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THE BIOLOGICAL SIDE-EFFECTS OF FENITROTHION IN FOREST ECOSYSTEMS

by C. H. Buckner

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ABSTRACT

Fenitrothion, applied as recommended for aerial control of forest insects in a single application of 3 oz/acre or in 2 applications of 2 oz/acre causes insect pest mortality for about 4-7 days. It degrades rapidly in water and soil, but may remain in trace amounts in certain plant foliage for several months. Although laboratory studies indicate that this insecticide is extremely toxic to honey bees, it causes no significant damage to commercial apiaries if applied as recommended. Forest amphibians are relatively insensitive to fenitrothion even at dosages several times the recommended level. Some species of small forest birds show slight mortality at applications above 4 oz/acre, and species in exposed niches such as yellowthroats, kinglets, Nashville and Tennessee warblers, and chipping sparrows show an increase in susceptability as dosages increase. Other species, notably the white-throated sparrow, are relatively insensitive to treatments even four times the recommended levels. Small mammals are less sensitive than birds: shrews first indicate impact at dosages beyond 6 oz/acre and rodents react at levels beyond 15 oz/acre. It is concluded that this insecticide presents only negligible environmental impact if used as directed.

RÉSUMÉ

Le fénitrothion provoque la mort des insectes ravageurs pendant environ 4 à 7 jours, s'il est appliqué selon le mode d'emploi pour la lutte aérienne contre les insectes forestiers en une seule aspersion de 3 onces/acre, ou en 2 aspersions de 2 onces/acre. Dans l'eau et le sol, il se dégrade rapidement, mail il peut en subsister des traces sur le feuillage de certains végétaux pendant plusieurs mois. Les études en laboratoire montrent que cet insecticide est extrêmement toxique à l'égard des abeilles domestiques, mais si on l'applique tel que recommandé, il ne cause pas de dommages aux ruches

commerciales. Les amphibiens forestiers sont relativement insensibles à l'action du fénitrothion, même quand sa concentration est de plusieurs fois supérieure à la concentration recommandée. Quelques espèces de petits oiseaux forestiers subissent une légère mortalité si les applications sont supérieures à 4 onces/acre, et la susceptibilité des espèces telles que les fauvettes à gorge jaune, à joues grises, les fauvettes obscures, les roitelets et les pinsons familiers qui vivent dans des niches exposées s'accroît avec les concentrations d'application. D'autres espèces, notamment les pinsons à gorge blanche, sont relativement insensibles aux traitements même quatre fois plus énergiques que le traitement recommandé. Les petits mammifères sont moins sensibles que les oiseaux: les musaraignes réagissent à des concentrations dépassant 6 onces/acre et les rongeurs, à des concentrations supérieures à 15 onces/acre. On conclut donc que cet insecticide n'a que des effets environnementaux néglibeables s'il est utilisé conformément aux recommandations.

INTRODUCTION

The insecticide fenitrothion, an organophosphate compound, has been widely used in the provinces of New Brunswick and Quebec for control of spruce budworm, *Choristoneura fumiferana* (Clem.), since the withdrawal of DDT. By 1969, fenitrothion was the prominent insecticide in budworm control programs throughout eastern North America and the biological side-effects have been under constant surveillance in Canada by The Canadian Forestry Service and The Canadian Wildlife Service since the pesticide has been put into widespread use. Preliminary studies indicated that fenitrothion was both efficacious against spruce budworm larvae and of low hazard to fish and wildlife compared with its predecessors and with compounds available currently. This material also appears under the trade names Sumithion, Accothion, Folithion, and Novation.

IMPACT ON THE PHYSICAL ENVIRONMENT AND PLANTS

The recommended applications for fenitrothion are 3 oz of the active insecticide per acre emitted from the aircraft on one application, or 2 oz/acre applied twice. It is registered for forestry usage in amounts up to 4 oz/acre. Under satisfactory meteorological conditions [illegible]u[illegible] [illegible]0-4[illegible]% of the ac[illegible]iv[illegible] m[illegible]r[illegible]l might b[illegible] [illegible]x[illegible]c[illegible] [illegible]posited (Armstrong 1973). This however, is an average figure for it has been shown to vary locall[illegible] between 0.3 oz/acre a[illegible]d 12 [illegible] d[illegible]posite[illegible], even un[illegible]er [illegible]ea[illegible] conditions for application. Uneven distribution is one of the principal causes of sporadic environmental overdoses. In the forest ecosystem, the largest proportion of the deposit is intercepted

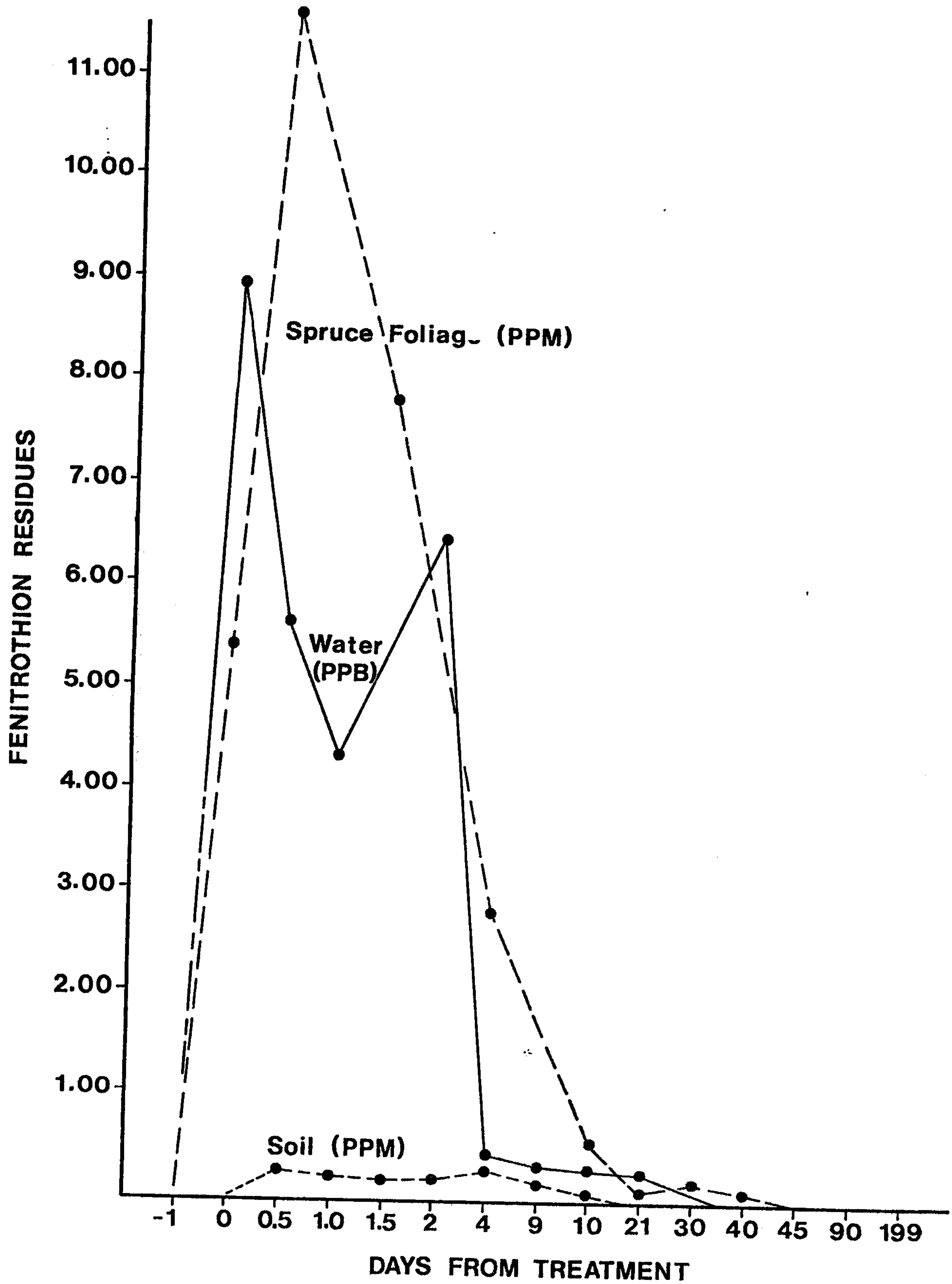
? where did this info come from?

by the crown canopy: a small portion filters through the various canopy strata, arrives at the ground surface and lodges in the top layer of soil. Penetration into the soil, however, is not deep. Salonius (1972), found under experimental conditions that massive doses of fenitrothion applied to forest soils had little effect on numbers or activity of soil flora. Fenitrothion commences to degrade immediately upon formulation, and degradation proceeds at varying rates in all the microhabitats it reaches (Fig. 1). Degradation on plants (e.g. spruce and fir foliage, Yule & Duffy 1972, Sundaram 1974) is rapid and biological activity is lost in about 4-10 days. Recently. Yule (1974) has detected an apparent accumulation of fenitrothion in the foliage of balsam fir in New Brunswick. Sundaram (1974) has been unable to confirm this in similar studies in the Larose Forest. Accumulation, if it exists, is confined to the older foliage and in very small amounts, and consequently would be of no biological significance to the invertebrate fauna of this tree species. The pesticide remains active in pollens somewhat longer (approx. 20-25 days, Fig. 2). It is difficult to detect in soil after about 7 days.

IMPACT ON FOREST INVERTEBRATES

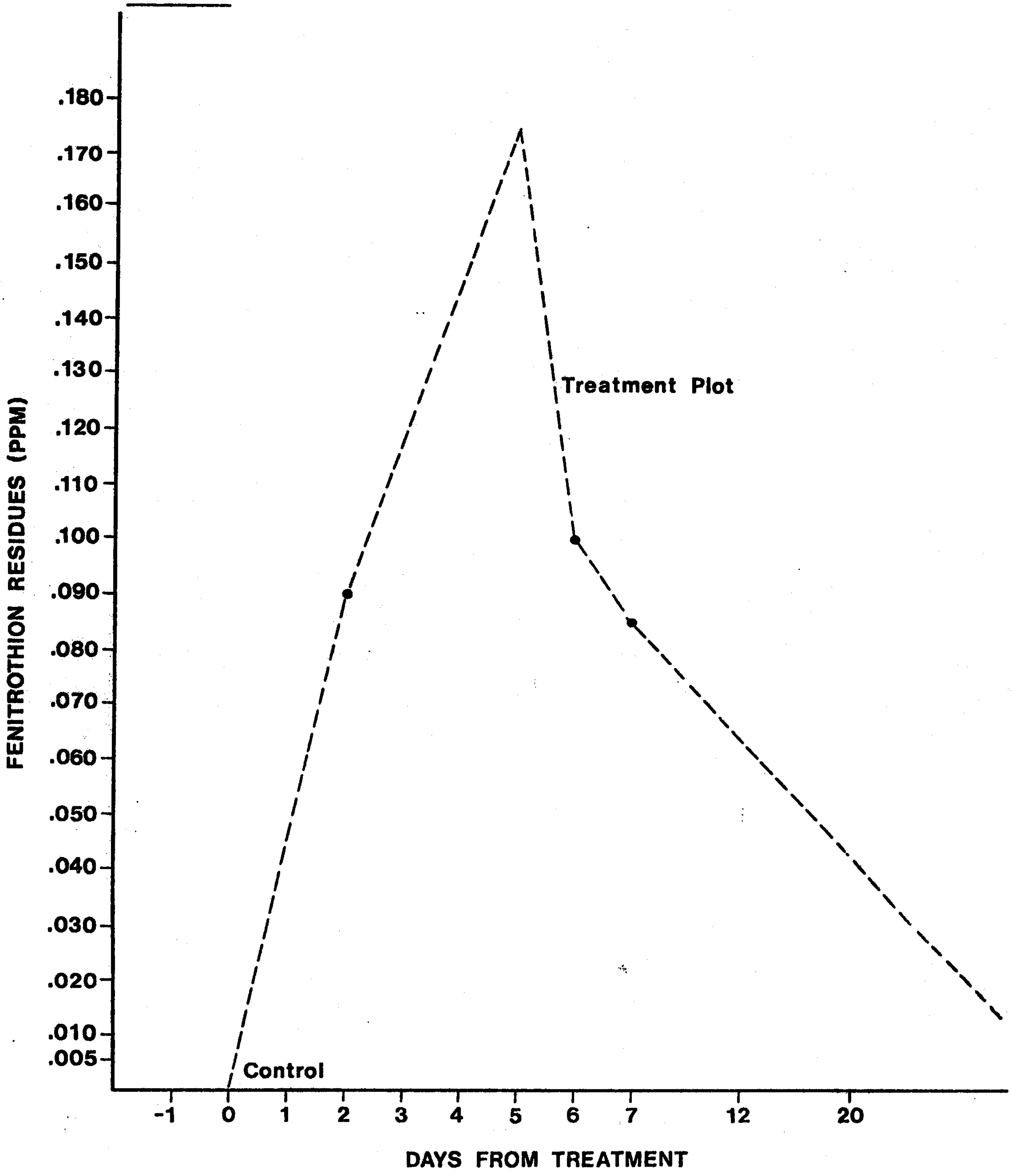
Mortality of the forest invertebrate fauna reflects the longevity of the compound in the various portions of the ecosystem. Ground inhabiting invertebrates declined in population after topical applications of fenitrothion for 2-3 days following treatment but the numbers of most species had returned to normal the year following treatment (Freitag and Poulter 1970, Carter and Brown 1973). Defoliating insects and their predators exhibited a similar immediate reduction,

Figure 1



Persistence of fenitrothion in spruce foliage, water and soil in the Larose Forest, 1973.

Figure 2



Fenitrothion residues in pollen collected from hives on an area in Larose Forest treated in 1973.

lasting 4-7 days and recovering in most cases within the next generation. Generally the field mortality curves reflect laboratory toxicity studies (Krehm 1973). Comparable values for terrestrial invertebrates other than forest pests are rare but those that are available are in general agreement. Mortality of the defoliators is more prolonged than that of other groups, indicating that contact poisoning through close proximity to contaminated parts of the environment is reduced rapidly after the application, whereas poisoning by ingestion may be prolonged somewhat due to the assimilation of greater concentrations. The impact on terrestrial invertebrates does not appear to be serious, perhaps because to date the treatment has been confined to a single or double application over a relatively short time period. There is no evidence that poisoned invertebrates provide an oral pathway for predators nor is there any indication that predators of vulnerable invertebrates suffer from acute food shortages because of the treatment. trophic levels ?

IMPACT ON HONEY BEES AND POLLINATORS

Recent investigations carried out jointly by the Canadian Forestry Service and the Canada Department of Agriculture have focused on the impact of various chemical and biological insecticides applied for control of forest insects on domestic honey bees. Impetus for these studies emanated from instances where control operations resulted in some mortality in private apiaries adjacent to areas under treatment. Although laboratory data were available on the toxicity to bees of the various insecticides currently in use in Canadian forestry practice, and also limited field data on the impact of pesticides in field and orchard trials, no data were available on the effects on bees of the much lower dosages and less frequent applications used in forestry. Claims from apiarists for damages to hives adjacent to control operations could not ve evaluated adequately either from the standpoint of eventual honey production or of immediate pollination potential. It was also recognized that insight into the relationship between wild pollinator populations and insecticide treatments might also be gained by studying the more easily handled honey bees.

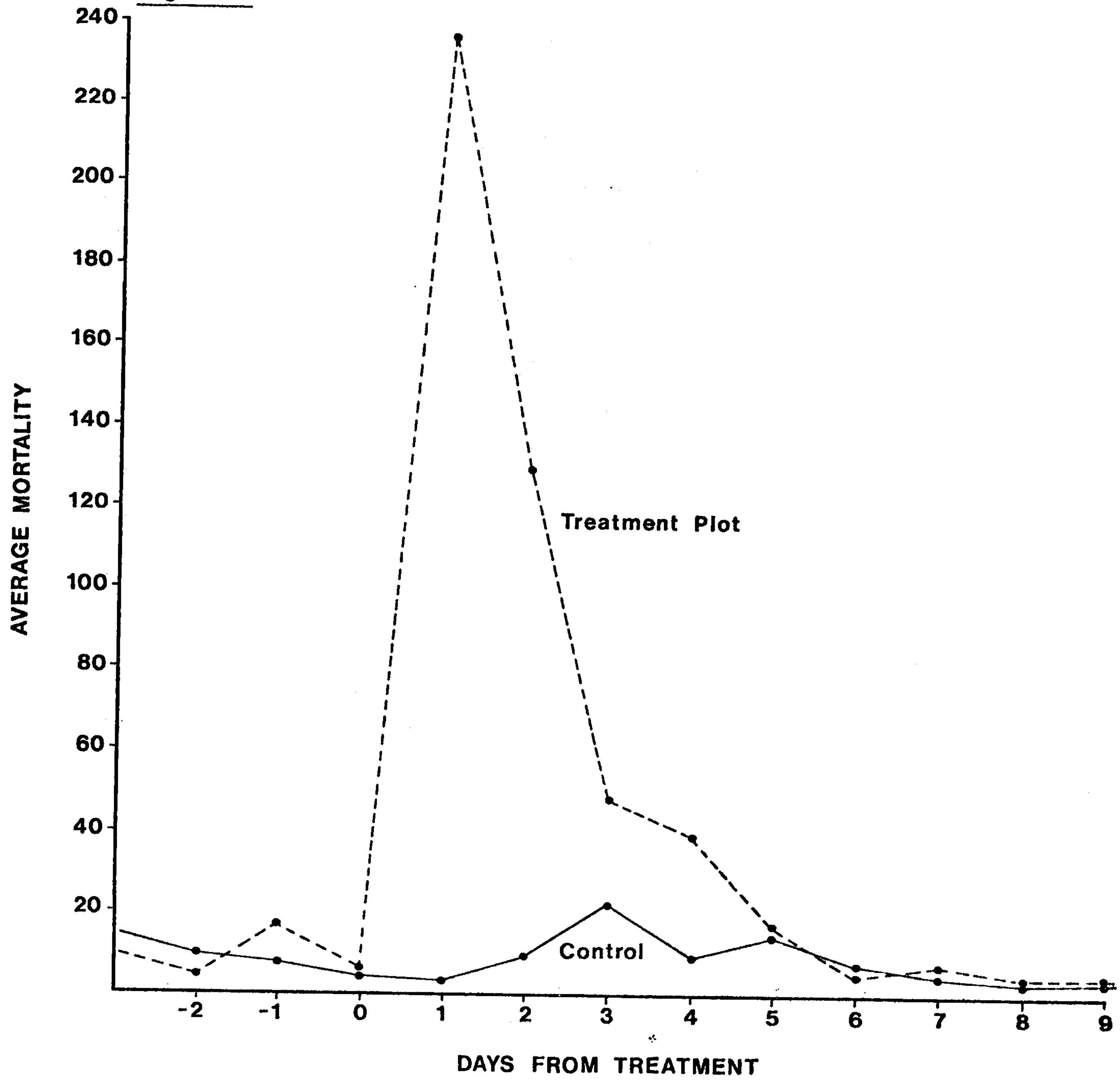
Definitive experiments were conducted on the effects of fenitrothion on bees in the LaRose Forest, 30 miles east of Ottawa, Ontario, from 1971 to 1973, and on operational applications of this insecticide near Mt. Laurier, Quebec, about 150 miles northeast of Ottawa in 1974.

Preliminary experiments on the impact of fenitrothion on domestic honey bees were initiated in the LaRose Forest in 1971. Hives were placed upon a 40 acre tract of forested land that was later treated with 4 oz of fenitrothion emitted per acre. Comparison with hives located on an untreated control plot indicated that there was little if any lasting effect on the treated hives from the standpoint of apiculture. Refinements resulting from the pilot trials included the addition to each hive of: a trap to collect the dead adult bees removed from the hive by the hive attendant bees; a weighing apparatus to record the weekly weight changes; an electronic counting device to record the numbers of bees entering and leaving; a pollen trap to measure daily pollen collection; and, a visual recording of the area of comb containing brood immediately prior to and following treatment. The pilot study was conducted on a small 40 acre block. Subsequent trials, except where comparisons were necessary with the small sized plot, were conducted on plots of minimum dimensions of 2 miles, to include the flight and foraging range of the worker bees.

With the fenitrothion applications, there was an initial knockdown of adult worker bees. Collections of dead adult bees removed from the collecting traps were at times spectacular until counts and estimates revealed that these represented perhaps only less than one percent of the worker bee force of the hive. Greatest mortality was experienced within a few hours after treatment, and this diminished rapidly until after about 4 days no further differences between treated and control hives could be detected (Fig. 3). There was indication that pollen collection was somewhat suppressed and that some treatments affected brood slightly. There were no detectable changes in either flight activity or rate of hive weight gain attributable to fenitrothion applications. No loss of queens could be attributed to the insecticide treatments. Experiments were conducted both in early morning prior to any foraging activity and towards mid day when maximum foraging activity was in progress. Only slightly greater impact was detectable at the higher level of foraging activity. Similar results were obtained in operational treatments of 2 oz/acre applied twice with a one-week interval between treatments.

Results from studies of the impact of fenitrothion on domestic honey bees indicate that although some adult bee mortality could always be associated with the chemical insecticide treatments, this was not high relative to the total strength of the hive. From the standpoint

Figure 3



Mortality of worker bees on an area in Larose Forest treated with fenitrothion, 1973.

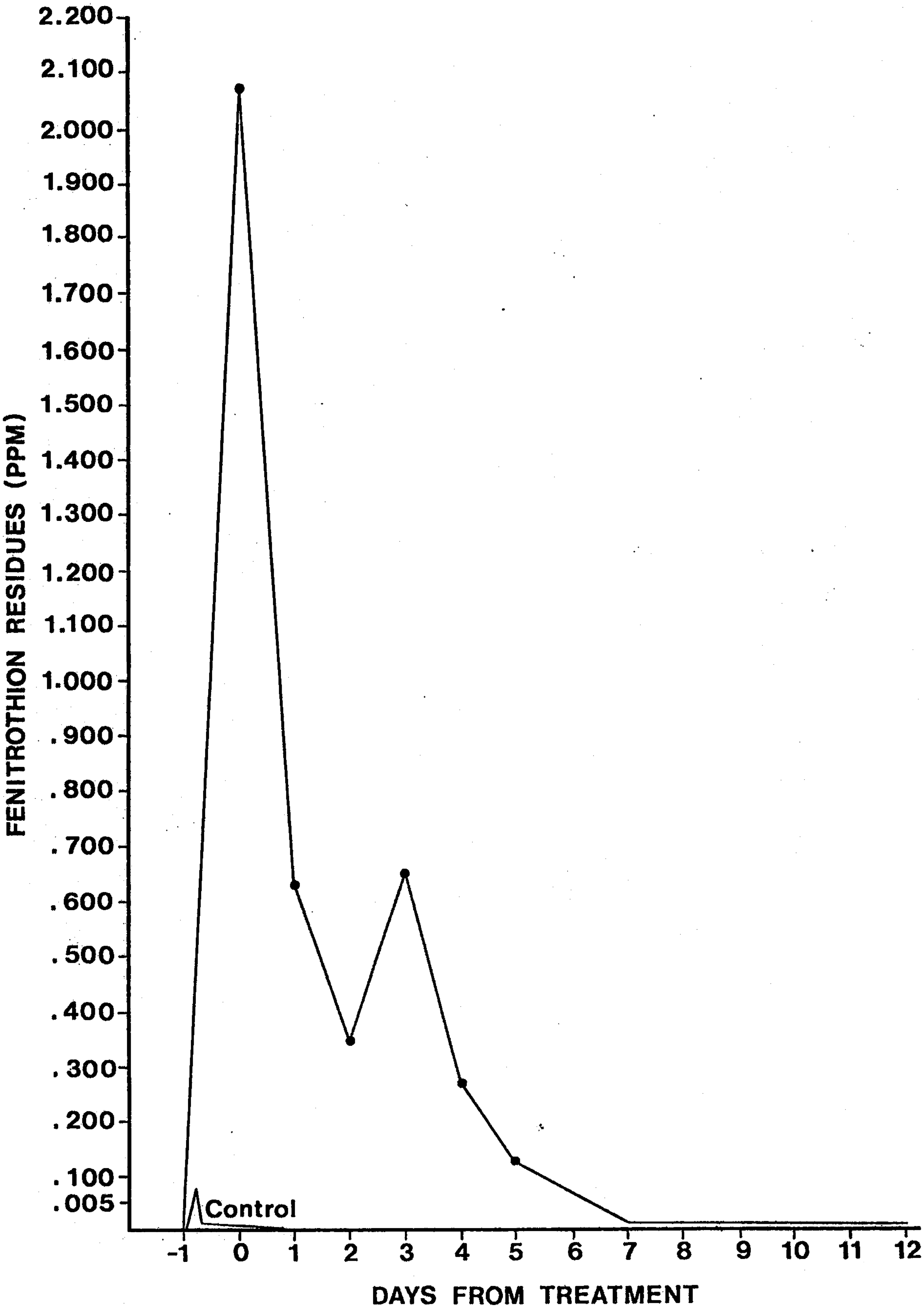
of both pollination and eventual honey production the impact from the apiculture point of view was negligible, even through collections of dead adult bees from treated hives at times appeared excessive. Other than adult mortality, no parameter measured was significantly affected by the treatments.

Studies on domestic honey bees and casual concurrent observations on wild pollinators indicate that such pest control treatments are likely to be only slightly damaging to wild bees. Extrapolations are of course dangerous, but the indications from these experiments suggest that only a minor disruption of wild pollinator populations is likely. Although mortality following treatment was several hundred times normal, the total impact represented less than 1% of the hive population. Some disorientation of the worker force followed each treatment. Residues determined on dead bees collected from traps located at the hive entrance also decreased rapidly and were at very low levels 3-4 days after treatment (Fig. 4). These determinations are lower than the LD_{50} (4.67 ppm) as determined by laboratory test (Atkins and Anderson 1967). Fenitrothion is listed among the pesticides highly toxic to honey bees (Anderson and Atkins 1968) but residues of other terrestrial invertebrates, mostly insects, found dead after treatment of 4 ounces per acre averaged 1.69 ppm, a value similar to that derived from analysis of dead bees.

IMPACT ON FOREST AMPHIBIANS

Amphibians are found in both adult and larval forms in many parts of the forest ecosystem. Adult frogs and toads feed heavily on insects and play a role in controlling insect pests. The Environment

Figure 4



Fenitrothion residues in worker bees found dead at the hive in an area in Larose Forest treated in June 1973.

Impact section of the Chemical Control Research Institute has monitored the effects of insecticide sprays on amphibians to determine if these treatments adversely affect their populations. Applications of fenitrothion using operational dosages have been applied to experimental plots in the Larose Forest Since 1971. Small shallow ponds containing large numbers of breeding amphibia have been monitored for side effects caused by the treatments. Spray deposits on the pond surfaces have ranged from 0.6 oz/acre (active ingredient) to 11.8 oz/acre (active ingredient). Caged specimens have been monitored and general observations on indigenous populations made throughout the test period. The results showed the operations to have no observable effects on populations of aquatic or terrestrial stages of the various amphibia inhabitating the area.

Laboratory experiments were initiated to determine the lethal dosage rates of fenitrothion for frog and toad tadpoles. Preliminary analysis of the data obtained to date has shown operational dosages to be harmless to all the aquatic stages with the possible exception of the very early gilled stage.

A shallow pond on a test plot on northern Vancouver Island received two applications of fenitrothion (2 oz active ingredient each). Observations were made immediately after treatment and six weeks later. Large numbers of salamander eggs and larvae were present on both occasions and no mortality due to the treatment was recorded.

The results of all these observations and tests would indicate that if fenitrothion is applied to the environment at recommended operational dosages no adverse side effects to the amphibian larvae will result. The low toxicity of organophosphate insecticides to tadpoles and frogs has been demonstrated by Mulla et al. (1963) and Tucker and Crabtree (1970). Crescitelli et al. (1946) showed that the functional integrity of frog nerves persists even at remarkable low cholinesterase levels and this may partly explain their resistance to organophosphate insecticides which are cholinesterase inhibitors. Organochloride insecticides, compared to fenitrothion, are relatively toxic to frog and toad tadpoles (Sanders, 1970) and DDT has been shown to significantly reduce adult amphibian populations (Fashingbauer, 1957). Tadpoles in a DDT treatment area quickly accumulated high residue levels but adult frogs contained low, variable DDT residue levels, possibly because their high fatty acid turnover rate increases their mobilization and excretion of DDT (Meeks, 1968). Cooke (1971) has shown that sub-lethal exposure to DDT made frog tadpoles more susceptible to predation by newts than normal by making them hyperactive. No such sublethal effects have been observed in the case of fenitrothion.

IMPACT ON SMALL FOREST BIRDS

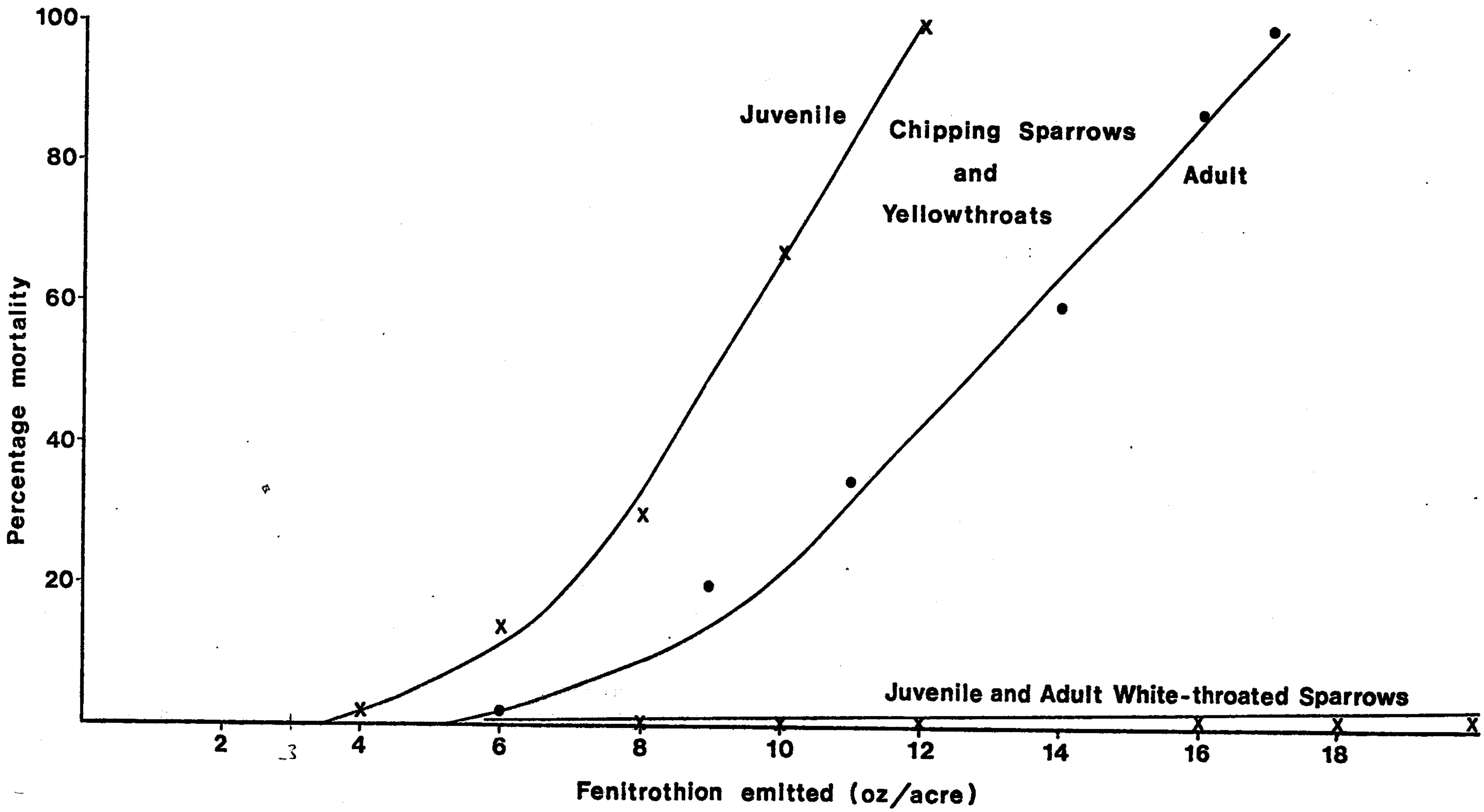
The ecological consequences of aerial applications of fenitrothion on bird populations have been investigated by Pearce (1968, 1971) in New Brunswick, Rushmore (1971) in Maine, and by the Chemical Control Research Institute, Ecological Impact team in New Brunswick, Quebec, Ontario, Manitoba and British Columbia.

To determine the impact of forest insecticides on birds in treated areas, bird populations ideally should either be measured before and after spray application, or populations on treated areas should be compared to those on untreated areas. Forest spray programs in Canada have been largely directed at larval forms of defoliating insects at a time early in the breeding cycle of most avian species when the males are territorial and quite vocal. Two bird census techniques have been used during monitoring activities, both dependent on the identification of singing males. The first method (Kendeigh 1944), involves the determination of the actual numbers of birds of each species in an area of known size. That is achieved by repeated traversing of gridded plots and delineating the territories of all singing males, a singing male repeatedly registered in the same area being assumed to represent a breeding pair plus offspring. Population density may be expressed as the number of breeding pairs per 100 acres. This method was modified by Buckner and Turnock (1965) by reducing the area censused, thus allowing a wider latitude of replicates and by including components of the populations additional to singing males. The objective of the second method is to obtain a population index of each species to provide comparisons of the relative abundance of various species or of the same species before and after spray application in an area of unknown size. Population indices, expressed as songs heard and birds seen and heard per unit of time, are obtained by an observer traversing a pre-determined route of two or more miles oriented across the anticipated flight paths of the spray aircraft. In both methods censuses should ideally be made in untreated control areas, so that population fluctuations attributable to factors other than the spray might be assessed more readily. There are advantages and disadvantages in each approach. The first method allows for more precision. By following the presence of individual birds in a time continuum, subtle changes in population and behaviour may be recorded. However, establishment of plots may be time-consuming, and the plots must be sufficiently large to sample birds with large territories adequately and yet not so large that birds with small home ranges cannot be counted with accuracy (Kendeigh, 1944). Furthermore, plots situated in operational programmes may be partially or completely missed by the spray or they may be "multiple-swathed" which would give data unrepresentative of the total treatment area. The second method compensates to some extent for the unavoidable gaps between and overlaps of spray swaths. A major defect is occasioned by the masking of the singing of birds distant from the observer by the singing of those close to him. A population reduction caused by spraying is not precisely reflected in changes in bird population indices because after such an event the observer's range of hearing is increased. It is also difficult to differentiate reduced singing caused by factors other than population reduction.

Searching for dead birds in treated areas comprises an integral part of the field techniques. If dead birds were found in numbers in or near spray zones, cause and effect could be related without much doubt. This is rarely the case. However, supportive evidence obtained by analysis of some avian casualties for residues of the insecticides employed and, in the case of cholinesterase-inhibiting compounds, brain acetylcholinesterase determinations have also been obtained. Depending on the density of ground vegetation, only a small fraction of the total number of casualties can be expected to be found. During post-spray searches birds are sometimes observed with evidence of aberrant behaviour and symptoms of poisoning.

Initial large-scale spray trials of fenitrothion produced conflicting results. Under certain circumstances this insecticide was lethal to birds when applied at 8 oz/acre (Pearce, 1968). Continued investigation showed that fenitrothion was acutely toxic to some birds when sprayed at rates as low as 4 oz/acre and there was further evidence that low-volume spraying, in which a relatively fine atomization of the insecticide is achieved, somehow increased the hazard to birds (Pearce, 1968). Similar observations have been made in the Larose Forest studies. Brain cholinesterase measurements in areas sprayed at 2 oz/acre were almost normal (1.80 am), indicating no deleterious effects (Rushmore 1971). At rates of about 2 oz and over behavioural changes, noticeably reduced singing by territorial males and reduced movements could be detected. At applications between 3 and 4 oz some mortality may be detected, principally confined to nestlings and fledglings and at rates over 4 oz adult avian mortality is experienced. Experimental applications of the chemical up to 18 oz/acre have been applied, resulting in complete mortality in some species (e.g. chipping sparrow *Spizella passerina*, Maryland yellowthroat *Geothlypis trichas*, Yellow warbler *Dendroica petechia*) reduced numbers in certain species (e.g. Nashville warbler *Vermivora ruficapila*, Blackburnian warbler *Dendroica fusca*, purple finch *Carpodacus purpureus*) and impaired fledglings in yet other species (e.g. Tennessee warbler, *Vermivora perigrina*, pine siskin *Spinus pinus*). Many species however remained unaffected even at these extreme dosages (e.g. chestnut-sided warbler *Dendroica pensylvanica*, white-throated sparrow *Zonotrichia albicollis*, yellow-bellied sapsucker *Sphyrapicus varius*). The impact upon any particular species is evidently related to its habits: the more exposed niche, the more severe the impact (Fig. 5). Most mortality

Figure 5



Relationship between bird mortality and fenitrothion dosage.

is discovered within 24 hours of application, and this fact plus the consideration that food contamination must be greater than any measurement so far made to provide lethal oral concentrations, suggests that physical contact with the spray cloud is the principal cause of impact. This might be either through dermal or respiratory pathways. In an accidental overdose in Quebec in May, 1973, several tree swallows (*Iridoprocne bicolor*) were recovered dead with high concentrations of fenitrothion on feathers and in the gizzard (197.20 and 2.28 ppm respectively). The feeding habits of this and related species of hunting flying prey would expose these predators to higher concentrations of the compound as they are flying through the spray cloud. It is however inconclusive as to whether the cause of poisoning is oral or respiratory. Laboratory studies (Table I) corroborate the field data, that fenitrothion has a relatively low toxicity to birds. Pilot studies on the impact of fenitrothion on forest birds in Manitoba and British Columbia are in agreement with results obtained in eastern Canada.

Conclusions drawn from sustained investigations of the influence of fenitrothion on forest birds may be summarized as follows: (1) fenitrothion is of relatively low toxicity to birds compared with other compounds currently in use; (2) larviciding conducted very early in the season reduces the hazard to birds because many are not yet on their summer range; (3) spraying in the late evening reduces the hazard to birds because they are relatively inactive at that time; (4) birds which exploit the upper forest canopy or sites exposed overhead are most vulnerable to aircraft sprays; (5) males are more vulnerable than females, probably because they are more active in the nesting season and come into greater contact with the spray cloud; (6) other factors

TABLE I

Toxicity of fenitrothion to birds*

Species	LD 50 mg/kg	Route
Domestic fowl	500	Oral
Hen	523	Oral
Male chicken	668	Subcutaneous
Mallards	1190	Oral
Pheasants	56	Oral
Bobwhite quail	27	Oral

* Data provided by Sumitomo Chemical Ltd.

being equal, fine sprays may be more hazardous than conventional ones; and (7) even at low recommended application rates, fenitrothion may be lethal to some birds subjected to over-exposure because of uneven spray distribution.

For several years fenitrothion has been the major insecticide used in Canadian forest protection programs, against a variety of insect pests. At recommended dosages of 2 or 3 oz/acre it has presented no significant hazard to Canadian forest bird populations. A few avian casualties have been reported almost annually, however, in zones treated with fenitrothion at those relatively low rates, suggesting a rather narrow margin of safety, or inadequate control against uneven insecticide distribution. Those lethal effects are tentatively attributed to local overexposure resulting from overlapping spray swaths or to aircraft flying at an insufficient spraying altitude. Fenitrothion has generally been applied as an emulsion by single-engined aircraft. A departure from that technology has recently taken place in Quebec where that insecticide has been applied in oil solution by multi-engined aircraft. Preliminary evidence indicates that this operation is comparable to those in New Brunswick with respect to impact on avian populations.

Nearly all monitoring of the influence of forest sprays on non-target animals has been in the context of larviciding operations, at a time before the young of most forest birds have hatched. The concept of spruce budworm control by application of chemical insecticides later in the season when moths are active has recently attracted some interest. That may be a more critical time for birds, in the sense that local populations are augmented by recruitment of young birds which themselves may be more directly or indirectly vulnerable to the spray. The potential increase of hazard to bird fauna posed by budworm adulticide spraying has not been assessed adequately. Attempts to do so in New Brunswick in 1973 were frustrated by excessive prior use of insecticides in study areas that year by the private sector.

The impact of this indiscriminate use of fenitrothion was measured on four plots in northwestern New Brunswick, and compared with two normally treated control plots. Breeding bird populations on all six plots were measured by the singing male technique (Kendeigh 1944, Buckner and Turnock 1965). Populations on the treated plots were unusually low compared with populations in the control plots. There was an absence of yellow-bellied sapsuckers, tyranid flycatchers, catbirds, Tennessee warblers, Nashville warblers, Maryland yellowthroats, and blackbirds, and a noticeably reduced population of nuthatches, kinglets, upper crown feeding warblers and certain fringillids. A summary of the data (Table II) suggested that total populations in Plots 1-4 were less than 60% of those in the control plots and the numbers of species on Plots 1-4 were less than 65% of those in the control plots. Parulid warblers and fringillids showed the greatest reduction in numbers.

Spruce foliage samples collected in the Plots 1-4 were subjected to chemical analysis for fenitrothion and the results ranged from 0.04 to 0.19 ppm. No insecticide was detectable in samples taken from the control plots. Residues in samples from Plots 1-4 are unusually high considering that budworm control operations should have terminated about one month previously.

TABLE II

Population and species distribution of small forest birds in areas treated with excessive amounts of fenitrothion, and in areas treated with conventional dosages

	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5 (Control)	Plot 6 (Control)
Populations in Pairs per 100 Acres	181	236	133	169	229	385
No. of Species	20	23	18	20	27	36

These studies indicate a sharply reduced songbird population as a result of excessive use of the insecticide fenitrothion. Safe-guards against inadvertent indiscriminate use of this or any other pesticide are now provided for in recent Federal and Provincial legislation dealing with permits, use, and procedures relative to forest pest control operations.

IMPACT ON SMALL FOREST MAMMALS

Of all the components of the forest ecosystem, mammals are perhaps one of the most difficult to assess in terms of the effects of aerial applications of insecticides. The large mammals are dispersed widely and any possible impact is likely to go unnoticed: small mammals are mostly nocturnal or secretive in habits and effects of treatment are difficult to measure. It is perhaps for these reasons that scant information is available on the impact of fenitrothion on forest mammals. Inferences may be gained from laboratory toxicology tests, mostly on domestic laboratory subjects, but with fragmentary information it is difficult to extrapolate to the forest ecosystem. The few studies that have been conducted indicate that mammals in general are relatively invulnerable to the aerial application of insecticides.

Studies on the ecological consequences of aerial application of fenitrothion on small mammals has been confined largely to the work of the ecological effects team of the Chemical Control Research Institute. At application rates below 6 oz/acre small mammals were not measurably affected by the treatments: at high application rates, populations of shrews, especially the cinerous shrew *Sorex cinereus*, were reduced. All the reduction occurred in the juvenile population. At 18 oz/acre, mortality of juvenile shrews reached 100%. A similar but less pronounced decline in juvenile populations of rodents *(Clethrionomys gapperi, Peromyscus maniculatus)* was also evident. In both Insectivore and Rodent groups there was a suppression of the first breeding cycle of adult females after the treatment at the extreme dosage level. The oral LD50 for laboratory mice is about 700 mg/kg (Gaines 1969). Intensive laboratory studies on the effects of fenitrothion on the white-footed mouse, *Peromyscus maniculatus*, the meadow vole, *Microtus pennsylvanicus*, and the red-backed vole, *Clethrionomys gapperi*, all common boreal forest inhabitants, have been carried out by the author. Subjected to aerosol treatment in spray towers, no immediate mortality was obtained in treatments equivalent to applications of up to 30 oz/acre, but when oil based carriers were used, several juveniles of each species contracted lung lesions at these above-normal application rates (10 oz/acre +) and a few died between 21 and 70 days after treatment. At normal application rates, no ill effects were detected either in short or long-term. Experiments using the same species and the same insecticide for chronic toxicity studies were less conclusive because sub-adult and adult animals (over the age of 35 days) consistently rejected food contaminated with even the slightest amount of the insecticide. The less discriminating juveniles learned very quickly also to detect and reject fenitrothion contaminated material. If a test animal consumed any amount less than a lethal dose it would in almost all cases reject even the slightest contaminated food in subsequent trials. These results indicate that the oral pathway except for juveniles is an unlikely poisoning route for wild populations subjected to fenitrothion applications. No data are available for shrews. Because of generally low mammalian toxicity it is unlikely that wild small mammals could accumulate sufficient oral doses of the poison to cause death. Because the decay within the environment is quite rapid after treatment, a respiratory or dermal route is likely.

Fenitrothion is of low mammalian and relatively low avian toxicity and is not likely to present a serious hazard to these groups under normal operating conditions. Accidents or misuse could cause an impact on these groups, however. The pathway of the compound into the animal is not understood clearly and further studies are required to define this more clearly.

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