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Operational Spraying of Acephate to Suppress Spruce Budworm Has Minor Effects on Stream Fishes and Invertebrates

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The Maine Forest Service sprays large areas of spruce-fir forest annually to suppress spruce budworm epidemics. In 1976 about 930,000 acres were treated, of which 63,000 acres near certain waterways received acephate because of its apparent low toxicity to aquatic life (USFS 1977). This was one of the first operational sprayings with acephate, and the goal of the study was to determine the effects on a stream ecosystem. The specific objectives were to measure: 1) Acetylcholinesterase (AChE) activity of fish brains as an index to direct effect. 2) Examine the effect of spraying on fish feeding. 3) Compare the growth of adult and young-of-the-year salmonids from treated and control streams. 4) Document the effects of spraying on macroinvertebrate standing crop and drift.

METHODS AND MATERIALS

North Brook and South Brook in the treated area entered Moosehead Lake, Piscataquis County, Maine on the east shore and Squaw Brook, the control, entered the lake on the south shore. The streams averaged 5-7 m in width with alternating pools and riffles. Discharges were 0.5 to 1 m^3/s during the week of spraying. Bottom materials were typically medium to large rubble. All streams were chemically similar with low dissolved constituents as determined by alkalinity ($\bar{x}$ = 8 mg/L) and conductivity ($\bar{x}$ = 28 umho). Application of acephate was made by helicopter between 6:30 and 8:15 A.M. on May 31, 1977. Water samples for residue were taken in plastic gallon jugs and frozen within 3 h.

Brook trout (Salvelinus fontinalis), landlocked salmon (Salmo salar), longnose sucker (Catostomus catostomus) and common sucker (C. commersoni) were captured by electrofishing. Fish were placed in a stream holding cage to recover for about 30 min. To analyze AChE, brains were removed, placed in plastic whirl-pac[R] bags, instantaneously frozen in a tank of liquid nitrogen, and stored in a freezer until analyzed by the method of COPPAGE & MATTHEWS (1974). Five brains were combined for each AChE sample. Fish for stomach analysis were preserved in formalin immediately after capture. Prey taken from the stomach were identified to order, and the volume per category was determined by liquid displacement for the combined total of all fish taken on each date. Growth and condition were determined for fish caught by electrofishing from May through October, with a target of 30 fish of each species for each

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sample. Fish were anesthetized with MS222, weighed, measured, had scales removed, and were released. Early in the season young-of-the-year were captured by seining. Condition factors, an expression of the relationship between length and weight, were calculated by the method of EVERHART et al. (1975).

Invertebrate drift was obtained from the three streams over an eight-day period before and after spraying. Each sample was taken in a drift net (1 ft^2) placed in midstream for 15 min. The control stream was sampled daily whereas in each treated stream 18 samples were taken at time intervals ranging from daily to every two hours. Water discharge through the nets was calculated from current meter readings and the amount of drift was standardized to adjust for different amounts of water filtered. Invertebrate standing crop was estimated with a Surber sampler. Similar riffle areas from each stream were selected and 9 samples each were taken pre-spray, 2 days post-spray and 9 days post-spray. The samples were preserved separately and later the fauna was identified to genus.

RESULTS

Acephate Concentrations in Streams. Acephate was not detected before spraying and it reached the measured maximum level within an hour after application (Table 1). Residues remained for at least two days, disappearing at about 40% per day due to chemical breakdown, and flushing downstream.

TABLE 1

Acephate Concentrations in the Study Streams (ppb).

	North Brook (treated)	South Brook (treated)	Squaw Brook (control)
Pre-spray	0	0	0
Post-spray 1 h	140	113	-
Post-spray 1 day	13	65	-
Post-spray 2 days	41	9	-

AChE in Fish Brain. Brain AChE activity was depressed in suckers but not salmonids exposed to acephate (Figure 1). Deviations of activity of less than 15% are considered normal (Holland et al. 1967); anything greater is considered to be enzyme inhibition. In addition, we considered variation in the AChE values from the control stream in assessing whether enzyme levels were depressed. The coefficient of variation for the 8 day period in the control stream was 3% in the longnose sucker, 15% in brook trout and 16% in salmon. A negative departure greater than one coefficient of variation was taken as evidence that inhibition had occurred in the sprayed streams. Mean AChE activity expressed as micromoles of substrate hydrolized/hour/mg tissue was 2.00 for longnose sucker, 0.53 in brook trout, and 0.67 in landlocked salmon, all from the control stream.

Using either criteria, depression of AChE activity in brook trout was not great (Figure 1); only one value was slightly below the 1 CV value. Salmon from one treated stream (South Brook) had no unusual depression of AChE activity. Insufficient salmon were collected from the other sprayed stream. The suckers were the only fish whose AChE levels were affected; activity dropped 28 and 29% for fish from each of the treated streams and then gradually returned to near pre-spray levels by day 8.

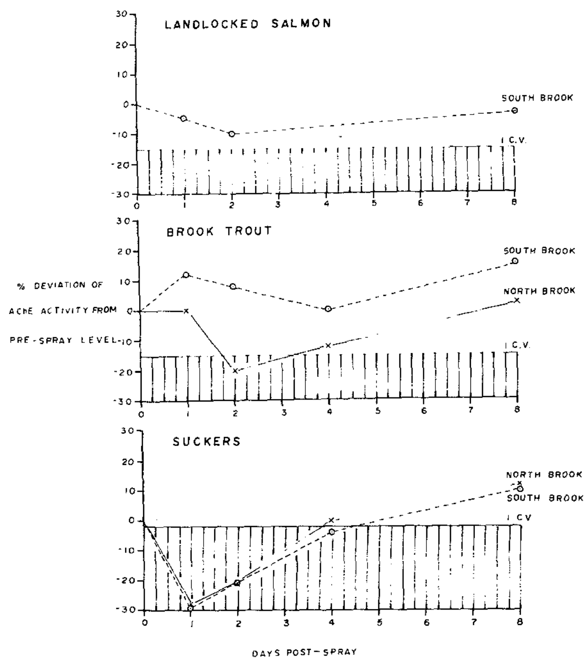

Figure 1. Changes in fish brain AChE. 1 C.V. = 1 coefficient of variation for control fish.

<u>Fish Feeding</u>. Brook trout unexposed to acephate preyed primarily on immature aquatic insects; Ephemeroptera, Plecoptera, Diptera, and Trichoptera. Fish captured 1 and 2 days post-spray consumed significantly more (χ^2 at 0.05) terrestrial forms including beetles, moths, wasps, and spiders (Table 2). The significant increase included both the number of prey items eaten per fish and the volume of prey per fish during the first 2 days post-spray (ANOVA at 0.05). At 4 and 8 days post-spray stomach contents were similar to pre-spray levels with respect to number of prey items, whereas volume remained high. The changes in prey consumption in trout after acephate spraying were probably a result of opportunistic feeding on the large numbers of riparian athropods entering the drift. More than 98% of all terrestrial arthropods collected in stream drift were from post-spray samples. The effect of the insecticide on fish diet was transient.

TABLE 2

Consumption of prey by brook trout. Pre-spray samples May 25-28, immediate post-spray June 1-2, late post-spray June 4-8.

	No. Fish	Vol. Prey (ml)/Fish	Vol. Prey (ml) per mm Fish	Prey Items per Fish
			SQUAW BROOK (Control Stream)	
PRE-SPRAY	8	0.35	0.003	18.6
IMMEDIATE POST	11	0.26	0.002	40.0
LATE POST	10	0.60	0.005	58.1
			NORTH BROOK	
PRE-SPRAY	10	0.35	0.003	14.6
IMMEDIATE POST	7	1.57	0.011	108.1
LATE POST	10	1.24	0.009	12.9
			SOUTH BROOK	
PRE-SPRAY	8	0.24	0.002	21.8
IMMEDIATE POST	10	1.07	0.008	93.8
LATE POST	12	0.93	0.007	29.0

Fish Growth and Condition. The growth of the different year classes of brook trout and landlocked Atlantic salmon was about the same between the treated and control streams. No unusual growth patterns were evident (Figure 2). The condition factors, or

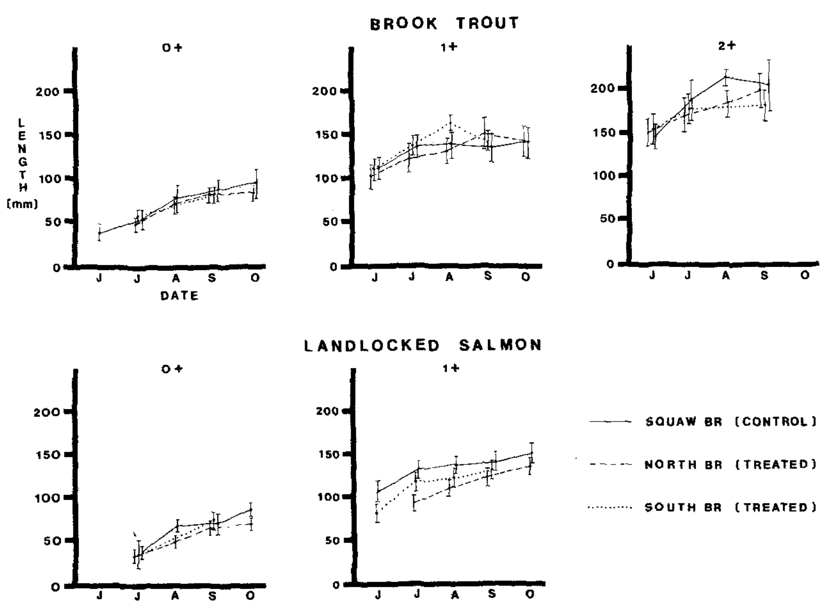

Figure 2. Fish growth in treated and control streams.

plumpness, of brook trout from North Brook were about the same as those from the control stream, suggesting that insecticide spraying did not affect the general health of trout or salmon. In South Brook, the condition factors were comparable to those of brook trout in the control except in August when brook trout had reduced condition factors. Salmon were already slimmer than in the control stream, even before exposure to spray.

Invertebrate Standing Crop. The variation in numbers of benthic invertebrates collected using the Surber sampler was high; some standard deviations were as large as the mean. Changes in standing crop of most taxa followed no consistent pattern and did not correlate with increase in the drift, therefore we conclude that population densities of benthos were not affected by the insecticide. The apparent reductions in fauna at the first post-spray sample were not significant and apparently densities returned to pre-spray levels by 9 days post-spray (Table 3).

TABLE 3

The standing crop of the major invertebrate orders reported as the mean ± S.D. of 9 Surber samples each. Dates same as Table 2.

	Pre-spray	Immediate Post	Late Post
		NORTH BROOK (TREATED)	
Ephemeroptera	19.3 ± 15.3	12.4 ± 7.6	20.3 ± 14.0
Trichoptera	4.3 ± 4.9	2.8 ± 2.7	5.6 ± 5.3
Diptera	8.0 ± 12.3	6.4 ± 5.4	12.7 ± 9.5
		SOUTH BROOK (TREATED)	
Ephemeroptera	17.2 ± 11.2	12.2 ± 5.4	21.1 ± 12.9
Trichoptera	13.8 ± 12.5	5.1 ± 5.8	12.9 ± 8.5
Diptera	20.9 ± 16.7	21.2 ± 14.3	17.7 ± 11.9
		SQUAW BROOK (CONTROL)	
Ephemeroptera	11.6 ± 6.0	9.3 ± 7.5	17.1 ± 9.8
Trichoptera	8.0 ± 6.4	7.1 ± 4.1	13.8 ± 9.4
Diptera	7.2 ± 5.2	14.4 ± 23.0	33.6 ± 44.7

Invertebrate Drift. The invertebrate drift in the control brook (Squaw) was consistently low, primarily Ephemeroptera, Diptera and Trichoptera. Terrestrial forms were uncommon. The two treated streams had increased drift after spraying (Figure 3). North Brook had more total drift in five out of the first seven post-spray collections than in the pre-spray period. This increase was due mostly to an increase in larval blackflies (*Simulium* sp.). Drift in South Brook increased after spraying, also due to blackflies (*Simulium* sp.). The results in this stream were less clear because one pre-spray sample had more organisms than many of the post-spray samples. We conclude that invertebrate drift was moderately and temporarily elevated by the application of the insecticide.

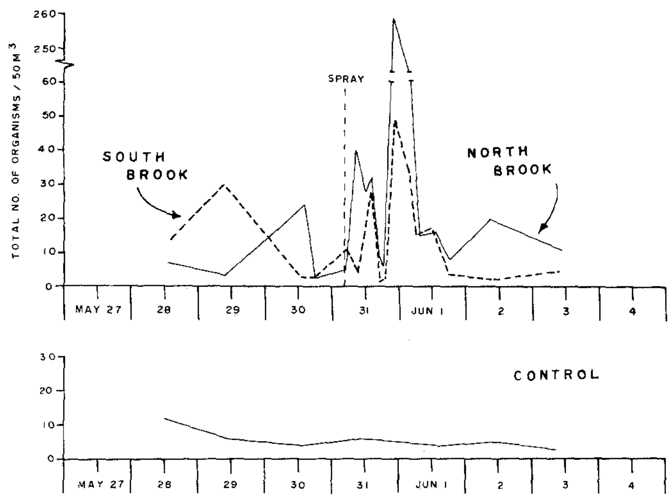

Figure 3. Invertebrate drift.

DISCUSSION

We conclude that acephate caused relatively minor, short term perturbations to the stream ecosystem; drift of macroinvertebrates increased, the standing crop of most invertebrates remained unchanged, brain AChE activity was depressed in suckers but not in trout or salmon, and brook trout altered their diet but growth was not affected. This conclusion was drawn because the effects observed were either transitory or were not adverse. If the streams were negatively affected by spray drift it could not be detected by the methods used.

We believe that cautious use of acephate causes minimum ecological damage, compared to previously used organochlorine compounds. No dead fish were noted in this study and it is unlikely that any direct mortality occurred because the acephate concentrations detected in the streams were about 1/10,000 the determined 96 h TL 50 for rainbow trout (ANON. 1973). Bioassays have shown acephate to be less toxic to fish than aminocarb, trichlorfon, or carbaryl (SCHOETTGER & MAUCK 1976), compounds that have been used on Maine forests with no reported fish mortality.

The AChE activity of fish exposed to a variety of insecticides has been evaluated and acephate caused the least depression. MARANCIK (1976) discovered significant AChE depressions in brook trout from streams contaminated with aminocarb and carbaryl and in northern creek chubs in streams treated with trichlorfon and fenitrothion, whereas brook trout from fenitrothion treated streams did not exhibit AChE depressions. HULBERT (1978) showed significant AChE depressions in brook trout exposed to carbaryl. In our study only suckers showed an acephate related depression. A similar depression of AChE activity in white suckers without a corresponding depression in brook trout or Atlantic salmon was detected using fenitrothion (ZITKO et al. 1970), but both MARANCIK and HULBERT reported inexplicable increases in sucker AChE activity.

There appears to be no effect of acephate on brook trout or Atlantic salmon growth and condition. Similar non-effects were reported with carbaryl (HULBERT 1978), which appears to be more toxic to aquatic life. Growth responses of fish to pesticides are difficult to evaluate. Pesticides may cause physiological or behavioral changes and fish may refuse to feed so that growth is slowed (BULL & MCINERNEY 1974). SYMONS (1977) predicted that for seasonal growth of salmonids to be affected there would have to be a 65% reduction in the stream invertebrate fauna. This did not occur in our treated streams.

The increased drift of benthos was the most pronounced ecological effect of acephate spraying, a result found in most studies of the effects of forest spraying on aquatic ecology. Our findings differ from a study of a spray operation of acephate over a small stream in New York where no significant increase in post-spray drift occurred (BOCSOR & O'CONNOR 1975).

Invertebrate standing crop reductions in Maine streams due to budworm spraying have been reported for fenitrothion (RABENI & GIBBS 1976) and carbaryl (COURTEMANCH & GIBBS 1977). Using similar techniques, standing crop reductions were not detected for aminocarb, trichlorfon (RABENI & Gibbs 1976) or acephate in this study. The failure to detect a reduction in standing crop does not mean that insecticides do not cause invertebrate mortality. EIDT (1975) showed that pesticide-affected drifting organisms often died but without reducing standing crop.

It is evident that acephate had less impact on aquatic ecosystems than most other insecticides used for spruce budworm suppression. This is not to imply, however, that effects were unimportant. The invertebrate community was disrupted, fish feeding habits were altered, and one species of fish was physiologically affected. There may have been other undetected effects. In laboratoty studies non-lethal doses of organophosphate insecticides caused physiological and behavioral modifications in salmonids, which may affect swimming performances (PETERSON 1974), reduce locomotion (BULL & MCINERNEY 1974), increase vulnerability to predation (HATFIELD & ANDERSON 1972), or decrease feeding (SYMONS 1973). We believe that future studies should evaluate behavioral and physiological responses of stream organisms to this chemical.

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