Variations in Aquatic Insect Densities Associated with Copper-Zinc Concentrations

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VARIATIONS IN AQUATIC INSECT DENSITIES ASSOCIATED WITH COPPER-ZINC CONCENTRATIONS

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ABSTRACT

Peterson, R. H. 1978. Variations in aquatic insect densities associated with copper-zinc concentrations. Fish. Mar. Serv. MS Rep. 1470, iii + 3 p.

In August 1974 and September 1975 benthic invertebrates were sampled in the Tomogonops River, which is contaminated by the effluent of a base metal mine and mill operation, and in the Northwest Miramichi. Densities of benthic insects in the Tomogonops and in the receiving water of the Northwest Miramichi were lower than in adjacent, uncontaminated sections of the Miramichi. Mayfly densities showed the greatest difference between contaminated and uncontaminated areas. Caddis and cranefly larval densities were lower to a lesser extent. The mean Cu^{++} and Zn^{++} levels in the Tomogonops were 15 and 206 ppb compared to 1 and 5 ppb respectively in uncontaminated parts of the Northwest Miramichi.

Key words: Benthic invertebrates, copper, zinc, Tomogonops R.

RÉSUMÉ

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En août 1974 et en septembre 1975, des prélèvements d'invertébrés benthiques ont été faits dans la Miramichi-Nord-Ouest et dans la Tomogonops, qui ets contaminée par l'effluent d'une fabrique et d'une mine de métaux communs. Dans la Tomogonops et les eaux réceptrices de la Miramichi-Nord-Ouest, la densité des insectes benthiques a été plus faible que dans les zones adjacentes, exemptes de contamination, de la Miramichi, surtout en ce qui concerne les éphémères, et de façon moins sensible dans le cas des phryganes et des tipules. Dans la Topogonops, les concentrations de Cu^{++} et de Zn^{++} on été de 15 et de 206 ppb, alors qu'elles étaient respectivement de moins de 1 et de 5 ppb dans les zones non contaminées de la Miramichi-Nord Ouest.

INTRODUCTION

A base metal mine and mill operation on the Little South Tomogonops River (tributary to the northwest Miramichi River, N. B.) began permanent operations in 1960. The early history of the effects of this mining operation on Atlantic salmon movements in the Miramichi below the mouth of the Tomogonops River has been documented (Sprague et al. 1965; Saunders and Sprague 1967). Aquatic stages of insects at the mouth of the Tomogonops and in the Northwest Miramichi about 75 km downstream of the confluence of the rivers were surveyed in 1960 and 1961 (Sprague et al. 1965). No mayfly nymphs were found in the Tomogonops compared to 30-40 ft^2 in unpolluted stretches of the Miramichi. Caddisfly and midge larvae averaged between 2 and 3/ft^2 and 30/ft^2 respectively in the Tomogonops compared to 30-40/ft^2 and 40/ft^2 in the unpolluted Miramichi.

Following the diversion of the little South Tomogonops into a new channel in May 1971, the concentrations of Cu^{++} and Zn^{++} decreased by 60-70% (Carson 1972). Mean concentrations of Cu^{++} and Zn^{++} in the mouth of the Tomogonops since January 1972 have been 15 (r = 5-81) and 206 (84-571) µg/L (Health-Steele mine daily records). Mean concentrations of Cu^{++} and Zn^{++} for the 4 mo prior to rechanneling were 49 (18-186) and 600 (407-1243).

This report presents results of a survey of aquatic insect densities in the mouth of the Tomogonops River and heavy metal content in these waters in 1974.

METHODS

Two sites (T) were sampled in the Tomogonops and one in the Northwest Miramichi (NW) upstream of the mouth of the Tomogonops (Fig. 1). Four transects of three sampling sites each were taken in the Miramichi at 0 m, 228 m, 456 m, and 684 m below the confluence of the streams (sites P1, 4; M2, 5, 7, 8, 10, 11; C3, 6, 9, 12 in Fig. 1). The transects were measured in the same way 100-ft chain) in 1974 and 1975, but the sites were not identical between years. The substrate of the Tomogonops and the downstream Miramichi area receiving Tomogonops water were covered with a slippery, brownish-gray film. The middle site of each transect (M2, 5, 8, 11 in Fig. 1) was chosen at the approximate boundary of this film.

Similar rubble habitat (stones 2.5-15 cm diam.) and water velocities were selected at all sites to reduce sampling variability. Benthic invertebrates were sampled with a Surber ft^2 (.093 m^2) bottom sampler. All large rocks within the sampling area were scrubbed, then the bottom was stirred for 30 sec (1974) or 1 min (1975) to a depth of about 6 cm.

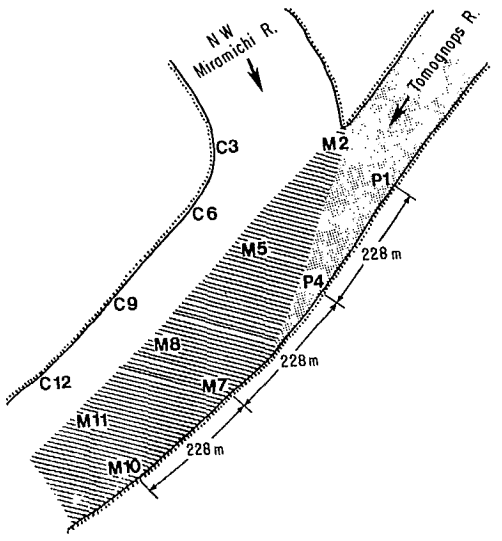

Fig. 1. Diagram showing sampling sites in Tomogonops and Northwest Miramichi Rivers. The sites are indicated by numbers which correspond to site numbers of Table 1. Shaded area indicates Tomogonops water. Hatched area indicates area of mixing. The stream substrate in areas represented by shading and cross-hatching was characterized by a slippery, brownish-gray surface film. Site numbers preceded by "C" are in relatively "clean" water; those preceded by "P" in "polluted" Tomogonops water; and those preceded by "M" are in water of mixed origin.

Water samples were taken at each of the sampling sites by opening an 800-mL bottle below the surface. The samples were then acidified with 2-3 drops of concentrated H_2SO_4 to prevent adsorption of metal ions to the container wall.

RESULTS

The densities of benthic insects in the Tomogonops River and in the receiving waters of the Northwest Miramichi were lower than in adjacent, relatively uncontaminated sections of the Northwest Miramichi (Table 1). Sites receiving water of high [Zn^{++}] and [Cu^{++}] had the lowest densities (means of 36 insects/ft^2 in 1974, 114 in 1975) and those with low [Zn^{++}] and [Cu^{++}] the highest (means of 146/ft^2 in 1974 and 314 in 1975).

Mayfly densities were only 1-2/ft^2 in sites with high [Cu^{++}] and [Zn^{++}] compared to 30/ft^2 in 1974 and 144/ft^2 in 1975 for sites with low heavy metal concentrations. Caddisfly numbers were lower at sites with high Cu^{++} and Zn^{++} levels but not to the extent that mayfly numbers were. Midge densities were lower at sites

receiving high heavy metal concentrations in 1974 but not in 1975. Cranefly densities were also lower in sites receiving high concentrations of Cu^{++} and Zn^{++}. Other organisms (annelids, stoneflies, dragonflies, water mites) were sampled irregularly and in such low numbers that comparisons were not meaningful, but their numbers are included in the totals.

Insect densities were highest in 1975, both at sites receiving clean water and those receiving contaminated water.

The measured levels of Zn^{++} and Cu^{++} in the water samples taken in 1974 were only one tenth to one twentieth those listed in Table 1 (20 µg/L Zn^{++} in Tomogonops water). It is considered probable that a dilution error occurred during analysis. Heath-Steele mine records of Zn^{++} and Cu^{++} concentrations at the mouth of the Tomogonops for the day of sampling were 384 and 10 µg/L respectively. These values were therefore used and were adjusted at the various sampling sites according to the dilution factors indicated by the water hardness data.

DISCUSSION

The results for mayflies are similar to those of Sprague et al. (1965) for samples taken in 1961. Mayflies were almost absent in the mouth of the Tomogonops in both studies, thus the decrease in heavy metal concentrations in the Tomogonops after 1971 has not resulted in a significant increase in mayfly densities. The densities of caddisfly larvae in 1974-75 (24 and 32/ft^2) in the Tomogonops are higher than those given by Sprague et al. (1965) (2-3/ft^2), indicating an increase in these organisms. Midge densities were only slightly lower in the Tomogonops in both 1961 and 1974-75 than in the Northwest Miramichi.

In addition to higher Zn^{++} and Cu^{++} concentrations, water hardness was much higher, due to addition of lime to the mine effluent (Table 1). Increase in water hardness decreases the toxicity of Zn^{++} and Cu^{++} to fish. For example, at a hardness of 20 mg/L $CaCO_3$ (commonly encountered in the Northwest Miramichi) the incipient lethal levels of Zn^{++} and Cu^{++} for rainbow trout are 700 and 50 µg/L respectively (Lloyd and Herbert 1962). At hardness of 160 mg/L (that of Tomogonops water), the ILL's are 2300 and 260 respectively. The pH's of both streams are nearly identical (7.0, range of 6.6-7.2), and the pO_2 was near air saturation in both streams when measured in August 1974.

The few toxicity data available indicate that aquatic insects are less susceptible to Cu^{++} than are fish. Warnick and Bell (1969) reported 96-h median tolerance limits of 8300 and 320 µg/L for Acroneuria (stonefly) and Ephemerella (mayfly). These concentrations are one to two orders of magnitude above Cu concentrations in Tomogonops water. A Zn^{++} concentration of 300 µg/L, however, was lethal to mayfly nymphs but not to stoneflies or caddisflies (APHA 1965). This latter Zn^{++} concentration is within the range of Zn^{++} concentrations present in the Tomognops River since 1971.

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Table 1. Concentrations of heavy metals (µg/L), water hardness (mg/L $CaCO_3$) and numbers of insects/ft^2 sampled at various sites in the Tomogonops and Northwest Miramichi Rivers. Sites are coded as in Fig. 1. Eph - mayflies, Trich - caddisflies, Chir - midges, Tip - craneflies. Totals include other types of invertebrates also collected. Copper and zinc concentrations indicated by asterisks are estimated from Heath-Steele mine records of concentrations on August 28, 1974 at the mouth of the Tomogonops, combined with dilution factors indicated by the water hardness data (ratio of hardness of water at sampling site (minus that of Miramichi water) to Tomogonops water (minus that of Miramichi water).

		August 28, 1974								September 2, 1975						
	Site	$[Cu^{++}]$	$[Zn^{++}]$	Hardness	Eph	Trich	Chir	Tip	Total	$[Cu^{++}]$	$[Zn^{++}]$	Eph	Trich	Chir	Tip	Total
	Tomogonops(T)	10	384	152	0	17	0	0	18	7	250	0	44	42	0	127
	"	"	"	"	2	21	19	0	43	-	-	-	-	-	-	-
High Cu^{++}-Zn^{++}	P 1	10*	384*	160	5	47	13	0	66	20	115	0	18	34	0	67
	P 4	10*	384*	160	0	13	5	0	18	5	115	3	33	99	0	149
	Means	10	384	157	2	24	9	0	36	11	160	1	32	58	0	114
	M 2	10*	384*	160	1	23	4	1	33	3	60	25	84	4	0	118
	M 5	8*	315*	135	10	58	3	0	75	2	20	53	119	18	0	195
Medium Cu^{++}-Zn^{++}	M 7	-	-	-	0	4	9	0	15	10	100	0	15	93	3	141
	M 8	1*	12*	24	1	14	30	3	53	5	20	4	46	6	0	57
	M 10	8*	315*	135	0	50	22	0	80	5	100	1	53	104	0	158
	M 11	1*	150*	75	2	61	13	4	85	1	6	35	106	87	1	234
	Means	6	225	106	2	35	14	1.3	57	4	51	20	70	52	0.7	155
	C 3	1*	3*	20	18	39	43	2	108	1	1	109	90	28	3	232
	C 6	1*	4*	22	40	82	53	2	188	1	7	147	45	56	9	273
Low Cu^{++}-Zn^{++}	C 9	1*	12*	24	33	46	93	4	186	2	11	202	115	151	17	533
	C 12	-	-	-	26	33	32	4	104	1	12	155	64	51	12	291
	Miramichi (NW)	1	3	20	-	-	-	-	-	1	10	109	93	29	0	242
	Means	1	5	22	29	50	55	3	146	1	8	144	81	63	8	314