Investigations of Fish Mortalities In and Adjacent to Areas of Quebec Treated with the Insecticide Fenitrothion in 1973.

by

P.D. Kingsbury

Chemical Control Research Institute

Ottawa, Ontario

Information Report CC-X-58

Canadian Forestry Service

Department of the Environment

November, 1973

Introduction

In 1973 the Quebec government conducted an aerial spraying operation to prevent defoliation of forests infested with spruce budworm, Choristoneura fumiferana Clem. The spraying of vast areas of infested forests required the use of very large spray planes capable of delivering large loads of insecticide and a sophisticated aircraft guidance system making it possible for pilots to fly parallel flight lines over stretches of trackless forest. The use of these spray techniques made it impossible to avoid introducing spray products into some of the numerous lakes of all sizes which dotted the spray areas without seriously reducing the efficiency of treatment of surrounding forests. In order to protect the aquatic fauna of lakes exposed to spray products the insecticide was applied in an oil based formulation rather than as an emulsion in water. Fenitrothion, the insecticide used, is insoluble in water and when introduced into a lake in an oil solution it should remain dissolved in a surface film of oil and not penetrate into the lake waters beyond the extent to which surface turbulence mixes it.

During the course of the Quebec spray program, two reports of fish mortalities in the vicinity of fenitrothion spray areas were received from personnel of the Canadian Wildlife Service and the Quebec government's Service de la Faune. The sites of both of these incidents were visited on June 5, 1973 and the findings and conclusions of these two investigations are presented herein.

Fish Mortality Investigations

Lac à la Truite - Introduction

On June 5th 1973, an investigation was made of fish mortality in Lac à la Truite, a small lake about a third of a mile long and a sixth of a mile wide situated about one mile north of Val-Viger in Labelle County, Quebec (Fig. I). This privately owned lake is stocked annually by its owner with speckled trout, *Salvelinus fontinalis* (Mitchill) for the purpose of running a put-and-take fishing operation. The lake's owner reported that on three separate occasions the lake was sprayed by large aircraft engaged in the aerial application of the insecticide fenitrothion to the surrounding forests. The dates of these three sprayings were reported as May 5, 20 and June 2, 1973, with the largest deposit of insecticide and most noticeable effects occurring on May 20. During the afternoon of this day a spray plane was reported to have made two passes within ten minutes of each other over the lake. Following this spraying, the lake's owner reported collecting between 20 to 25 dead brook trout from along the shoreline and seeing many others lying on the bottom of the lake but out of reach.

On the 28th and 29th of May, M. Jacques F. Bergeron, a biologist with the Quebec government's Service de la Faune, visited the lake. He collected data on water chemistry and plankton populations and found eight dead brook trout along the lake's shoreline. He also observed large numbers of Diptera larvae on the lake's surface but was unable to conclude if these were cast exoskeletons of emerged adults or dead larvae. On June 5th, M. Bernard Vincent, the chief biologist for the district, visited the lake and snorkeled along a large portion of the shoreline with another diver. They found two dead brook trout and reported seeing several live ones. In order to further determine the extent of fish mortality the author conducted an underwater search of the bottom using scuba equipment on June 5, 1973. Three locations were searched at depths of from five to twenty feet; off the inlet, off the outlet and in front of lake's owner's cottage. Total bottom time was 45 minutes during which approximately 24,000 square feet of bottom were searched. The search was hampered by suspended particles in the water which reduced visibility on the bottom to about five feet. During the search no live or dead fish were seen.

The owner of the lake reported a sharp drop in angling success on the lake immediately following the spraying on May 20. Mr. M. Gilbertson of the Canadian Wildlife Service obtained some incomplete data on this from a register compiled by the lake's owner (Table 1). No record of angling effort in terms of the rod-hours fished each day was available, but the data obtained shows a sharp drop in angling success on the day after the lake was sprayed, with an immediate recovery the next day anglers were on the lake. In the entire period the lake was open to fishing in 1973 about 2600 fish were caught-about 1600 up to and including May 20 and about 1000 after May 20.

The water chemistry data collected by M. Jacques F. Bergeron (Table 2) shows that on May 29, the lake exhibited strong thermal stratification with the thermocline at a depth of between ten and twenty feet (Bergeron, 1973).

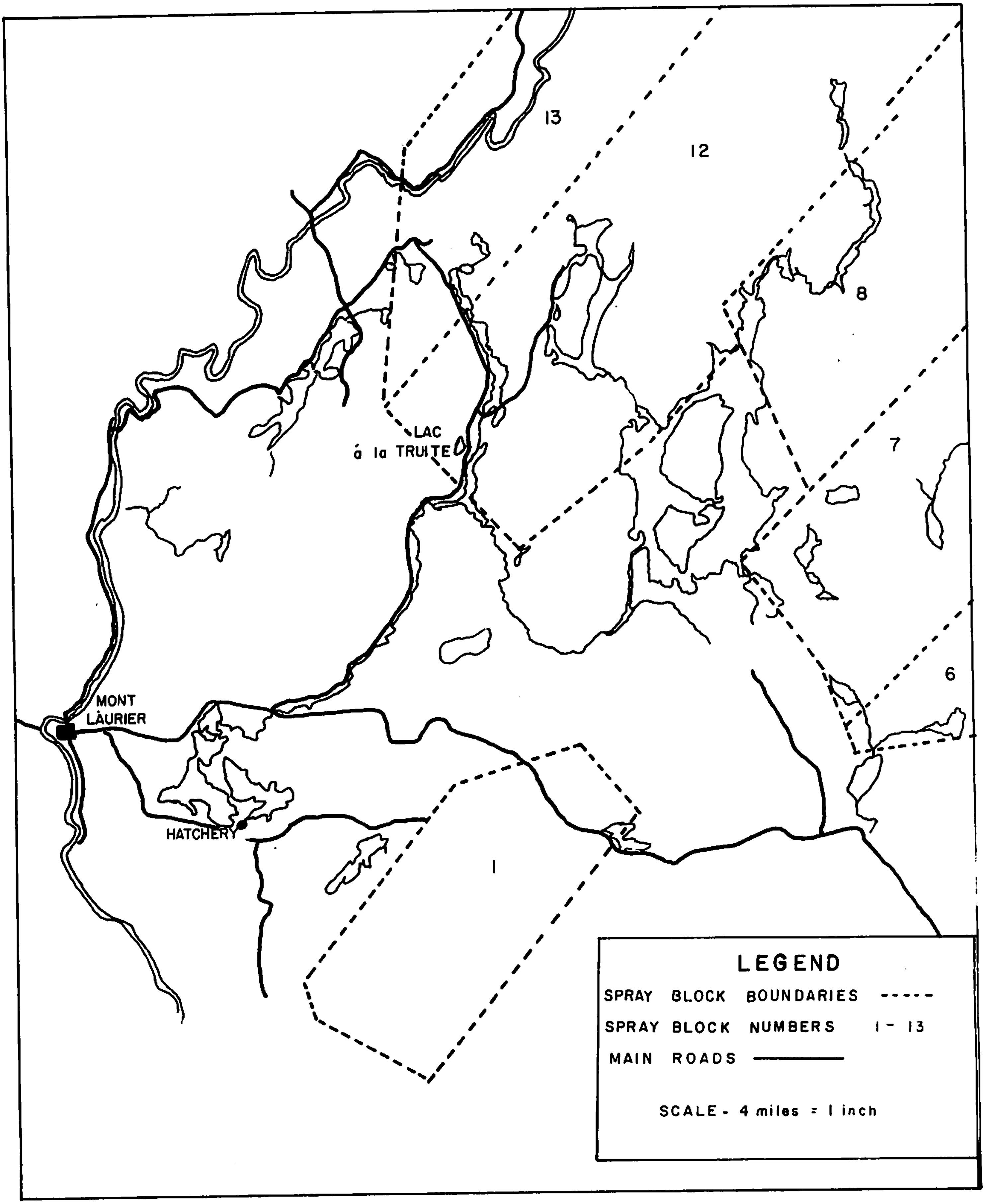

Fig. 1. Locations of investigations of fish mortality in western Quebec during 1973.

Table 1

Number of anglers and fish caught at Lac à la Truite, P.Q., 1973.

Date	No. of fishermen on lake	No. of fish caught
May 11 - 20	> 100	1602
May 21	18	1
May 22	0	0
May 23	2	18
May 24	2	9
May 25	3	19
May 26	17	97
May 27	14	34
May 20 to Aug. 6	approximately 200	approximately 1000

An examination of the weather records for May from Mont-Laurier airport, fourteen miles south-west of Lac à la Truite, show that the first half of the month was generally cool and windy but from May 17 right into June the weather was hot and calm. This would indicate that the lake was rapidly stratifying when it was sprayed on May 20.

Table 2

Temperature, dissolved oxygen, and pH at various depths near the outlet of Lac à la Truite, P.Q. at 10:15 A.M. on May 29, 1973. Taken from Bergeron, 1973.

Depth	Temperature	O_2	% saturation	pH
0	61°F	9ppm	95	6.8
10'	60°F	10ppm	105	6.8
20'	47°F	8ppm	70	6.0
32'	47°F	5ppm	45	5.9

The underwater search revealed that the bottom of the lake drops quickly from sandy shores and then becomes rather flat and featureless. It consists of firm, gelatinous ooze several feet thick but with a rigid surface capable of supporting clams and rooted plants. Sponges and small rooted aquatic plants were the main life forms seen readily. Clams, water mites and bryozoan colonies were much less abundant. During the underwater search, samples of water and clams were collected to be analyzed for fenitrothion residues. Five brook trout collected dead and frozen by the lake's owner a day or two after the 20th of May spray and the two brook trout found dead on June 5th by the Service de la Faune divers were also obtained for analysis. Water samples were stored at a constant temperature of 34°F and fish and clam samples were frozen until they could be analyzed (Table 3).

Table 3

Chemical Analysis for Fenitrothion of Water, Fish and Clams Taken From May 21 and June 5, Lac à la Truite, P.Q., 1973

Sample	Date Collected	Fenitrothion Concentration
Water - Surface	June 5	3.43ppb*
Water - 15'	June 5	1.67ppb*
5 Brook Trout (Whole)	May 21	0.77ppm†
2 Brook Trout (Whole)	June 5	0.19ppm†
5 Clams (Shell Removed)	June 5	0.026ppm†

* ppb - parts per billion

† ppm - parts per million

Lac à la Truite - Discussion

In order to interpret the meaning of the analytical results presented in Table 3 three factors must be taken into consideration: the concentration of fenitrothion in water lethal to brook trout, the breakdown rate of fenitrothion in water, and the levels to which fenitrothion can be accumulated in fish before it produces lethal effects.

Bioassays conducted to determine LC50 values (the concentrations of fenitrothion in water lethal to 50% of test groups of fish during a set exposure period) indicate a lethal threshold to juvenile salmonoides of 0.9 ppm fenitrothion in the water (Sprague, 1966). Actual LC50 values given by Canadian researchers range from 2.0 ppm when exposure time to the insecticide is 24 hours to 1.0 ppm for a 96-hour exposure period (Sprague 1966, Bull. 1971, Hatfield & Anderson 1972). Concentrations of fenitrothion of about a tenth these values (e.g. 0.1 ppm) caused no mortality but reduced feeding and altered social behaviour of test groups of fish (Bull. 1971).

The very small amounts of fenitrothion present in the water samples on June 5, only three days after the lake was last reported sprayed, rule out the possibility that concentrations of fenitrothion in the lake water ever reached the levels shown by laboratory studies to cause extensive fish mortality. The half-life of fenitrothion in water with a pH of 6.8, the pH of the lake's surface water, ranges from about two to two and a half days as determined from field and laboratory studies (Sundaram 1973, Buckner unpublished data). This means half the fenitrothion in the lake waters would break down over this period of time. From the analytically determined concentration of 3.43 ppb fenitrothion in the lake's surface water on June 5 we can calculate a theoretical initial concentration in the order of only 10 ppb fenitrothion in the lake's surface water on June 2 following an application of two to three ounces of insecticide per acre. This value is in close agreement with concentrations of fenitrothion found in natural waters of experimental fenitrothion spray areas receiving similar insecticide doses. (Buckner, unpublished data).

The decrease in insecticide concentration with depth seen in the analytical results show that mixing of fenitrothion in the lake's surface waters was incomplete. This can be attributed to the close association of the insecticide with the surface film of oil. The lake has been shown to be in the process of stratifying at the time of spraying and this would prevent the penetration of fenitrothion through the thermocline into the cold hypolimetic waters. This layer of water extended to the bottom from about twenty feet and was cold (47°F) and reasonably well oxygenated (45 to 70% saturation) (Bergeron, 1973), presumably due to the presence of springs on the lake bottom. It would serve as a relatively insecticide-free environment for brook trout which would usually be found in this bottom layer of water except when feeding near the surface.

The accumulation of fenitrothion residue in the brook trout to levels many times higher than those of the surrounding water is similar to that documented for caged and wild brook trout populations exposed to similar fenitrothion sprays. Caged trout in Manitoba fenitrothion spray areas accumulated fenitrothion residues to levels as high as 1.87 ppm without experiencing acute or chronic toxic effects (Lockhart, 1973). Residues from none detectable up to 0.77 ppm were found in live fish from fenitrothion spray areas in Newfoundland while dead fish from the same areas contained residues between 0.31 and 0.72 ppm (Hatfield & Riche, 1970). The spread in residue levels in both live and dead fish reflect the variation in individual fish's rate of accumulation and tolerance towards fenitrothion. This in turn reflects differences in diet, habitat selection and other aspects of behaviour of individual fish. In light of this, it is interesting to note that stomach content analysis of the five brook trout collected dead on May 21 showed all these fish were feeding almost exclusively on dragonfly nymphs of the Family Aeshnidae which live amongst the aquatic vegatation along the shores of lakes at depths of only one and a half feet or less (Walker 1912, p. 51). In selectively feeding on this relatively scarce, very shallow-dwelling food organism these trout would spend long periods of time searching the littoral zone of the lake. This would place them in close proximity to and occasionally in contact with the surface film of oil where most of the insecticide was concentrated and would result in these fish accumulating more insecticide than brook trout which fed in deeper water on planktonic or benthic organisms and spent much of their time below the thermocline. The relatively low concentration of fenitrothion found in clams collected from about ten feet of water reflect the smaller amounts of insecticide organisms were exposed to in deeper water as compared to very shallow water.

The decline in angling success after the May 20th spraying can be attributed to the stratifying of the lake waters and the emergence of adult Diptera from the lake's surface at this time. Creel censuses conducted each spring on lakes in Algonquin Park have shown that up to eighty per cent of the brook trout caught in these lakes by anglers each year are taken between the time the ice leaves the lakes and when the lakes becomes stratified (Fraser, personal communication). These creel censuses have also shown that during this period angling success drops sharply when large numbers of flying ants emerge and provide the brook trout with an abundant food supply as they drop into the lake. The Diptera larvae observed by Bergeron on the lake's surface on May 28 were probably cast exoskeletons of emerging adults and these would provide the brook trout with an abundant food supply as they rose from the bottom of the lake to the surface.

Lac à la Truite - Conclusions

It can be concluded from analysis of the data collected that introduction of fenitrothion into the lake probably resulted in mortality of only about thirty brook trout, an insignificant number of fish in terms of the lake's population of several thousand. The insecticide introduced into the lake water was insufficient to cause significant mortality and was primarily confined to the surface water where brook trout spend very little of their time after the lake stratifies. The fish which appeared to have been killed by fenitrothion poisoning may have been exposed to larger amounts of the insecticide due to their selective feeding habits which brought them into contact with insecticide on the lake's surface.

Val-Barrette Fish Hatchery - Introduction

On June 5, 1973, an investigation was made of fish mortality at the Service de la Faune fish hatchery at Val-Barrette, about six miles southeast of Mont-Laurier, Quebec. The purpose of this investigation was to establish if there were any connection between this mortality and the nearby aerial spraying of fenitrothion being carried out by the Québec Government. The hatchery itself was located outside the boundary of the areas sprayed (Fig. 1), but close enough that personnel at the hatchery could see planes spraying nearby. It was unlikely that any insecticide drifted into the hatchery's open raceways but it was possible that the water supply for the raceways could have been contaminated with fenitrothion as it originated from a watershed partially within the spray area.

The extent of the fish mortality up to and including June 5, was estimated by hatchery personnel to have been about 6,500 brook trout, Salvelinus fontinalis (Mitchill). The first noticeable mortality occurred on May 30, and over 1,000 fish were reported dead each day from June 1 to June 5. All mortality, however, was limited to fish in only one of the hatchery's several raceways. All the raceways contained brook trout at the same stage of development (4-6 in.) and were supplied with water from a single intake from an adjacent river. Approximately 1,000,000 small brook trout fry (< 1 in.) housed in a large building and supplied with the same water showed no mortality during this period. As these smaller and more crowded fish would have been more vulnerable to an insecticide entering via the water supply, it seemed highly unlikely that fenitrothion poisoning was the cause of mortality in the affected raceway.

To confirm this observation, samples of brook trout and water were taken from the affected raceway and an adjacent raceway where no fish mortality had occurred. Fish which were still alive but apparently dying were selected from the affected raceway while healthy fish were netted at random from the unaffected raceway. The fish from each raceway were homogenized together and a 20 gram aliquot was analysed for residues of fenitrothion. A 200 ml aliquot of the water from each raceway was also analysed (Table 4).

Table 4

Chemical analysis for Fenitrothion of water and fish taken from the Val-Barrette Hatchery, P.Q., June 5, 1973

Sample	Origin	Fenitrothion Concentration
Water	Affected Raceway	Trace (<0.0001 ppm*)
	Unaffected Raceway	Trace (<0.0001 ppm)
Brook Trout	Affected Raceway	0.013 ppm
	Unaffected Raceway	0.012 ppm

* parts per million

Val-Barrette Fish Hatchery - Discussion

The low levels of fenitrothion residues present in the water and fish samples confirm that the fish mortalities were not caused by insecticide poisoning. Bioassays conducted to discover LC50's for juvenile salmonoides (the concentration of fenitrothion in water lethal to 50% of test groups of fish during a set exposure period) indicate a lethal threshold of 0.9 ppm fenitrothion in water and 24 to 96-hour LC50 values ranging from 2.0 ppm to 1.0 ppm (Sprague 1966, Bull. 1971, Hatfield & Anderson 1972). The concentration of fenitrothion present in the raceway water on June 5 was only a thousandth of this level.

The fish in both affected and unaffected raceways had concentrated fenitrothion residues to a level about a hundred times higher than that found in the water. Similar insecticide accumulation has been observed in caged and natural trout populations within fenitrothion spray areas. Fish containing residues up to 0.7 ppm and averaging about 0.1 ppm fenitrothion have remained healthy (Hatfield & Riche, 1970). The hatchery fish accumulated insecticide to only a tenth of this concentration.

Val-Barrette Fish Hatchery - Conclusions

It can be concluded that there was no connection between the fish mortality which occurred at the hatchery and the aerial application of fenitrothion to nearby forests. This conclusion is based on the low insecticide residues present in hatchery fish and water on June 5 when large numbers of dead fish were still being found each morning. It is supported by the lack of fish mortality outside of the one affected raceway despite all fish at the hatchery being exposed to similar amounts of fenitrothion introduced in river water which had flowed through sprayed areas.

Discussion

In 1970 fenitrothion replaced DDT as the principle insecticide used in Canada to control forest defoliators. For several years beforehand laboratory tests and field trials were conducted to determine the effects of fenitrothion on fish. Experimental and operational sprays from 1966 to 1969, with applications ranging from three to eight ounces of fenitrothion per acre, were judged to have had no significant effect on fish populations in spray areas (Penney and MacDonald 1966; MacDonald and Penney 1967, 1968 and 1969; Hatfield and Riche 1970). Fenitrothion sprays are still being monitored for effects on fish populations and experimental programs have been established to look for long term or sub-lethal effects of this insecticide on fish (eg. Bull. 1971, Hatfield and Anderson 1972, Lockhart 1973).

The findings made by the investigations described in this report agree with the results reported by other workers monitoring the effects on fish populations of operational aerial applications of fenitrothion. No significant mortality amongst fish populations could be attributed to the introduction of fenitrothion into aquatic ecosystems. Neither could the decrease in angling success in a sprayed lake be attributed to lethal or sub-lethal effects of the insecticide as there were sufficient natural occurrances to account for this decrease.

It appears certain that large scale chemical control programs will be required for several years to protect the forests of Quebec from the present spruce budworm infestations. It is imperative, therefore, that an experimental program be established to study the fate and effects of aerially applied insecticides which end up in lakes in treated areas. An important result of such an experimental program would be the pin-pointing of organisms which would indicate the level and effects of insecticides in a lake by the insecticide residues they contained or the general health of their populations. This would allow monitoring of much larger numbers of lakes in an operational spray area than would be possible if numerous components of each lake had to be sampled to determine effects of the insecticide on that lake. By spot checking the condition of such an indicator organism in numerous lakes it would be possible to determine if any of these lakes appeared damaged and required further investigation.

Summary

In 1973 large forested areas of Quebec were aerially treated with the insecticide fenitrothion to protect them against an infestation of spruce budworm, *Choristoneura fumiferana* Clem. Reports of fish mortalities within and adjacent to treated areas were received and subsequently investigated. About thirty brook trout, *Salvelinus fontinalis* (Mitchill) were found dead on one small lake. This was an insignificant number of fish in terms of the lake's total brook trout population as the lake was stocked annually with several thousand fish and in 1973 a total of about 2600 brook trout were removed from the lake by anglers alone. The fish found dead may have died of insecticide poisoning as they had accumulated fenitrothion residues to levels which might cause mortality to a small portion of the total population. It appears that these particular fish accumulated residues because they were brought into proximity or contact with a surface film of insecticide dissolved in the oil carrier while they were searching for and feeding on shallow dwelling dragonfly nymphs. The rest of the lake's several thousand brook trout were unaffected by the insecticide as the chemical did not penetrate into the deeper waters where they were feeding. Mortality among brook trout in a hatchery raceway receiving small amounts of fenitrothion in its water supply was found to be unrelated to the presence of the insecticide. It was concluded that no significant mortality amongst fish populations could be attributed to introduction of the insecticide into aquatic ecosystems.

Acknowledgements

The author wishes to thank Dr. K.M.S. Sundaram of the Chemical Analysis Service Section, Chemical Control Research Institute for analysis of the samples collected for fenitrothion residues.

Appreciation is also extended to M. Antoine Villeneuve, the owner of Lac à la Truite, and to personnel of the Quebec governments Service de la Faune and the Department of the Environment's Canadian Wildlife Service for their co-operation in providing information and samples for analysis.

The help of Drs. J.A. Armstrong, C.H. Buckner and W.N. Yule in reviewing the manuscript is gratefully acknowledged.

The interest, encouragement and suggestions of Dr. C.H. Buckner and Dr. J.J. Fettes were of particular assistance in preparing this report.

Appreciation is also extended to Mr. J. Umpherson for his assistance in collecting samples.

References

Bergeron, J.F. 1973. Rapport Concernant les Arrosages de Fenitrothion dans le District des Laurentides. Service de la Faune, Quebec. 5 pp. typewritten.

Bull, C.J. 1971. The effects of Sumithion, an organophosphate insecticide, on the behaviour of juvenile Coho salmon Oncorhynchus kisutch (Walbaum). M. Sc. Thesis, U. of Victoria. B.C. Fish & Wildlife Branch.

Hatfield, C.T., and J.M. Anderson. 1972. Effects of two insecticides on the vulnerability of Atlantic salmon (Salmo solar) parr to brook trout (Salvelinus fontinalis) predation. J. Fish. Res. Bd. Canada 29:27-29.

Hatfield, C.T., and L.G. Riche. 1970. Effects of aerial Sumithion spraying on juvenile Atlantic salmon (Salmo solar L.) and brook trout (Salvelinus fontinalis Mitchill) in Newfoundland. Bull. Env. Contam. Toxic. Vol. 5(5):440-442.

Lockhart, W.L. 1973. A Biochemical and Residue Study of Rainbow Trout (Salmo gairdneri) Caged in a Stream during an Aerial Application of Fenitrothion: A Preliminary Report. Dept. of Environment, Freshwater Institute, Winnipeg.

MacDonald, J.R. and G.H. Penney. 1967. Preliminary report on the effects of the 1967 New Brunswick forest spraying on juvenile salmon and their food organisms. Resource Development Branch, Dept. of Fisheries Can., Halifax.

______________. 1968. Report on the effects of the 1968 New Brunswick aerial forest spraying on juvenile salmon and their food organisms. Resource Development Branch, Dept. of Fisheries Can., Halifax.

________.1969. Preliminary report on the effects of the 1969 New Brunswick forest spraying. Resource Development Branch, Dept. of Fisheries Can., Halifax.

Penney, G.H. and J.R. MacDonald. 1966 . Preliminary report on the effects of the 1966 forest spraying on New Brunswick salmon. Resource Development Branch, Dept. of Fisheries Can., Halifax.

Sprague, J.B. 1966. Preliminary estimates of toxicity of five insecticides to juvenile Atlantic salmon. Fisheries Research Bd. of Canada Biological Station, St. Andrews, N.B. 2 pp. typewritten.

Sundaram, K.M.S. 1973. Degradation dynamics of Fenitrothion in aqueous systems. Information Report, Chemical Control Research Institute, Ottawa. In Press.

Walker, E.M. 1912. The North American Dragon flies of the Genus Aeshna. Univ. Toronto Studies, Biol. Ser. No. 11: 1-213.