

**The effect of Kraft paper mill effluents
on insects inhabiting the St. Francis River
near East Angus, Quebec**

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Abstract

Les insectes ont été recueillis de la rivière St. François aux emplacements en amont et en aval du moulin à papier d'East Angus. Des échantillons recueillis seulement l'Ephemeroptera et le Trichoptera ont statistiquement montré des réductions sensibles (en aval du moulin) dans le nombre de familles, de genres et individus. Cependant, le Diptera et le Plecoptera ont démontré une perte nette de familles, genres et individus en aval du moulin comparativement au nombre de chaque recueillis en amont. Quoique les effluents du moulin modifiaient la composition chimique de l'eau, ces valeurs chimiques modifiées ne semblaient pas être la cause d'une flore insecticide diminuée étant donné que les paramètres chimiques mesurés se rétablissaient aux valeurs de ceux en amont du moulin après une distance de 1.5 - 3.0 km en aval de celui-ci. Les principales composantes de l'effluent qui semblaient nuisibles à la flore du fond étaient les solides en suspension (fibres de pulpe) et ceux-ci formaient une couche au fond de la rivière qui diminuait, ou éliminait, les sites de nourriture, de refuge, et d'espace de vie.

Abstract

Insects were collected from the St. Francis River at sites above and below the East Angus paper mill. Of the six orders collected, only the Ephemeroptera and Trichoptera showed statistically significant reductions (below the mill) in the number of families, genera and individuals. However, the Diptera and Plecoptera exhibited a net loss of families, genera and individuals below the mill compared with the numbers of each collected above. Although the mill effluents altered the water chemistry, these disrupted chemical values did not seem to be the cause of the reduced insect fauna since the chemical parameters measured returned to above-mill values after a distance of 1.5 - 3.0 km downstream from the mill. The major constituent of the effluent that appeared detrimental to the bottom fauna was the contained solids (pulp fibers) which settled and formed a blanket over the river bottom that reduced, or eliminated, sites for feeding, refuge, living space, etc.

Introduction

The St. Francis River flows into the St. Lawrence River about 88 km NE of Montreal, Québec. There are 3 pulp and paper mills located along the St. Francis River and, in terms of water quality, the pulp and paper industry is the most serious polluter in the basin. For example, Tate (1973) says that the total Biochemical Oxygen Demand (BOD) loading from the mills is about 60,400 kg/day. In terms of the municipal populations of the towns in which the mills are located, the corresponding population increase equivalent of the BOD loading is 50 times the present population.

The pulp mills monitor the effect of their effluents on the river but this information is not published and therefore largely unavailable. To document the effect of paper mill effluents on aquatic insects I undertook a study of the Domtar paper mill located at East Angus, Québec. This mill is the furthest upstream of the 3 mills located on the St. Francis River. According to Blouin (1976, personal communication), chief of technical services at the mill, the effluents from this mill amount to over 15 million liters/day which contains 4.5 metric tons of suspended solids (largely pulp fibers). The town of East Angus discharges its raw sewage directly into the St. Francis River and for a 1970 town population of 4,800 this resulted in an estimated BOD of 370 kg/day (Tate, 1973). This figure is low, however, when compared with the industrial (pulp and paper mill, textile mill, dairy) BOD of 16,467 kg/day, a BOD theoretical population equivalent of 213,554 persons releasing untreated sewage into the river (Tate, 1973). In addition to an increased BOD, the paper mill discharges large quantities of waste materials; wood chips, rotting logs, and unusable, partially processed wood litter the river banks and stream bed in this area (Tate, 1973). These materials give off lignin which is toxic to aquatic life (Tate, 1973). The effluent from the mill also contains detergents which cause a foam on the river surface that is visible for kilometers downstream. It is not known what effect this foam has on the river's biota but it is certainly aesthetically displeasing and considerably lowers the recreation potential of the St. Francis River Basin (Tate, 1973).

Methods

Nine permanent sampling sites were selected, 4 upstream (U1 - U4) from the pulp mill at East Angus (45° 29'N, 71° 40'W) and 5 downstream (D1 - D5). The distances (in km) of each site from the mill are as follows: U1 (1.9), U2 (2.0), U3 (2.1), U4 (2.3), D1 (0.04), D2 (1.5), D3 (4.8), D4 (6.1), D5 (16.3). One water and one bottom fauna sample was taken from each station at weekly intervals beginning June 10, 1974 and ending August 21, 1974. Water samples were taken and chemically analysed according to the directions given in the LaMotte water pollution detection outfit, model AM-22. Benthic insects were collected with a Surber sampler which was placed at a depth of 0.3m and a 0.3 sq. m area of substrate immediately in front of the sampler's net was agitated by hand to dislodge any insects so the water current would carry them downstream into the net. Care was taken to sample similar rocky substrates at all stations.

Changes in water chemistry and insect abundance from one sampling station to another were checked for statistical significance (at the 0.01 level) using the Student-

Neuman-Keuls multiple range test (Sokal and Rohlf, 1969). These data have been put in tabular form (Figs. 1-4 are based upon these tables) and are available to any investigator upon request.

Results & Discussion

Water Chemistry

It is obvious from Figs. 1 & 2 that the pulp mill effluents alter various chemical parameters of the river but that these altered values soon return to above-mill ranges. In fact, only total alkalinity, CO_2 , O_2 and pH are significantly changed, and these only at site D1. At site D2 (a distance of 1.5 km) the chemical values measured have returned to ranges exhibited above the mill. This is probably due to the auto-purification of the river (Tate, 1973).

FIGURE 1: Effect of pulp mill effluents on CO_2 , O_2 , pH and silica concentrations in the St. Francis River. Concentrations between U1 and the pulp mill are an estimate based upon the means of sites U1-U4. (U: upstream from pulp mill; D: downstream from pulp mill).

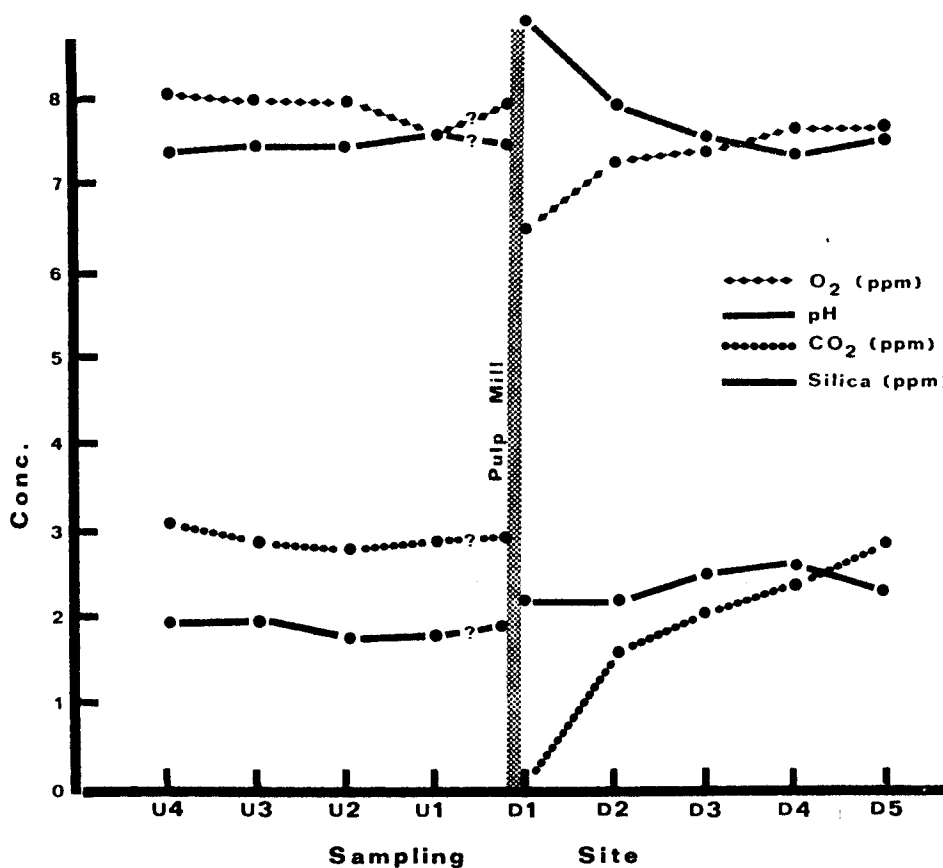
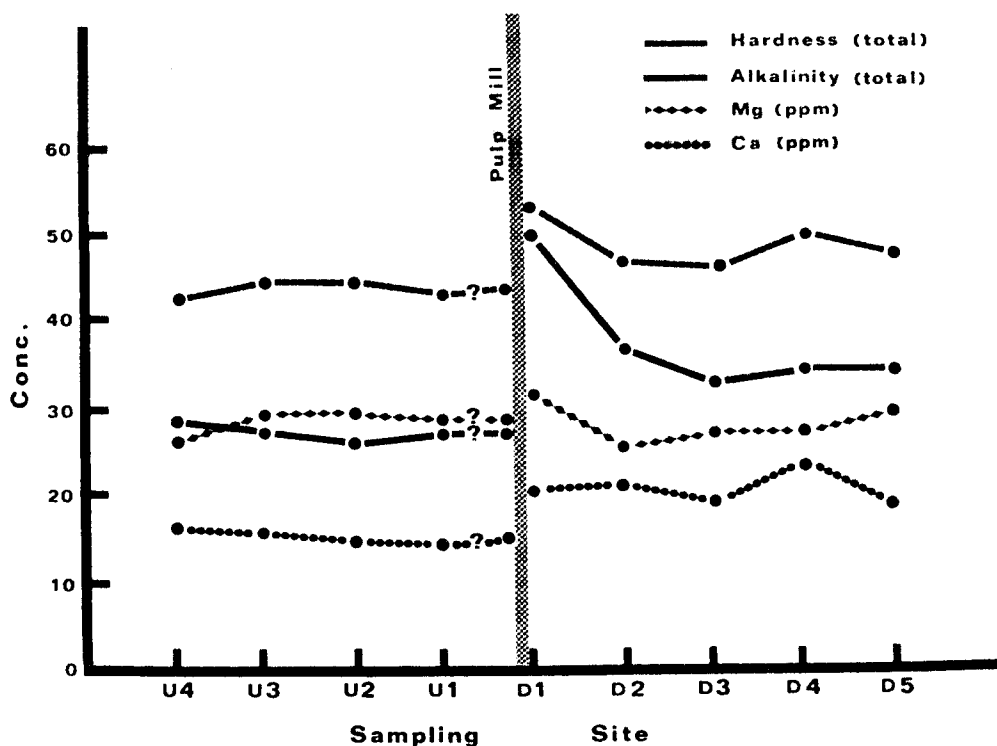


FIGURE 2: Effect of pulp mill effluents on alkalinity, Ca, Mg and hardness concentrations in the St. Francis River. Concentrations between U1 and the pulp mill are an estimate based upon the means of sites U1-U4. (U: upstream from pulp mill; D: downstream from pulp mill).



Benthic Insects

Although more than 40 genera of insects were collected (Table 1), only *Cinygma* sp. (Ephemeroptera) and *Chimarra* sp. (Trichoptera) were present in consistently high numbers above the mill (but absent below) and could be considered useful as indicators of polluted or unpolluted conditions. However, when one considers higher taxa such as families or orders there is evidence that entire groups can be indicators of polluted conditions. This is in accord with Roback's (1974) statement that, "As far as insects are concerned, I am convinced that the concept of indicator organisms has little validity, and that the presence or absence of any species of insect in a stream indicates (as far as damage is concerned) no more or less than the bald fact of its presence or absence. It is probably more valid to speak of indicator assemblages of species...". In the St. Francis River the Diptera, Ephemeroptera, Plecoptera and Trichoptera can be considered indicator assemblages since they suffered serious depletions in the number of families, genera and individuals below the mill (Tables 1, II, Figs. 3 & 4). These differences are more qualitative than quantitative and, because of the wide range in numbers of individuals collected of each genus, most of the reductions in the fauna below the mill are not statistically significant.

TABLE 1. TOTAL NUMBERS OF INSECTS COLLECTED AT SITES UPSTREAM (U1-U4) AND DOWNSTREAM (D1-D5) FROM THE PULP MILL.

Insects Collected *	Sampling Site									
	U4	U3	U2	U1	D1	D2	D3	D4	D5	
COLEOPTERA										
Dytiscidae										
Hydroporus (Oreodytes) sp.						1				
Unidentified							1			
Elmidae										
Dubiraphia sp.									2	
Optioservus sp.			1	1		2				
Stenelmus sp.		3	1	2			1	1	2	
Unidentified							1		1	
Psephenidae										
Psephenus sp.			1	2				1		
DIPTERA										
**Ceratopogonidae				2					1	
**Chironomidae	32	34	68	75	22	112	86	63	108	
Empididae										
Hilara sp.	1		1							
Unidentified		8	1	2			2	1	1	
Psychodidae										
Psychoda sp.			1							
Unidentified			1	1	3					
Simuliidae										
Prosimulium sp.				1						
Unidentified				1						
Tipulidae										
Antocha sp.		3		5						
Unidentified	2			2		1			1	

TABLE 1. CONTINUED.

Insects Collected *	Sampling Site									
	U4	U3	U2	U1	D1	D2	D3	D4	D5	
EPHEMEROPTERA										
Baetidae										
Baetis sp.	3	6	9	34		2	6	13	3	
Baetisca sp.									1	
Caenis sp.			1	1						
Ephemerella sp.	2	3	2	22		1			6	
Paraleptophlebia sp.	6	1	3	14				1		
Pseudocloeon sp.	1	2	4	1	1	1	1			
Siphonurus sp.									1	
Tricorythodes sp.	1		1	1			1	2	16	
Unidentified	5	5	9	12			3	2	3	
Heptageniidae										
Cinygma sp.	5	15	19	29						
Stenonema sp.	1		1							
Unidentified	3		1	11				2		
NEUROPTERA										
Sialidae										
Sialis sp.									2	
ODONATA										
Gomphidae										
Gomphus descriptus								1		
Macromiidae										
Macromia illinoiensis				1						
PLECOPTERA										
Chloroperlidae										
Alloperla sp.				1						
Nemouridae										
Nemoura sp.					1				1	

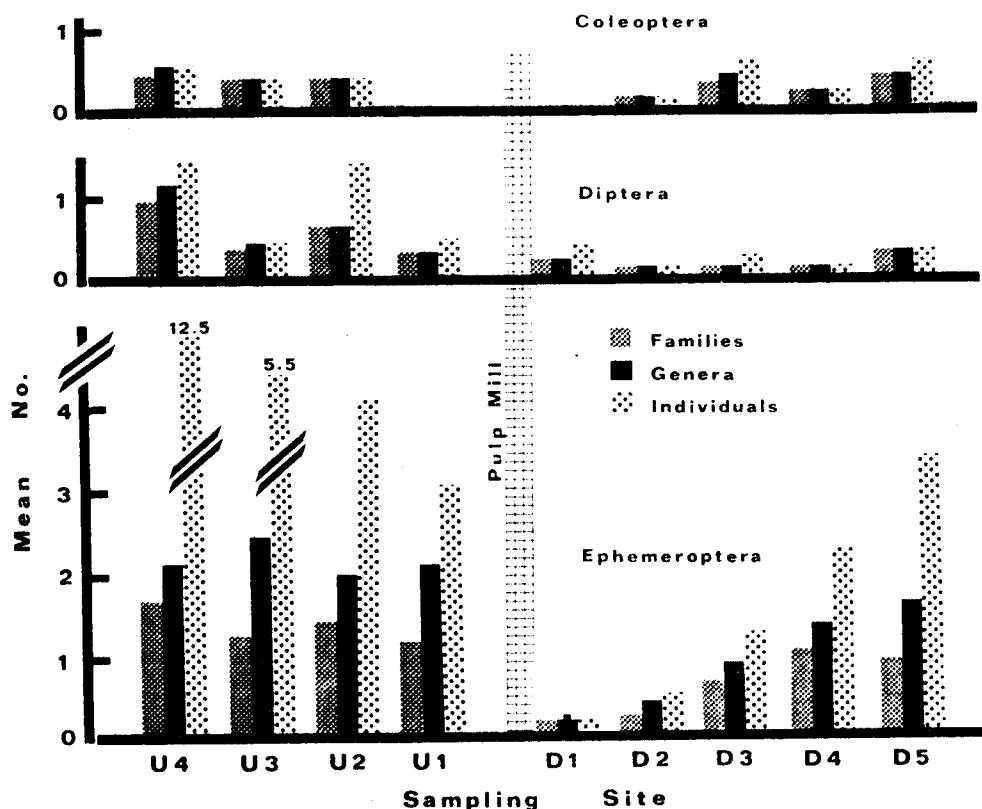
TABLE 1. CONTINUED.

Insects Collected *	Sampling Site									
	U4	U3	U2	U1	D1	D2	D3	D4	D5	
Perlidae										
<i>Acroneuria</i> sp.			2	1						
<i>Neoperla</i> sp.	2			1						
<i>Phasganophora</i> sp.	1			1						
<i>Paragnetina</i> sp.		1								
Perlodidae										
<i>Isoperla</i> sp. or <i>Isogenus</i> sp.				1						
Unidentified			1	1						
TRICHOPTERA										
Brachycentridae										
<i>Micrasema</i> sp.			1							
Hydropsychidae										
<i>Cheumatopsyche</i> sp.		8	18	1						
<i>Macronema</i> sp.	3	7	25	17		2	1			
Hydroptilidae										
<i>Hydroptila</i> sp.				4			1			
<i>Ochrotrichia</i> sp.				7						
<i>Oxyethira</i> sp.			1							
Leptoceridae										
<i>Oecetis</i> sp.		1								
Philopotamidae										
<i>Chimarra</i> sp.	2	10	14	3						
Polycentropidae										
<i>Polycentropus</i> sp.	1		3						2	
Unidentified			3	2						

* listed alphabetically rather than phylogenetically.

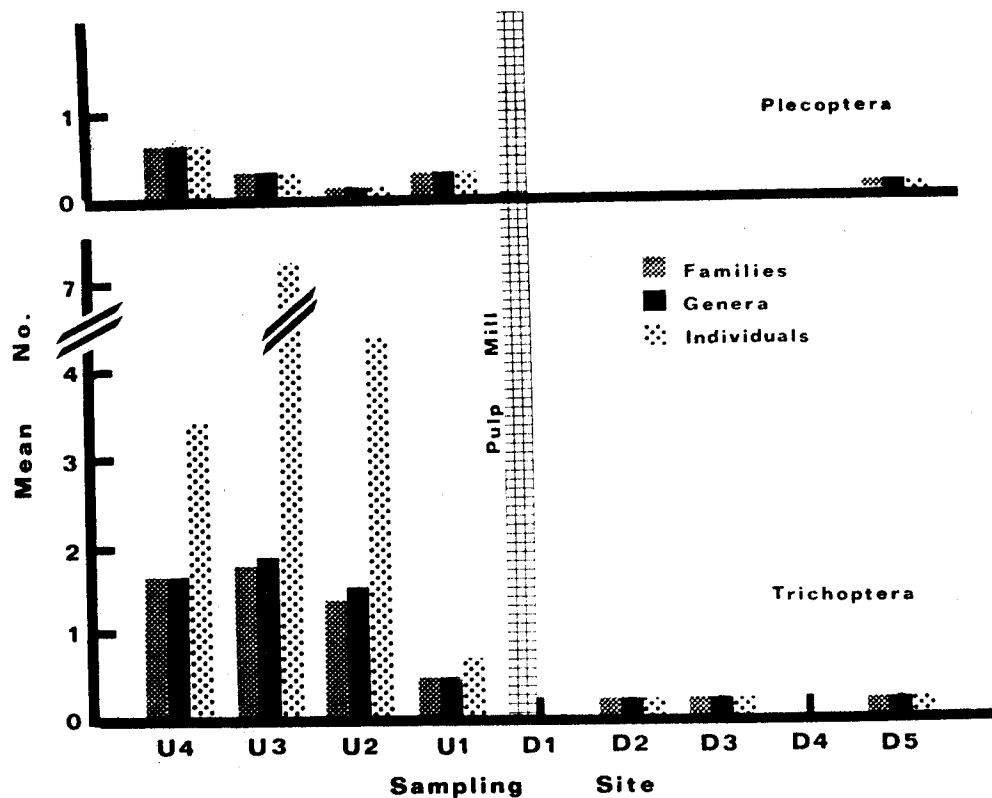
** identified to family only.

FIGURE 3: Effect of pulp mill effluents on the mean number of families, genera and individuals of Coleoptera, Diptera and Ephemeroptera in the St. Francis River. (U: upstream from pulp mill; D: downstream from pulp mill).



Since auto-purification of the river takes place relatively quickly (see above), I suspect that the huge quantities of pulp fibers in the effluent are responsible for the reduced insect fauna below the mill (although it is possible other chemical or physical parameters that were not measured may play an important role). These fibers settle on the river bottom and cover the substrate like a blanket, thus reducing, or even eliminating, sites for feeding, refuge, living space, etc. Such sites are particularly important for rock and crevice dwellers like many Ephemeroptera, Plecoptera and Trichoptera. The further downstream from the mill the fewer fibers left to settle on the river bottom and this results in an increasingly thinner covering over the rocky substrate. This is perhaps reflected in the gradually increasing Ephemeroptera fauna (Fig. 3) the greater the distance downstream from the mill. The Plecoptera and Trichoptera seem more sensitive, however, and they were absent or in very low numbers at all downstream stations (Fig. 4).

FIGURE 4: Effect of pulp mill effluents on the mean number of families, genera and individuals of Plecoptera and Trichoptera in the St. Francis River. (U: upstream from pulp mill; D: downstream from pulp mill).



Diptera also suffered a decrease in the number of families, genera and individuals below the mill but this was masked somewhat by the increase in numbers of Chironomidae (Table I). Presumably these midges, many species of which have higher tolerance levels to pollution (Hynes, 1960), were able to colonize niches left vacant by insects intolerant to pulp mill effluents. Of the Coleoptera, Neuroptera and Odonata only the Elmidae (Coleoptera) were collected in sufficient numbers for comparisons to be made and this family did not appear to be affected by the mill effluents in any way that would cause an increase or decrease in their numbers.

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TABLE 2. RELATIVE CHANGES IN THE MAJOR INSECT FAUNA* ABOVE AND BELOW THE PULP MILL.

<i>Insect Order</i>	<i>Above Pulp Mill</i>		<i>Below Pulp Mill</i>		<i>Net change in insect fauna from above to below pulp mill</i>	
	<i>No. of Families</i>	<i>No. of Genera</i>	<i>No. of Families</i>	<i>No. of Genera</i>	<i>No. of Families</i>	<i>No. of Genera</i>
Coleoptera	2(0)**	3(0)	3(1)***	5(2)	+ 1	+ 2
Diptera	6(1)	6(4)	5(0)	5(0)	- 1	- 4
Ephemeroptera	2(0)	8(3)	2(0)	7(2)	0	- 1
Plecoptera	4(3)	7(6)	1(0)	1(0)	- 3	- 6
Trichoptera	6(3)	9(6)	3(0)	3(0)	- 3	- 6

*Based upon confirmed identifications only.

**No. in brackets refers to no. of families or genera above pulp mill that were not present below.

***No. in brackets refers to no. of families or genera below pulp mill that were not present above.

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