Fenitrothion Toxicity to the Freshwater Crayfish, *Orconectes limosus*

D. W. McLeese
Department of Environment,
Fisheries & Marine Service,
Biological Station,
St. Andrews, New Brunswick
Canada E0G 2X0

Fenitrothion, 0,0-dimethyl 0-(4-nitro-m-tolyl) phosphorthioate, an organophosphate insecticide, has been used in New Brunswick as an aerial forest spray for spruce budworm control since 1968. Measured fenitrothion concentration in the Waweig River, New Brunswick, peaked at 4.8 ppb within 2 hr and averaged 2.5 ppb for the first 12 hr after spraying (PETERSON and ZITKO 1974). SYMONS (in preparation) reports an average peak concentration of about 5 ppb in streams about 1 hr after spraying, declining to 50% of peak concentration by 6 hr, and to 10% by 15 hr. A further report (EIDT and SUNDARAM 1975) indicates that maximum concentration in streams following spraying seldom exceeds 15 ppb.

The lobster (*Homarus americanus*) is extremely sensitive to fenitrothion with a lethal threshold of 0.015 ppb for larvae and of 0.3 ppb or lower for adults (McLEESE 1974). No information for fenitrothion toxicity to other marine crustacea was found except that the 48-hr LC50 for the shrimp, *Penaeus aztecus*, in flowing sea water is 2.5 ppb (BUTLER 1964) indicating that it is also extremely sensitive.

Because of the sensitivity of these marine crustaceans, it was considered that a similar freshwater crustacean, the crayfish (*Orconectes limosus*), might also be extremely sensitive. Tests were done to determine if fenitrothion at concentrations known to occur in streams after spraying is a threat to the crayfish. In addition, fenitrothion toxicity to the crayfish was measured in static tests.

Methods and materials

Crayfish were caught in the upper St. Croix River, New Brunswick, in October 1975 by electrofishing. They were held for about a month in running fresh water at the Biological Station, St. Andrews, New Brunswick, at 12 C, and were fed shredded beef liver. They were not

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fed during tests. Small crayfish averaged 32 mm total length and 1.0 g in weight (range 0.6-1.6 g), large ones averaged 63 mm and 7.2 g (3.5-9.2 g).

For tests with simulated stream conditions, 6 ℓ of fenitrothion solution at 1, 5, and 10 ppb were contained in 6-ℓ Erlenmeyer flasks. Five small crayfish were added to each flask. The flasks were set in a temperature bath at 12 C and each was aerated gently. After 1 3/4 hr, each flask was flushed with clean water at a rate of 14 mℓ/min, to cause 50% water exchange in 5 hr and 90% exchange in 14 hr, presumably causing a corresponding decrease in fenitrothion concentration. The crayfish were observed for 7 days.

For toxicity studies at constant concentrations, groups of 5 small and of 5 large crayfish were exposed to 0.01-100 ppb fenitrothion for 168-240 hr. Each group was held in 3 ℓ of solution contained in a 4-ℓ flask. Test solutions were renewed daily, temperature was maintained at 12 C, and each flask was aerated gently.

Fenitrothion concentration was measured by gas chromatography (PETERSON and ZITKO 1974) following extraction of 100-mℓ samples of water with chloroform. Some of the samples at the higher concentrations were analyzed to check on the initial accuracy of the test-solutions and to indicate change in concentration during 24 hr.

Times to 50% mortality (LT50) and 95% confidence limits were estimated by probit analyses (LITCHFIELD 1949). Lethal thresholds were interpolated from plots of percentage mortality (probit scale) against concentration (logarithmic scale) as described by SPRAGUE (1969).

Results

There were no deaths among control or treated crayfish during the 7-day observation period following exposure to peak concentrations of 1-10 ppb fenitrothion. No behavioural changes were observed in any of the test situations. The measured fenitrothion concentration in the 10-ppb test followed the pattern of reported stream conditions fairly closely, starting at 10.8 ppb. After 5-hr flushing, the concentration was reduced by 40 instead of the expected 50%, and at 11 hr by 64 instead of 56%.

With crayfish exposed to constant concentrations of fenitrothion, there were no deaths at 0.01-1.0 ppb up to 168 hr, the duration of the tests. At 10 ppb the LT50 was 100 hr for small crayfish, contrasting with no mortality among large crayfish up to 240 hr. At 32-100 ppb the LT50 ranged from 19-24.5 hr for small and from 60-75 hr for large crayfish (Table 1). This indicates a size effect with large crayfish being more resistant to fenitrothion. An approximation of the 96-hr LC50 is 10 ppb for small and 30 ppb for large crayfish. The lethal threshold is 4 ppb for small and 20 ppb for large crayfish.

The measured concentrations of fenitrothion in the 10-100 ppb tests, sampled 1 1/2-2 hr after mixing were close to expected values, the concentrations declining by about 50% during 24 hr.

Discussion

Simulated stream conditions, with fenitrothion at peak concentrations from 1-10 ppb for 1 3/4 hr, did not kill small crayfish. Based on the other toxicity tests, the peak concentration of 1 ppb is well below and of 5 ppb is only slightly above the lethal threshold for small crayfish, and short exposure to these concentrations would not be expected to affect them. The peak concentration of 10 ppb is within the lethal range but would have to persist for about 100 hr to kill 50% of the small ones. A peak of 15 ppb, as suggested by EIDT and SUNDARAM (1975), would require exposure for about 50 hr to cause 50% mortality. Because of the higher lethal threshold, large crayfish should not be killed by peak stream concentrations up to about 20 ppb, regardless of their duration.

The test temperature of 15 C for lobsters (McLEESE 1974) and of 12 C for crayfish are close enough to allow comparison of the sensitivity of the two species. Lobster larvae and adults are equally sensitive to fenitrothion at concentrations down to 1 ppb and possibly lower (McLEESE 1974). The lethal threshold of 0.015 ppb for larvae is based on exposures of 262 hr, that of 0.3 ppb for adults on 127 hr. It was argued that with longer exposure, the threshold for adults might have been as low as that for larvae. In contrast, there is a definite size effect with crayfish, the large ones having longer resistance times at a particular lethal concentration and having a higher lethal threshold than small ones. Also the lethal thresholds of 4 ppb for small and 20 ppb for large crayfish are much higher than for larval and adult lobsters.

Crayfish are considerably more sensitive than small stages of the salmon (*Salmo salar*), considering

TABLE 1. Toxicity of fenitrothion to crayfish at 12 C. Five crayfish in each group.

Fenitrothion concentration (ppb)	Small Crayfish LT50 (hr)	Small Crayfish 95% Confidence limits (hr)	Slope	Large Crayfish LT50 (hr)	Large Crayfish 95% Confidence limits (hr)	Slope
0	None dead, 168 hr		-	None dead, 168 hr		-
0.01	None dead, 168 hr		-	None dead, 168 hr		-
0.1	None dead, 168 hr		-	None dead, 168 hr		-
1.0	None dead, 168 hr		-	None dead, 168 hr		-
10.0	100	57-175	1.95	None dead, 240 hr		-
32	24	20-30	1.28	75	47-120	1.66
56	19	16-23	1.24	60	39-93	1.65
100	22	19-25	1.12	66	52-83	1.30
Estimated 96-hr LC50		10 ppb			30 ppb	
Estimated *lethal thres-hold*		4 ppb			20 ppb	

TABLE 2. Summary of fenitrothion toxicity, expressed at 24-hr or 96-hr LC50, to various aquatic invertebrates.

Invertebrate	24-hr LC50[a,b]	96-hr LC50[a]	Temp.C	Source
Culex tarsalis (Diptera)	0.5	-	20	FLANNAGAN, 1973
Aedes atropolis (Diptera)	0.75	-	20	" "
Acronearia sp. (Plecoptera)	2	-	15	WILDISH & PHILLIPS, 1972
Aedes aegypti (Diptera)	5	-	20	FLANNAGAN, 1973
Daphnia pulex (Cladocera)	50	-	20	" "
Ophiogomphus sp. (Odonata)	66	3	15	WILDISH & PHILLIPS, 1972
Gammarus lacustris (Amphipoda)	>100	-	20	FLANNAGAN, 1973
Nigronia serncornis (Neuroptera)	186	15	15	WILDISH & PHILLIPS, 1972
Pycnopsyche sp. (Trichoptera)	610	28	15	" "
Eriocela spinosa (Diptera)	40.4 ppm	14 ppm	15	" "
Lymmaea elodos (Gastropoda)	>50 ppm	-	20	FLANNAGAN, 1973
Homarus americanus, larvae	100	1	15	McLEESE, 1974
" " adults	>10-<100	1	15	" "
Orconectes limosus, small	32	10	12	This paper
" " large	>100	30	12	" "

[a] LC50's as ppb(µg/ℓ) except where specified as ppm(mg/ℓ)

[b] 24-hr LC50's for FLANNAGAN (1973) data are estimated from his graphs.

that the lethal threshold for alevins, fry, and parr is about 1 ppm (WILDISH et al. 1971).

The approximated 24-hr LC50, and in some cases the 96-hr LC50, for 11 species of freshwater invertebrates are compared with these measures for crayfish and lobsters (TABLE 2; WILDISH and PHILLIPS 1972; FLANNAGAN 1973). Two species, a Diptera and a Gastropod, are very resistant with 24-hr LC50's of 40-50 ppm or more. Of the remaining 9 species, 4 are more sensitive than small, and 6 or 7 are more sensitive than large crayfish. Based on the limited 96-hr LC50 data, it appears that most of the 9 species are more sensitive than the crayfish and that the lobster is one of the most sensitive of these aquatic invertebrates.

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