impact on aquatic insects was highly variable. Aminocarb and trichlorfon apparently had little effect, as assessed from survival of bottom-dwelling insects and from drift of dead insects. Mortality associated with the highest prescribed dosage of fenitrothion ranged from none to very heavy. No direct effect on fish was observed.

Pollinators: Insecticide drift into blueberry fields from nearby forest spray zones ranged from none to heavy. Wild bee abundance was not substantially changed by light deposits. Experience with heavy deposits of fenitrothion indicated population recovery in 1-4 years.

Biological control agents: Large-scale, recurrent applications of fenitrothion in the 1970s do not appear to have eroded the effectiveness of biological control by parasites and predators, nor to have triggered irruptions of non-target pests.

Insecticide distribution and persistence: The deposit of insecticide from a given emission rate varied from place to place by a factor of 10. Double swathing within the spray block and drift into farmland sometimes occurred. Local contamination by accidental spillage was minor. Experimental use of tracer dyes showed wide variation in deposit, even within a small group of trees. The persistence of some of the insecticides in the forest evironment was found to be brief.

In the long term, the monitoring agencies are looking for symptoms of ecosystem disturbance and associated degradation of resource productivity, with the aim of modifying protection tactics that are deleterious. They face acute sampling problems because of the size of operations and of the variability of spray regimes, deposition patterns, and animal abundance. It is recommended that the monitoring and research effort be expanded, that liaison with spray agencies be closer, and that certain treatment dosages be used cautiously.

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INTRODUCTION

Aerial spraying to control spruce budworm damage in New Brunswick began in 1952, and has continued almost annually. Over the years, environmental surveillance was loosely maintained and results were reviewed by a federal interdepartmental committee. A formal mechanism for the authorization of insecticide use in forest insect control operations was established in 1974 under provisions of the Pest Control Products Act, administered by Agriculture Canada.

Field studies have been conducted as long as the budworm spray program itself. The toxicity of insecticides to many kinds of vertebrate and invertebrate animals and the widespread distribution and persistence of some of these chemicals have long attracted the interest of resource managers and environmental biologists. However, during the last 25 years much of the research and monitoring has been sporadic, understaffed, and often limited to the faunal discipline and the institutional priorities of observer agencies. Recently, federal government dissatisfaction with the scale of monitoring, New Brunswick government concern over the integrity of its natural resources and public opposition to spraying have combined in a call for more comprehensive organization of surveillance. In March 1976, Environment Canada established an Atlantic Regional Committee for Environmental Monitoring of Forest Insect Control Operations (EMOFICO) to coordinate research and monitoring of the distribution of spray and its environmental consequences. (That mandate, however, does not cover consideration of human health, including the problem of Reye's Syndrome.) Members of the Committee represent the various services of Environment Canada: Environmental Management Service (Forestry, Inland Waters, Wildlife), Atmospheric Environment Service, Fisheries and Marine Service, and Environmental Protection Service. Agriculture Canada and provincial departments (New Brunswick Natural Resources, New Brunswick Environment, and Nova Scotia Environment) are affiliated.

The aims of the Committee are to coordinate monitoring and research, to review and evaluate reported effects in the context of the resources problem, and to inform governmental bodies and the public accordingly. Each federal service is responsible for advising federal, provincial, and industrial agencies and the public about the particular ecological effects and contamination aspects of each seasonal operation. They seek over the years to detect any trend to ecosystem degradation resulting from repeated spraying, and to advise on measures of environmental protection.

The object of monitoring is to survey change; the object of research is to find how to monitor and how to interpret change. The monitoring and associated research include the following major areas of investigation:-

Songbirds, because their habitats, diet, behavior, and physiology expose them to considerable contact with aerial sprays.

Small Rodents, because they are good indicators of the exposure and reaction of mammals in general.

Stream Insects, because of their importance in food chains culminating in trout, salmon, and other sport and commercial fish.

Terrestrial Insects, especially the beneficial insects having roles in parasitism, predation, pollination, weed control, and nutrient turnover. The integrity of these processes depends upon adequate survival of hundreds of species populations.

Fate of Insecticides, the transport, breakdown, and persistence of insecticides are of concern with regard to the potability of water, and to drift contamination of habitations and farmland, as well as to their implications in forest ecology.

Inspection, the purview of the committee includes contamination of land and water surfaces, verification that the prescribed dosages are adhered to, and analysis of insecticide quality in the barrel.

The effects of the following insecticides were investigated:- fenitrothion (the registered insecticides Sumithion, Folithion, Novathion), trichlorfon (Dylox), aminocarb (Matacil) and phosphamidon (Dimecron).

The monitoring and research effort in 1976 is part of a continuing program which will be needed as long as there are chemical insecticides in forest use. Insecticide spray practice is dynamic: there may be annual changes in insecticide products employed, in formulation, dosage, delivery system, timing, target stage, and target area. All of these factors influence the ecological consequences. The monitors observe specific treatments in specific areas and try to generalize from their experience. The populations of non-target animals are also dynamic; trends of species abundance must be followed over a period of years. No single year's monitoring is complete in itself; it must be viewed in the context of the spray history and the natural variation in animal numbers.

This report, at November 1, is itself tentative, in that most data gathered in 1976 have not been fully analyzed at reporting date. Early information is offered, at risk of premature interpretation, so that planning of future protection tactics may take into account environmental considerations from the current year, and so that the public may be kept up-to-date with the most recent appraisals of environmental hazard. The report presents the highlights of work in 1976 as a defined mix of fact (from completed data analysis), inference (using intuition and raw data), and statement of intent (where the facts are still unknown). The highlights are set in background context to relate to earlier problems and experience. The Committee has aimed at keeping the report short and terse, but fuller documentation on all aspects will follow during the winter and spring.

The cost of monitoring and research in 1976 was in the vicinity of $450,000. Environment Canada has long promoted such studies, and in 1976 the Province of New Brunswick supported a substantial additional effort (through the Forestry Sub-agreement of the General Development Agreement with the Department of Regional Economic Expansion). Summer field work involved about 60 investigators - scientists, technicians, and student workers - in collecting data from New Brunswick and to a small extent from Nova Scotia and Prince Edward Island. The knowledge gained regionally is supplemented by a similar monitoring program operating in Quebec.

THE INSECTICIDE REGIMES

Spray operations in 1976 were the largest ever conducted in New Brunswick: of the 9.6 million acres treated, nearly 9 million acres were sprayed twice and the remainder three times. About 1900 tons of insecticide were sprayed: about 85% was fenitrothion, and the remainder consisted of trichlorfon, aminocarb, phosphamidon and some experimental insecticides. The spray agencies were Forest Protection Ltd. and J.D. Irving Ltd. Woodlands Division. Most of the spraying was carried out by the Grumman Avenger (TBM) aircraft (65% of the acreage) and the 4-engined Douglas DC-6 (about 20%); the rest was sprayed by Thrush Commander, Curtis-Wright C-46, and Cessna Agwagon aircraft.

An insecticide spray regime is the sequence of treatments applied at prescribed dosages by specific aircraft. An insecticide by itself should not be categorized as environmentally harmful; rather it is the combination of insecticide, dosage, formulation, spray aircraft and equipment, season, and timing that must be considered.

There were 23 spray regimes in 1976, nine of which were used in areas exceeding 100,000 acres. It was not practicable to monitor all these regimes, and most effort was concentrated on the large-acreage treatments. Some of the environmental effects of fenitrothion are well known because it has been monitored in spray operations since 1968. Phosphamidon also has a long history of investigation, dating back to 1963; but trichlorfon and aminocarb, used operationally since 1974, are less well researched. All have qualified for forest use under the Agriculture Canada criteria that they should have low toxicity to man and other vertebrate animals, should be of low persistence in the environment, and noncumulative in animal tissue. All except aminocarb have been used extensively in international crop protection practices.

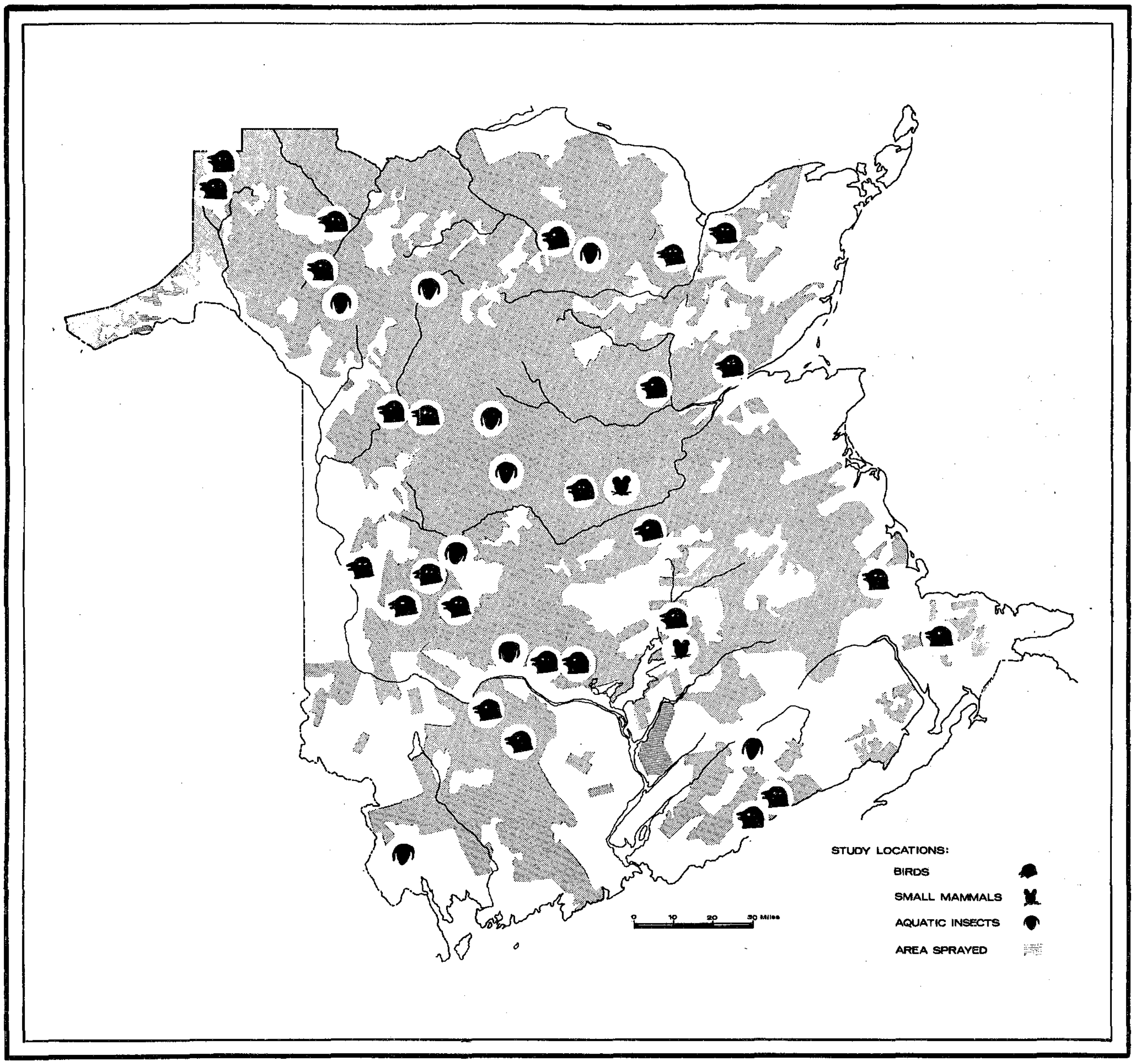
FAUNAL STUDIES

Songbirds

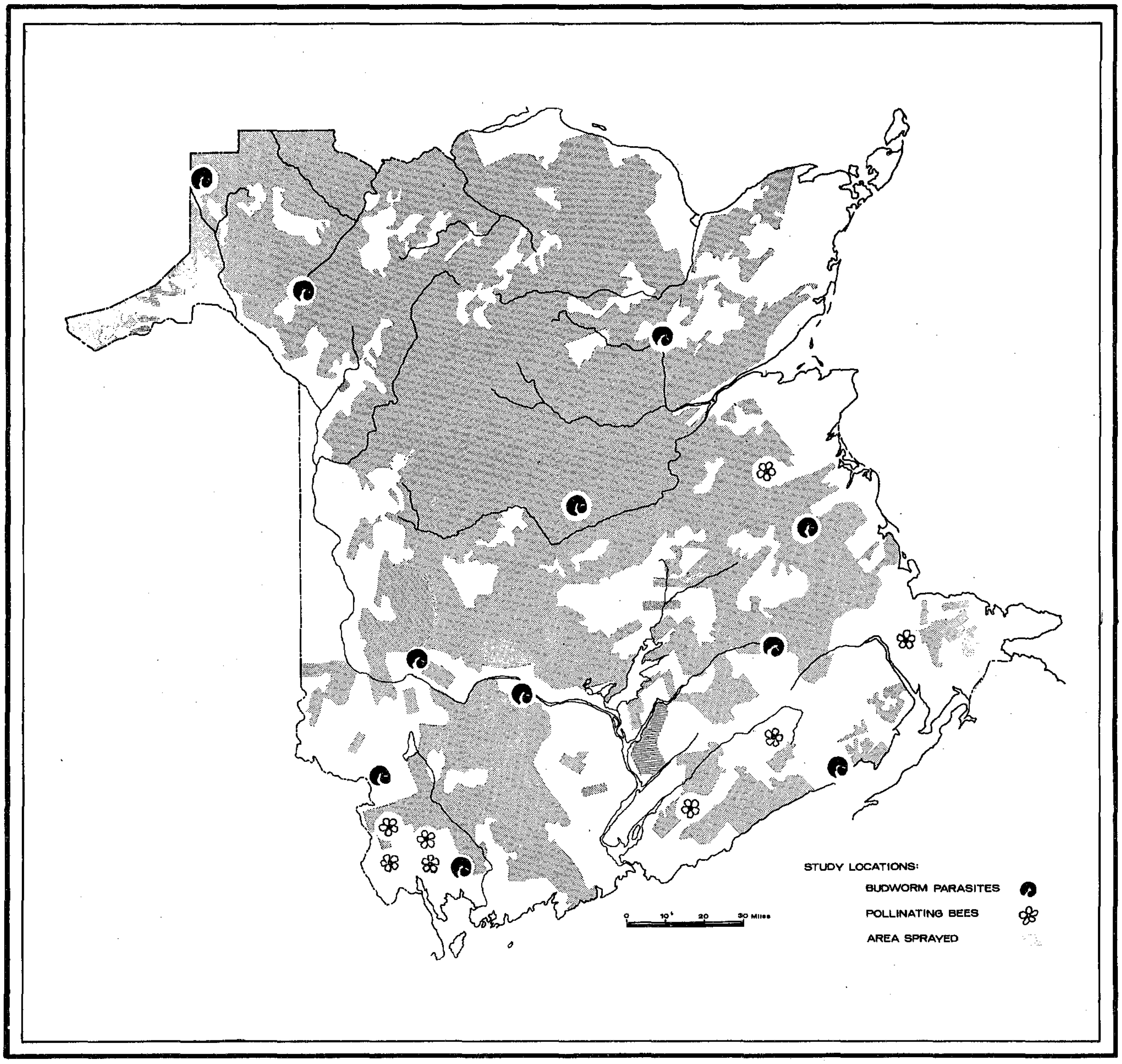
(Integrated investigations conducted by P.A. Pearce (Canadian Wildlife Service) and A. Madden (N.B. Natural Resources) and independent studies by B.B. McLeod (Canadian Forestry Service).

The New Brunswick forest provides food and shelter to a richer diversity of bird life than is found in most regions of Canada. Birds help to maintain the integrity of the forest ecosystem mostly as a factor in controlling insect populations, though their role as predators of the spruce budworm is not fully understood. Songbirds have a high aesthetic value, and most of the migratory species constitute a renewable resource protected under provisions of an international treaty.

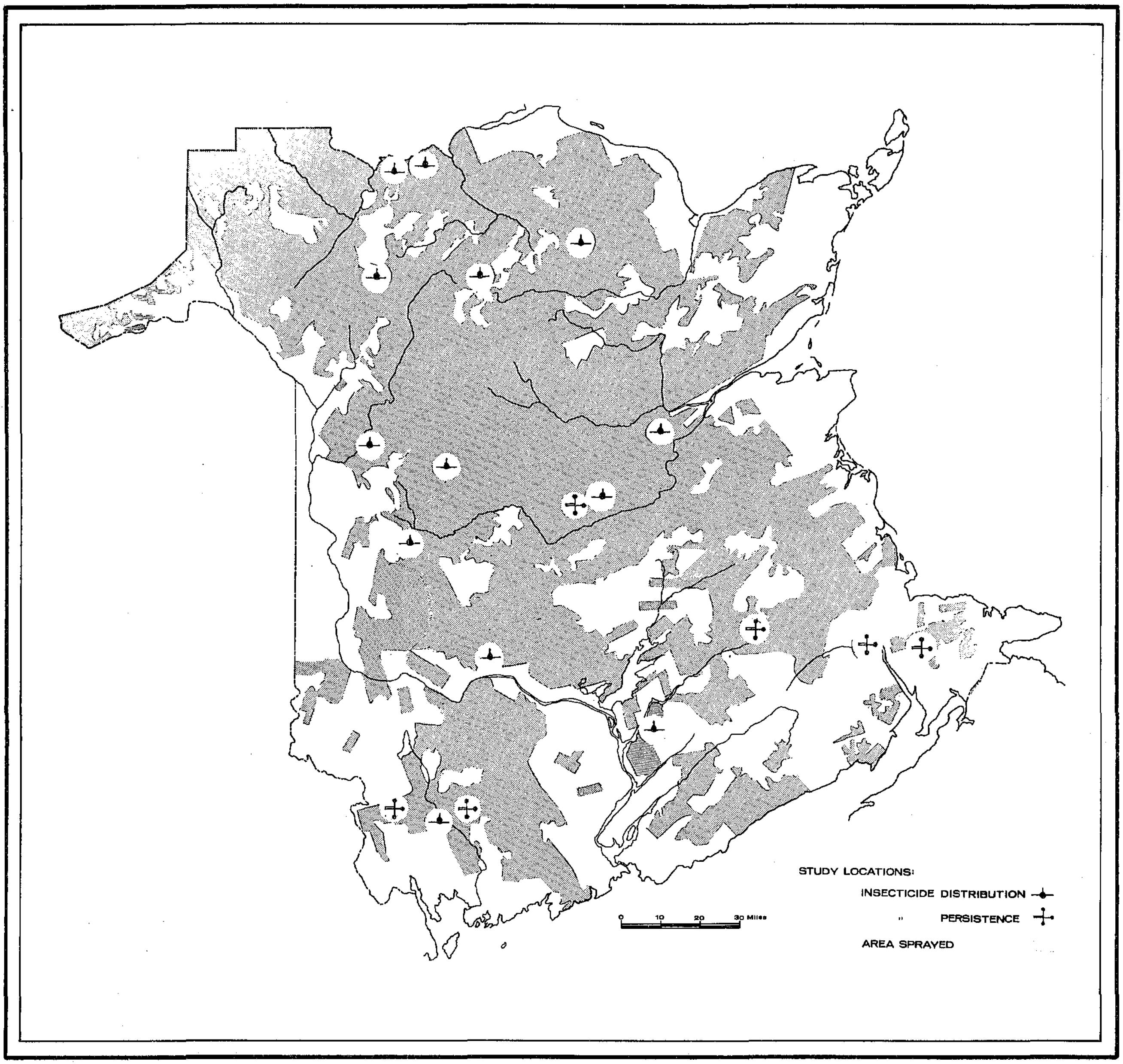
Forest spray operations are usually underway at a time when birds are subject to much physical and physiological stress resulting from migration and the onset of the breeding season. Birds may be directly exposed to the spray, and the New Brunswick experience has shown that some current spray regimes, in certain circumstances, cause bird kill.



Location of study plots and transects for birds, small mammals, and aquatic insects in New Brunswick, 1976.



Location of study plots for budworm parasites and pollinating bees in New Brunswick, 1976.



Location of sample areas for insecticide studies in New Brunswick, 1976.

In keeping with the record size and complexity of spray operations in 1976, a larger than usual bird-monitoring program was undertaken. Repeated censusing of birds was made before and after sprays were applied. Such counts were based largely on song identification. Intensive post-spray searches for casualties were conducted. The studies were made in four plots and on 24 three-mile road transects distributed from Fredericton to Bathurst, and from Moncton to Edmundston. Poisoning was suspected where bird song diminished significantly, and mortality was presumed. Seven of the largest spray regimes, representing the major part of the total area sprayed, were studied. Also monitored were experimental sprays conducted in small plots in summer against the adult budworm.

The influence of spray operations was generally characterized by an uneven distribution of effects on birds, as gauged by loss of song, recovery of bodies, and observation of aberrant behavior; a given treatment regime caused demonstrable impacts in some areas but not in others. A big wave of migrants, especially warblers, arrived in late May and may have masked the effects of some early sprays. Only a few reports of local bird mortality were received from the public. About 30 dead or moribund birds were found in spray zones by investigators and have been analyzed for insecticide residue. Twelve species, nearly all warblers, were represented among those confirmed casualties.

Monitoring effort was concentrated in areas sprayed with fenitrothion twice at 3 oz/acre by either TBM or DC-6 aircraft. Those spray regimes accounted for about 75% of the total area sprayed in 1976. Although data have not been fully analyzed, some broad conclusions may be drawn. The results show that for forest canopy birds, especially highly susceptible kinglets, fenitrothion delivered by TBM caused a significantly greater reduction of singing activity than the same insecticide sprayed by DC-6. There was no difference in impact when data for ground-dwelling birds, less exposed to the spray, were examined.

Further evidence of the toxicity of phosphamidon to birds was obtained. In small-scale trials in May, severe reductions of kinglets were caused by phosphamidon at 3oz/acre and at 2 oz/acre when applied by TBM. In contrast, three applications of phosphamidon at 1 oz/acre to kill budworm moths in July had little measurable effect on birds. In operational spraying, phosphamidon reduced the numbers of some species of forest canopy birds when sprayed at 2 oz/acre by C-46 aircraft. Phosphamidon was used in less than 5% of the total area sprayed.

Aminocarb appeared to present little hazard to birds when applied twice at 1 oz/acre operationally by TBM and experimentally (July) by Agwagon aircraft. In the operations in which aminocarb followed either phosphamidon or fenitrothion, the observed effects on birds were chiefly related to those insecticides rather than to aminocarb. Carbaryl (Sevin-4-oil) applied twice at 8 oz/acre or once at 16 oz/acre, and acephate (Orthene) sprayed twice at 4 oz/acre or once at 8 oz/acre during budworm moth suppression trials revealed no significant effect on adult birds.

Clearly, a considerable reduction of some warblers and of kinglets sometimes occurred in the days following sprays. On a unit area basis, the apparent reduction in numbers of kinglets, derived from transect counts made in all operational spray regimes monitored in 1976, was between one quarter and one third of estimates of presumed mortality of that species last year. A final assessment of insecticide influence on bird populations cannot be made at this time.

Mammals

Small rodents (voles, deermice) were trapped in four plots: phosphamidon 4 oz/acre (experimental); fenitrothion 3 oz/acre applied twice; phosphamidon 3 oz/acre + fenitrothion 3 oz/acre + fenitrothion 3 oz/acre (experimental); and an untreated check plot (Study by B.B. McLeod, Canadian Forestry Service). Previous experience had shown that such treatments do not affect the survival of adult voles, but there has been uncertainty as to the effect on unborn young and juveniles. Accordingly, the samples in 1976 were taken about 6 weeks after spraying to check the age-class structure of the populations. The investigation showed that a large portion of the vole and deermouse populations consisted of young of the year, and most of the adult females were either pregnant or contained placental scars indicating recent birth of a litter. These expressions of continuing fertility occurred in all plots, regardless of treatment. Therefore, it is reasonable to assume that population dynamics of voles and deermice were not affected.

Since harmful effects of forest sprays on livestock and big game animals were considered unlikely, specific monitoring was not undertaken. Scattered reports of apparent ill-health of livestock were investigated but no association with forest spraying was established (C.S. Rammage, N.B. Agriculture).

Stream fauna

Earlier research and monitoring have shown that the current organophosphate and carbamate insecticides in dosages prescribed for budworm control are very unlikely to kill fish. Laboratory experiments with very heavy concentrations of these insecticides have shown that the most poisonous material to fingerling rainbow trout was aminocarb, followed by fenitrothion, phosphamidon, and trichlorfon (P. Wells, E.P.S). The prescribed dosages for all these insecticides, however, are capable of killing some stream insects. Since stream-dwelling fish, especially trout and young salmon, subsist largely on a diet of insects, depletion of insect populations or interference with the food chain by insecticides could result in loss of fish production.

The problem in 1976 was to determine whether the main regimes, some with dosages heavier than in previous years, would substantially reduce the seasonal abundance of stream insects. This is a difficult sampling problem because the distribution and abundance of insects is constantly changing. There are population additions when eggs hatch, and subtractions when larvae leave to become airborne adults; moreover, there is a migration, passively downstream, by a fraction of the insect population - the phenomenon of drift. After insecticide contamination there is sometimes a drift of dead and living insects. The insecticide concentration usually is highest just after spraying, then diminishes until in 2-3 days it can no longer be detected. Thus the period of insect mortality is brief. Kill is not the only disturbance caused by insecticides; sublethal dosages may cause an increase in live drift which may also impoverish fish food resources if downstream habitat is not available.

Sampling in 1976 was conducted by four agencies: the Fisheries and Marine Service (P.E.K. Symons), N.B. Natural Resources (G. Gillis, Montreal Engineering Co. Ltd., under contract), the Environmental Protection Service (D.A. Lord), and the Canadian Forestry Service (D.C. Eidt, B.B. McLeod). Fenitrothion treatment at the 3 oz/acre dosage, monitored on nine streams, produced no detectable kill of insects in six instances, and a light to moderate kill on nine other occasions. Seasonal abundance of insects was decreased probably not more than 5% on average, after each application, but this conclusion requires verification. Although fenitrothion contamination was detected in the interstitial water 8 inches deep in the bottom gravel, caged insects buried in the gravel survived.

The 4 oz/acre dosage of fenitrothion also resulted in highly variable effects ranging from 0 to 80-90% reduction of bottom-dwelling insects, and ranging from no drift to heavy drift of dead insects in three streams monitored. It is not yet possible to generalize on the safety of this dosage to stream insect survival.

In five streams exposed to aminocarb at 1 oz/acre, neither increased drift nor reduced survival was detected. In two streams exposed to trichlorfon at 8 oz/acre, drift was not affected but some caged insects died. Much more sampling is required to verify the apparent absence of adverse effect from these two insecticides, which are relatively new in forest insect control.

The present technology requires tedious and costly tallies of a broad complex of immature insects. The use of caged insects promises to be a more efficient monitoring technique, but it requires further development.

In summary, a minimal survey of spray regimes was accomplished. Except for the heaviest treatment with fenitrothion, stream insect kill was rarely severe. The lighter treatments can be tentatively considered tolerable for aquatic organisms, with the reservation that sampling resources are inadequate for a full monitoring survey. The next important goals - to relate insect abundance to fish productivity, and to survey fish growth - are not yet within reach.

Pollinators

Pollination by insects is a key process indispensable to the proper functioning of forest and farm ecosystems. It determines the seedset and fruitset of various species of trees, shrubs, and herbs, and is important to plant competition, to the food supplies of birds, small mammals, and beneficial insects, and to crop production (blueberries, apples, clover). The most important agents of pollination are social bees (bumble and hive) and solitary bees. Agricultural insecticides are known to kill bees and damage pollination, and there is now some regional evidence that forest spraying may also be deleterious on occasions. Good spray weather in spring coincides with the prime weather for bee activity, so the probability of exposure is high. The key problems, not yet resolved, are to establish how much insecticide drifts beyond the forest spray blocks, how much mortality of bees occurs from direct sprays and drift, and to what extent this results in reduced production of fruit, seed, and honey, this season and beyond.

Bees and blueberries. (Study by G.W. Wood, Agriculture Canada, supported in 1976 by N.B. Natural Resources funding). Interest in the link between fenitrothion spraying over forests and productivity of adjacent blueberry crops was prompted in 1971 by abnormally low fruit harvest in Charlotte County and elsewhere in New Brunswick. Subsequent litigation attested the need for quantitative data on bee population densities and insecticide contamination through drift. Such data have now been gathered for 4 consecutive years (resources provided by Canadian Forestry Service, N.B. Natural Resources, and Agriculture Canada). Meanwhile Forest Protection Ltd. has avoided spraying within a 2-mile buffer zone around commercial blueberry fields; in adjoining forests it has substituted the insecticide trichlorfon because of its reputedly lower toxicity to bees.

In 1976, three blueberry fields adjacent to fenitrothion blocks in Kent and Westmorland counties were selected for monitoring of insecticide drift. One non-flowering field received a heavy deposit comparable to the expectation from direct overhead emission; the effect on pollinator density will be measured in 1977. The second field received a light deposit of insecticide, but bee tallies indicated no change in activity. The third field showed only trace deposits, such as may drift for miles; bee densities in this field were the highest ever recorded in New Brunswick. Thus, despite all precautions, insecticide drift into blueberry fields from forest spray blocks sometimes occurs but there is not always a measurable effect on bees or fruitset. Insecticide does not contaminate the berry crop itself because the berries have not formed at spray time.

Continuing studies of bee abundance in Charlotte County in 1976 showed strong bee activity in most sampled blueberry fields. A full recovery of bee population density in two fields exposed to drift 3 years ago was noted. In Kings County bee populations had declined in sample fields after insecticide drift last year, but in 1976 densities tended towards recuperation. In general, native bee populations can fully recover in 4 years or less after severe depression due to exposure to insecticides.

Wild bees in the forest. Wild bees are scarce in high forest, but they do frequent flowers that proliferate in openings and along roadsides, foraging on the seasonal succession of plants such as willow, strawberry, and raspberry. There are no well-established methods for estimating bee abundance in forests, nor is there any extensive literature on the diversity of bee species or on their ecology.

A study (I.W. Varty, Canadian Forestry Service, supported by N.B. Natural Resources) was aimed at testing three bee survey methods: tallies of bees attracted to cut-flower traps; tallies of bees on measured flower patches; and net traps to intercept flight lanes. The last method was the most promising but requires development. Solitary bees tended to outnumber bumble bees tenfold in various plots in Charlotte County in 1976. Solitary bees continued to be abundant even after treatment with trichlorfon and fenitrothion. The data on bumble bees, showing low abundance in fenitrothion and trichlorfon blocks compared with the untreated area, suggested an adverse effect from sprays. The results do not imply a drastic effect on pollination.

A study (R.C. Plowright, University of Toronto, supported by a contract on behalf of Environment Canada) was conducted in 1976 to assess the effects of fenitrothion usage on the abundance and ecology of a complex of bumble bee species in forest and blueberry habitats in Charlotte County. The study assessed both short-term effects on species populations by field experiments and sampling, and long-term effects on the bumble bee community in areas repeatedly exposed to fenitrothion over the years. Field investigations were successfully completed, and a report will be issued in November 1976. The results indicate that bumble bees are suitable indicators of insecticide stress and that sampling methodology could be developed for monitoring purposes. The report established an ecological base for further investigations of the pollination process.

Biological Control Agents

Predation and parasitism by insects are major components of biological control regulating the abundance of scores of species of major and minor pests in forests. Entomologists have speculated that broadcast insecticides applied annually over large sections of the province might kill so many predators and parasites that little-known pests might be released from natural regulation at low population level, and might then develop as defoliator outbreaks in various types of forest. If this has been happening, ecosystem stress should be manifested in several ways: as abnormally low percentage parasitisms in indicator host species; as a lower abundance of predatory insects, mites, and spiders; or as a generally higher incidence of pests, some already at epidemic levels in the frequently-sprayed districts, but not in untreated districts.

Parasites. Since it is impossible to investigate the dynamics of the thousands of host-parasite relationships potentially affected by insecticides, a regional surveillance of the parasite-spruce budworm relationships across the Maritime Provinces has been maintained (F.A. Titus, Canadian Forestry Service). About a dozen species of budworm parasites are normally abundant and can be easily sampled. The following results for 1976 show that spraying in spring does not appear to damage the effectiveness of parasites attacking larvae and pupae. In nine sprayed plots in New Brunswick the level of parasitism averaged 13.9% (about 5000 reared budworm). In untreated areas, parasitism was 12.1% in three New Brunswick plots (3500 budworm) and 10.3% in nine Nova Scotia plots (8000 budworm).

Parasite survival in the moth suppression trials in July was monitored. In that month, the most important budworm parasites are in the free-flying adult stage. Their behavior makes them vulnerable to direct contact with spray, so that the hazard to the parasitism process is potentially high. The 1976 data have not yet been fully analyzed.

Predators. Hundreds of species of predatory insects, mites, and spiders occur on forest trees, but their abundance is generally low compared with pest insects, and the techniques of survey are not well developed. Many individuals of many species are killed by sprays for spruce budworm control, but the effects of such mortality on species populations dynamics and on the process of predation are not well understood.

Populations of predators on fir have been monitored since 1970. From 1972 to 1975, the abundance of various groups of predaceous insects has been in slow decline. Some possible causes are: change of habitat due to budworm defoliation, the cyclical scarcity of the predators' staple diet (aphids), and the intervention of insecticides. In contrast, there has been a continued high abundance of predaceous mites and spiders, suggesting that their dynamics are little influenced by those three factors. Data for 1976 are not yet available.

Other insects. Minor pests such as scale insects, mites, and larvae of other moths feeding on balsam fir have not shown unusual population instability over a 6-year examination of sprayed plots. However, a sharp increase occurred in the abundance of some beneficial insects and mites that graze on algae and fungi in defoliated crowns.

Several minor-pest irruptions in various host trees have occurred in New Brunswick over recent years. The outbreak of the lesser maple spanworm, 1973-5, was closely investigated, but there was no evidence that fenitrothion was the cause. An outbreak of spruce scale in sprayed plantations is now under investigation, but the incidence of parasites and predators remained strong, and the pest population has now collapsed. Irruptions of tussock moth, saddled prominent moth, and spruce coneworm have had as severe an incidence in unsprayed districts as in sprayed ones, so the hypothesis of the insecticide trigger appears unlikely.

The available evidence suggests that conventional dosages of insecticide in spring do not degrade biological control processes. However, the evidence is slim, because the complexity of ecological systems under stress is very large relative to survey capacity.

INSECTICIDES ACROSS THE LANDSCAPE

Insecticide distribution

Agriculture Canada, with advice of federal and provincial departments, approved the operational plan for the spray program in 1976. Monitoring to determine the nature and extent of deviations from the authorized plan was undertaken by the Environmental Protection Service (D.A. Lord). In cooperation with Agriculture Canada, particular attention was paid to spray program verification at airstrips, spray deposit and drift in the forest, spillages of insecticides, and insecticide handling and decontamination procedures.

The uniformity of spray deposit was assessed in exposed locations within the spray blocks. Variation in spray deposit between adjacent samples was low whereas variation within an entire spray block was substantial. Variations in spray deposition greater than a factor of 10 were observed in most spray blocks sampled. Overlap of spray swaths was observed on occasions, and subsequent analysis showed that very heavy deposits sometimes resulted from such overlap. Drift of the spray cloud was frequently substantial. Indeed, the sprayer uses drift as part of his technique. Samples taken beyond spray block boundaries showed that in some situations spray deposit occurred at least 1 mile beyond block boundaries and was equal in magnitude to a direct overspray. Some imprecision is inherent in complex, large-scale spray practices. The findings in 1976 are not surprising, and do not differ from what has been observed in other spray years but the extent of monitoring in 1976 was considerably greater.

To find a faster and cheaper method of detecting and measuring local variation in operational spray deposit, an experiment (I.W. Varty, Canadian Forestry Service) was conducted using fluorescent dyes. Variations of deposit on foliage were analyzed by counting dyed spray droplets or by washing to extract dye, and measuring the concentration fluorometrically. Results showed that the spray cloud is not homogeneous and that the variability of deposit is increased by the filtering effect of the upper forest crown, especially on the windward side of each tree. The indicator dye technique is promising but requires further development. The dye results and plate deposits lend support to the contention that under normal spraying conditions a uniform spray deposit is not likely to occur in any given area. Therefore, verification of authorized dosages has major sampling problems. Ecological effects are also likely to be highly variable within a treatment block.

There were three incidents of insecticide spillage involving the release of insecticide loads from aircraft at airstrips, and seven incidents of loads jettisoned during flight. Local contamination occurred at the sites of two plane crashes. These incidents were investigated to ensure that appropriate decontamination procedures were carried out, where possible (Environmental Protection Service and N.B. Environment).

Samples of technical grade insecticides from the barrel at airport loading sites and samples of formulations from the mixing tanks were chemically analyzed for concentration, and were found to conform to the tolerances prescribed by Agriculture Canada. Five trace impurities were detected in technical grade fenitrothion (S. Matheson, E.P.S.): two identified to date are nitrocresol (< 1%) and s-methyl fenitrothion (0.3 - 1.0%).

Inspections of operations at airstrips indicated that procedures for the handling of insecticides and formulations and for decontamination of the facilities and equipment were variable. Small spills were frequent and decontamination was often insufficient. The testing of aircraft spray booms with insecticide formulation for extended periods while the aircraft were stationary on runways, was frequently observed. Many incidents of leaking valves and insecticide-transfer hoses, direct spillage from damaged or upturned insecticide drums, and overflow of insecticide from aircraft tanks by foaming during loading were observed. Analyses of soil samples from airstrips following completion of operations revealed localized areas of high contamination by insecticides.

In summary, the Environmental Protection Service observed inadequate insecticide handling procedures at some airstrips: at others, procedures were satisfactory. Over all, pollution at airstrips is not a serious problem but some of it could be avoided.

Insecticide Persistence

The monitoring team must answer three questions: where did the insecticide go? how long did it last? and what were the breakdown products? Field programs were conducted in 1976 to monitor the persistence of the organophosphate insecticides fenitrothion and trichlorfon in the New Brunswick forest. Fenitrothion was extensively used, whereas trichlorfon was restricted to use in the vicinity of blueberry fields.

The chemical structures of fenitrothion and trichlorfon are similar and the literature indicates a short field persistence for both. The aim of the current study of trichlorfon (I.W. Varty and K.M.S. Sundaram, Canadian Forestry Service) is to determine the "half-life" of the parent compound in various substrates representing the forest environment: foliages of fir, spruce, and maple, surface soil, and stream water. Samples of these were collected over a 4-month period commencing the day prior to spraying.

From another survey area (P.E.K. Symons, Fisheries and Marine Service) streamwater samples were analyzed for trichlorfon. Analysis showed that concentrations could range from high (lethal to caged insects) immediately following spraying, to medium or low later in the spray day. The next day, concentrations usually diminished several-fold.

In another study (V.N. Mallet and L. Lapierre, University of Moncton) levels of fenitrothion and its by-products are being measured in foliage commonly ingested by deer. Samples were collected to determine the increase of fenitrothion in the foliage due to spraying and also the rate of decrease after spraying.

In a separate extensive program (D.H. Cullen and J.P. Witteman, Inland Waters Directorate, Environment Canada), fenitrothion was monitored in upper soil horizons and in water and sediment from streams and bogs or swamps to determine the persistence and concentration of the parent compound and its degradation products. Those samples were collected from three spray blocks during three sampling periods: before, shortly after, and 1 to 2 months after spraying. In the second sampling period, six water samples were collected at each site at intervals (1, 2, 4, 8, 12, and 24 hours) after spraying. Fenitrothion was found in about half of the 80 samples collected directly after application of the spray; it was not detected in any samples taken before spraying or 1 to 2 months after. Shortly after spraying, an extremely high concentration of fenitrothion was found in surface water from a swamp. Concentrations in other stationary waters and in flowing waters ranged from moderate to barely a trace. The maximum concentration was reached 2 to 4 hours after spraying and decreased rapidly thereafter to low or non-detectable concentrations, 24 hours later. The decrease of fenitrothion with time was not coupled with an increase in its major degradation products; fenitrooxon, aminofenitrothion, and nitrocresol were not detectable in most samples, and only at very low concentrations in the other samples. Major ions such as calcium, magnesium, sulphate, and chloride were routinely monitored in all water samples. Data will be analyzed statistically to see if any correlation exists between water quality parameters and fenitrothion persistence.

The residue analysis of sediment and soil samples is in progress. Preliminary analyses of samples collected shortly after spraying reveal the continuing presence of DDT, its isomers, and degradation products in all samples. Presumably these residues derive chiefly from aerial spraying operations in the 1960s. Fenitrothion was occasionally detected in the soil litter after spraying, but its persistence is expected to be brief.

To improve monitoring technology, a research study of certain resins as possible preservatives for fenitrothion and its degradation products in water samples is being conducted (V.N. Mallet, University of Moncton, with support by N.B. Natural Resources and Environment Canada). The results show that the insecticide and its degradation products can be stabilized without change for up to 6 days, perhaps as long as 2 weeks. If this stabilizing technique can be developed, the capacity of monitors to sample and analyze water and air for insecticide contaminants will be greatly enhanced.

Methods are also being refined (V.N. Mallet and B. Trottier, University of Moncton) for measuring fenitrothion and several of its metabolites in animal tissues. These methods will simplify the monitoring of fenitrothion residues in birds and small mammals exposed to the spray.

IMPACT OF REGIMES

All the major regimes were strikingly successful in killing budworm and in protecting foliage. The reasons for the high percentage kill are not fully known at this time (Study by E.G. Kettela, Canadian Forestry Service). A summary assessment of the impact on non-target fauna follows.

Fenitrothion

Fenitrothion sprayed twice at 3 oz/acre at an interval of 4-8 days gave good control of spruce budworm (75-99% kill). Its environmental record in 1976 is broadly acceptable. Nevertheless, considerable stress on small birds (reduced birdsong, presumed sporadic mortality) sometimes occurred when fenitrothion was sprayed at these treatment levels. It is hypothesized that the stress may be a function of the irregular distribution of insecticide laid down by TBM; the response in areas sprayed by DC-6 was significantly less, perhaps because of differences in spray droplet size and distribution. The reproductive success of small mammals appeared to be unaffected. The mortality of stream insects was erratic but in line with previous experience. Effects on sports fish were not expected or monitored. There was no reported fish kill. The roles of beneficial insects (parasites, pollinators) in the spruce-fir ecosystem remained largely intact, based on the evidence of indicator species. Contamination of water, soil, and foliage was generally low and brief but the occasional incidence of high deposit requires further investigation.

The 4 oz/acre dosage (90-99% budworm control from two applications) must be more harmful to the non-target fauna than lighter dosages, but the investigations in 1976 revealed no major impact apart from heavy kill of aquatic insects in some streams. There again, high variability in insecticide deposit entrains high variability of ecological effect, and more conclusive answers cannot be obtained without more study, both intensive and extensive.

With both 3-oz- and 4-oz-treatments, the opportunity for toxicity is brief. In all subtrates examined, the insecticide and its major metabolites persist in appreciable quantities for only a few days, but the fate of the nitrocresol derivative is still unresolved. The presence of trace quantities of impurities in the technical insecticide was confirmed but their ecological significance is unknown.

Trichlorfon

The environmental reputation and pest-control efficacy of this insecticide are good. In 1976, as in former years, its use was restricted to forests in the blueberry-growing districts. The 8 oz/acre dosage, applied twice, is low by agricultural standards. Budworm larval mortality was 65-85%. Because of other priorities only minimal environmental research has so far been directed to its side effects, but no noteworthy harmful influence is known.

Aminocarb

This product is highly toxic to spruce budworm at low dosages, and the principal regime (fenitrothion 3 oz/acre + aminocarb 1 oz/acre + aminocarb 1 oz/acre) gave 90-99% control. Monitoring in 1976 was not extensive, but apparently the prescribed dosages present relatively little hazard to birds. Laboratory data indicate that these dosages are not toxic to fish. The chemical is reputed to break down very rapidly in animal tissues, so there is little likehood of delayed toxicity. Preliminary investigations of its effects on non-target insects are in progress but results are not yet available.

Phosphamidon

This insecticide has been highly regarded for budworm control. In 1976, it was used mainly in the regime phosphamidon 2 oz/acre + aminocarb 1 oz/acre + aminocarb 1 oz/acre, which achieved 90-95% kill of the pest larvae. It has low toxicity to fish, but high toxicity to birds. The effect of this low dosage on songbirds was sometimes severe. The still lower dosages (1 oz/acre) used in sequence against budworm moths in July did not affect bird survival. Phosphamidon at the 4 oz/acre and 3 oz/acre dosages did not affect the reproductive success of voles and deermice.

Moth suppression trials

Small plots were aerially treated with carbaryl (Sevin-4-oil), acephate (Orthene), aminocarb, and phosphamidon to kill budworm moths. From preliminary analysis, none of the spray regimes was highly successful. Birds were apparently not affected. Aminocarb and phosphamidon produced a heavy knock-down of flying adult parasites. The effect of this mortality on parasitism in budworm hosts will be measured in 1977.

DISCUSSION AND RECOMMENDATIONS

Environment Canada has a mandate to conduct research and to advise on natural resources, and to enhance environmental quality. It has a responsibility to promote forest management practices that satisfy diverse needs for fibre, water, fish, wildlife, recreational opportunity and other resources. The Province of New Brunswick is responsible for management and protection of the public forest estate. Both governments share an interest in the budworm problem, and therefore need adequate information on insecticide ecology. The formation of an environmental committee, EMOFICO, to coordinate monitoring studies and to establish that information base is a useful step. The team approach in its first year has produced some good results: coordination of effort in the monitoring, research and inspection fields, a better cross-disciplinary appreciation of the whole environment, a concerted attempt to transmit information to provincial resource departments, and continued rapport between environmental monitors and the spray agencies.

The ecological consequences of spray operations are hard to quantify, but in the current state of knowledge the environmental response to insecticides broadcast over the forest is seen to be resilient. Under operational conditions, some currently-used insecticides at prescribed dosages may clearly exceed threshold levels of toxicity to birds and aquatic insects. Ecological responses are only partly predictable, but the potential for environmental damage is real, particularly if some dosages are increased slightly or the highest dosages reported here are applied more widely. Continued vigilance will be needed.

Monitoring agencies have three long-term concerns: first, the productivity of resources - for example, the continuing abundance of fish and birds appropriate to the carrying capacity of the habitat; secondly, the maintenance of ecosystem integrity - this is the concept that acknowledges the interrelationships of all the fauna and flora of the forest, and hypothesizes that the healthiest and most productive forest has all its components and processes intact; and finally, the control of pollution.

Monitoring faces acute scientific and budgetary problems. The most immediate is the difficulty of sampling. There is such variability in the insecticide regimes, in the local deposition of insecticides, and in species population dynamics, that it is frequently impracticable to sample at an intensity which would give a statistically significant overview of environmental effects to the whole forest landscape of New Brunswick. Forest spray programs in New Brunswick are complex and extensive, taxing the capacity of monitoring resources to meet the task adequately. Since an overview of a spray program's effects on the non-target fauna is desirable, the investigators must exercise considerable judgment in interpreting and projecting from an inevitably thin information base. Monitoring methodologies may vary and divergent inferences may be drawn by different investigators. Any differences in interpretation are not necessarily a measure of opposing viewpoints but rather illustrative of the complexity of the problem.

There continue to be inadequacies in the monitoring effort and weaknesses in applying the results. Most of these are evident in the body of this report. They are:

(1) the thin sampling effort on all organisms: birds, fish, predators, pollinators; the weakness of knowledge about the processes and interactions in which these organisms are involved.

(2) the imprecision of knowledge of the cause-and-effect relationship between spraying and the response of non-target organisms, when there is a lack of a good measure of insecticide deposition.

(3) the absence of adequate baselines concerning fluctuating resource abundance, i.e. a knowledge of what is normal, against which change can be measured.

(4) the slowness in acquiring basic data on new insecticides and spray regimes, and the difficulty of monitoring all major regimes.

(5) the difficulty of providing practical and timely advice so that spray agencies may take steps to minimize environmental hazards.

(6) the problem of informing the public on complex issues.

Recommendations for 1977

At the time of writing, none of the Atlantic provinces has committed itself to a spray program in 1977, but all four governments are concerned over the budworm threat to fibre resources. The decisions on whether, where, and how to spray obviously have a bearing on the scope and kinds of environmental monitoring that should be undertaken. The following recommendations assume that a spray program will be conducted in New Brunswick.

1. Increased fiscal support for the in-house research, monitoring and inspection teams, and for contracted services and research will be necessary. This is not merely a matter of additional summer students and equipment; scientific expertise and technical support are insufficient. Support for monitoring should not be tied too closely to the size of the spray operation. It takes almost as much effort to monitor 1 million acres as 10 million. The needs for increased support will be identified and quantified later.

2. There is a conflict over priorities regarding routine monitoring with customary techniques, research on new techniques, and research in the broad field of pesticide ecology. The same people are involved in all aspects, so this conflict also is a function of the inadequacy of resources.

3. New spray regimes should be thoroughly field-tested on a few operational blocks before possible adoption in full-scale operations. For example, in 1976, the regime phosphamidon + aminocarb + aminocarb was launched over 320,000 acres without a preliminary operational test of its environmental safety. Spray programs are so subject to change that it is hard to maintain monitoring continuity.

4. Because of the insufficiency of current monitoring experience the Committee considers that none of the spray regimes can be fully accepted without reservation. Caution is urged with the following treatments and regimes:

a) phosphamidon at the 2 oz/acre dosage or heavier. Such treatments can produce an undesirable level of mortality of songbirds.

b) fenitrothion at the 4 oz/acre dosage; such treatments can exceed the threshold level of mortality to birds and aquatic insects.

c) moth suppression spray regimes with a long sequence of applications, because monitoring experience is still limited.

The Committee recommends that any such treatments be limited to a few spray blocks and that monitoring agencies should seek more definitive knowledge of their ecological effects. Further, there should be a comparison of the ecological effects caused by spraying with different spray techniques (e.g. aircraft type) to determine whether the quality of the spray cloud influences faunal response.

5. In making a spray plan, a spray agency should not employ so many regimes that the monitors cannot keep track of their effects. The Committee urges a less complex operational plan.

6. Closer liaison between monitors and the spray agencies is urged. Monitors could conduct their surveys with greater effectiveness and could produce better results if they had a measure of control or influence over the spraying of some operational blocks monitored or researched. In practice, Forest Protection Ltd. was very accommodating to monitors in 1976 but its prime responsibilities are operational. The brief time frame for effective spraying, the vagaries of the weather, and the hectic pace of flight scheduling allow the spray agency little opportunity to fully meet the monitors' requirements for traditional scientific methodology. However, the relationship is still not satisfactory for monitors waiting in the wings. The liaison between monitors and J.D. Irving Ltd., Woodlands Division, is more tenuous; that agency's activities appear to be insufficiently documented and information is harder to obtain. At the very least, monitoring agencies should have the operational spray map 6 weeks before spraying begins so that study areas may be located. The call for closer liaison with the spray agencies is not a suggestion that the tail should wag the dog. The Committee seeks recognition that monitoring is a necessary check on the spray tactics, and is an indispensable appendage to resource protection strategy.

7. Liaison with monitoring groups in Quebec and Maine should be strengthened. Mechanisms for exchange of technical information do exist, but in practice each monitoring group works in partial isolation. Moreover, comparison of ecological effects is quite difficult because of differences in spray techniques, aircraft, and chemicals.

Conclusion

The Committee recognizes the limitations of the scientific data produced by the monitoring agencies, and admits the tentative nature of ecological interpretation. Nevertheless, this report is presented as an insight into the ecological aspects of forest spray practice. It explains attendant environmental effects and risks, and should contribute to future spray operation design. The Committee believes the report will help to promote broader resource management and better environmental protection, and is a valid contribution to the science of ecology.

MONITORING AGENCIES

AGRICULTURE CANADA
  Research Station, Fredericton, N.B.

ENVIRONMENT CANADA
  Fisheries and Marine Service
    Freshwater and Anadromous Division, St. Andrews, N.B.
  Environmental Management Service
    Canadian Forestry Service
      Maritimes Forest Research Centre, Fredericton, N.B.
      Chemical Control Research Institute, Ottawa, Ont.
    Canadian Wildlife Service, Fredericton, N.B.
    Inland Waters Directorate, Moncton, N.B.

  Environmental Protection Service
    Environmental Services Branch, Halifax, N.S.

MONTREAL ENGINEERING CO., LTD. (under contract)

NEW BRUNSWICK DEPARTMENT OF AGRICULTURE AND RURAL DEVELOPMENT
  Veterinary Services Branch, Fredericton, N.B.

NEW BRUNSWICK DEPARTMENT OF THE ENVIRONMENT
  Pollution Control Branch, Fredericton, N.B.

NEW BRUNSWICK DEPARTMENT OF NATURAL RESOURCES
  Fish and Wildlife Branch, Fredericton, N.B.
  Forest Service, Campbellton, N.B.

UNIVERSITY OF MONCTON, Moncton, N.B.
  Department of Chemistry (under contract)
  Department of Biology

UNIVERSITY OF TORONTO, Toronto, Ont.
  Department of Zoology (under contract)