Influence of a Pulp and Paper Mill Effluent on Aspects of Distribution, Survival and Feeding of Nipigon Bay, Lake Superior, Larval Fish

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ABSTRACT

Surface distribution of Nipigon Bay larval fish was characterized by high abundance, between 500 and 2100 larval fish/10,000 m^3 near shore, particularly in proximity to the pulp and paper mill effluent discharge, and low abundance, less than 100/10,000 m^3 away from shore. Static bioassay indicated that approximately 60% effluent concentration was intolerable to the natural mixed larval fish community. No wood fibre was found among stomach contents and no difference was apparent in stomach contents of fish caught in influenced and uninfluenced areas. Data therefore suggest that larval fish either were not greatly influenced by plume conditions or were transients.

INTRODUCTION

Little is understood of ichthyoplankton distributional ecology (AMUNDRUD et al. 1974) and even less is understood regarding the effect of contaminants on early aspects of fish ecology. The initial intent of this study was to determine, without regard to cause, the presence or absence of larval fish in or near the discharge of the pulp and paper mill in Nipigon Bay, Lake Superior. Once it became evident that larvae were abundant not only in lower plume concentrations but within areas of maximum influence, bioassays were performed to examine tolerance limits of the larval fish community normally experiencing wastewater exposure. To further interpret and understand effect of concentrations, stomach contents of smelt captured in influenced and uninfluenced areas were examined.

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METHODS

Larval fish were collected with a conical net towed astern of a boat. The net, 2.6 m long with a diameter of 1.0 m at the mouth and 7.5 cm at the cod end, had a windowed 1ℓ plankton bucket clamped to the cod end. The netting in the forward 2 m of the net was 1050μ and the remainder was 505μ mesh Swiss grit gauze. Volume of water filtered and average tow speed were determined from a calibrated flowmeter affixed to the net. Twenty-five surface tows were made in circular paths near known reference points. Larvae were preserved on site.

Measurement and identification (FISH 1932; MANSUETI and HARDY 1967; MAY and GASAWAY 1967) was performed using a Wild M5 stereomicroscope calibrated with a stage micrometer. The stomachs of 144 smelt larvae were examined for content.

For bioassay experiments, fish larvae were caught with a dip-net at the mill dock, counted into 14 lots of 100 each and placed in 4ℓ plastic bags filled with Nipigon Bay water. Species were not separated but each test generally contained 85% sucker (*Catostomus sp.*) and 11% spot-tail shiner (*Notropis atherinoides*). Larvae were transferred to 14 plastic containers so that 4 sets of 200 larvae were held in effluent diluted in a logarithmic series of 10^{-1}, 10^{-2}, 10^{-3} and 10^{-4}. One set of 200 larvae was placed in raw effluent, and one set of 400 served as a control. The aerated units were in a water bath with continuous-flow Nipigon River water. Temperature was continuously monitored.

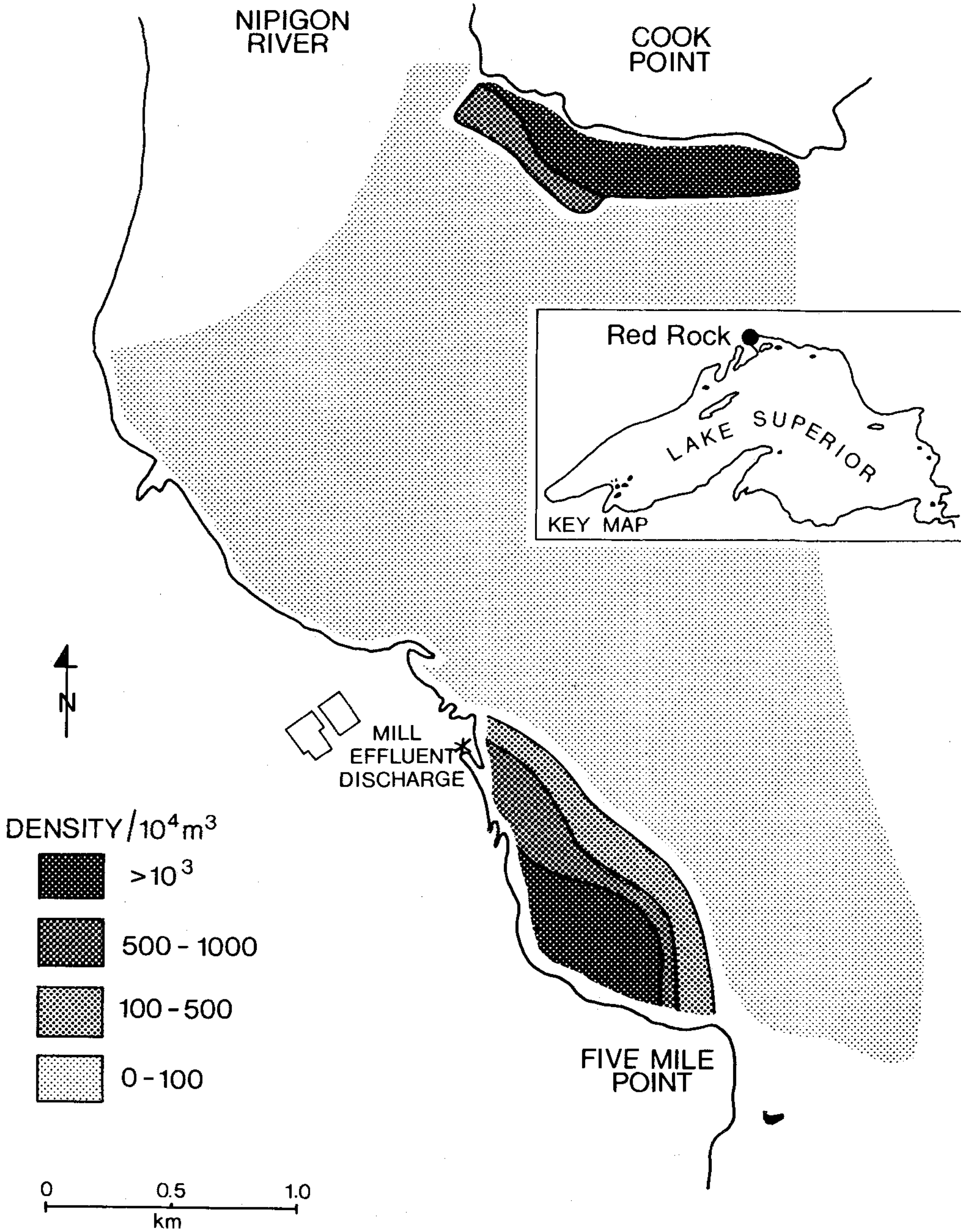
The first static bioassay was immediately followed by a second, in which larvae were split into 4 groups of 50 each and placed in plastic bags containing fresh effluent diluted by Nipigon Bay water to concentrations of 80%, 60%, 40%, and 20% (v/v). The plastic bags were immersed in a water bath with continuous flow Nipigon Bay water and aerated.

RESULTS

Distribution and Species Composition

A total of 2,063 larval fish was captured, 65% of which were caught in shallow, <5 m, water in six tows made near the mill outfall and 26% from 3 tows made near Cook Pt.

FIGURE 1



Distribution and abundance of larval fish, all species, adjacent to the pulp and paper mill, Nipigon Bay.

In contrast, only 77 larval fish were caught in 10 tows made in deeper water. Catch per unit effort was high, between 500 and 2100 larval fish/10,000 m^3, in all near-shore tows except those made north of the discharge (Fig. 1). Abundance was consistently low offshore, generally less than 100/10,000 m^3.

The dominant species was rainbow smelt, which were most abundant in the near-discharge and Cook Point areas (Fig. 1). Although smelt dominated catches, the greatest variety in species composition occurred in the area north (Fig. 1) of the pulp and paper mill discharge. Both white (Catostomus commersoni) and longnose (C. catostomus) sucker were present in Nipigon Bay (KELSO 1977) but separation of larval stages of the two species was not done.

TABLE 1

Date	Species			
1974	O. mordax	P. flavescens	Catastomus sp.	Other
July 17	62.1 (18)	37.9 (11)	0.0	0.0
July 19	62.5 (60)	15.6 (15)	18.8 (18)	3.1 (3)
July 23	98.4 (1014)	0.9 (9)	0.2 (3)	0.5 (4)
July 25	99.9 (907)	0.0	0.1 (1)	0.0

Nipigon Bay, 1974 larval fish occurrence as percent of total catch, and number (in parenthesis).

To examine differences in larval smelt from influenced and uninfluenced locations, similar numbers were measured from each location. No significant difference ($F = 0.403$ df = 1208) was found between standard lengths of larval fish caught at the influenced and the uninfluenced area.

Food of larval smelt in two levels of influence

Stomachs of 72 larval smelt from both effluent and Cook Point locales were examined.

TABLE 2

	Effluent	Cook Pt.
Number of samples	72	72
Number of empty stomachs	5 k = 0.9	8 k = 0.9
Number of stomachs with unidentified material	7	11
Leptodiaptomus minutus	62.9 (73.6) k = 0.7	72.1 (65.2) k = 0.7
Unidentified calanoid	16.3 (40.3) k = 0.4	6.9 (16.6) k = 0.2
Leptodiaptomus ashlandi	9.9 (27.8) k = 0.3	5.2 (15.3) k = 0.2
Epischura lacustris	1.9 (8.3) k = 0.1	9.6 (22.2) k = 0.2
Diaphanosoma	2.9 (9.7) k = 0.1	1.7 (5.6) k = 0.1
Diacyclops bicuspidatus thomasi	2.6 (6.9)	1.7 (2.8)
Cyclopoid copepod	1.3 (5.6)	0.4 (1.4)
Unidentified copepodids	0.6 (1.4)	1.3 (2.6)
Leptodiaptomus sicilis	0.3 (1.4)	0.4 (1.4)
Daphnia galeata mendotae	0.3 (1.4)	0.0 (0.0)
Daphnia retrocurva	0.0 (0.0)	0.4 (1.4)
Diaptomus oregonensis	0.3 (1.4)	0.0 (0.0)
Bosmina longirostris	0.3 (1.4)	0.0 (0.0)
Isopod	0.3 (1.4)	0.0 (0.0)

Percent of total stomach content and occurrence (in parenthesis) for larval smelt caught at 2 locations. For description of k, see text.

A total of 14 identifiable food items was noted, and of these, Leptodiaptomus minutus occurred in 71% and 65% of influenced (effluent) and uninfluenced (Cook Pt.) specimens, respectively. Unidentified calanoids (40%), Leptodiaptomus ashlandi (28%), Diaphanosoma sp. (10%) and Epischura lacustria (8%) were evident in the gut of influenced larvae, while occurrence of the same species in uninfluenced larval fish was 17%, 15%, 6%, and 22% respectively. Other plankters common to both groups but in fewer than 15 of the total stomachs were Diacyclops bicuspidatus thomasi, cyclopoid copepods, unidentified copepodids, and Leptodiaptomus sicilis. Less than 10% of the guts were empty and significantly, wood fibre was never evident.

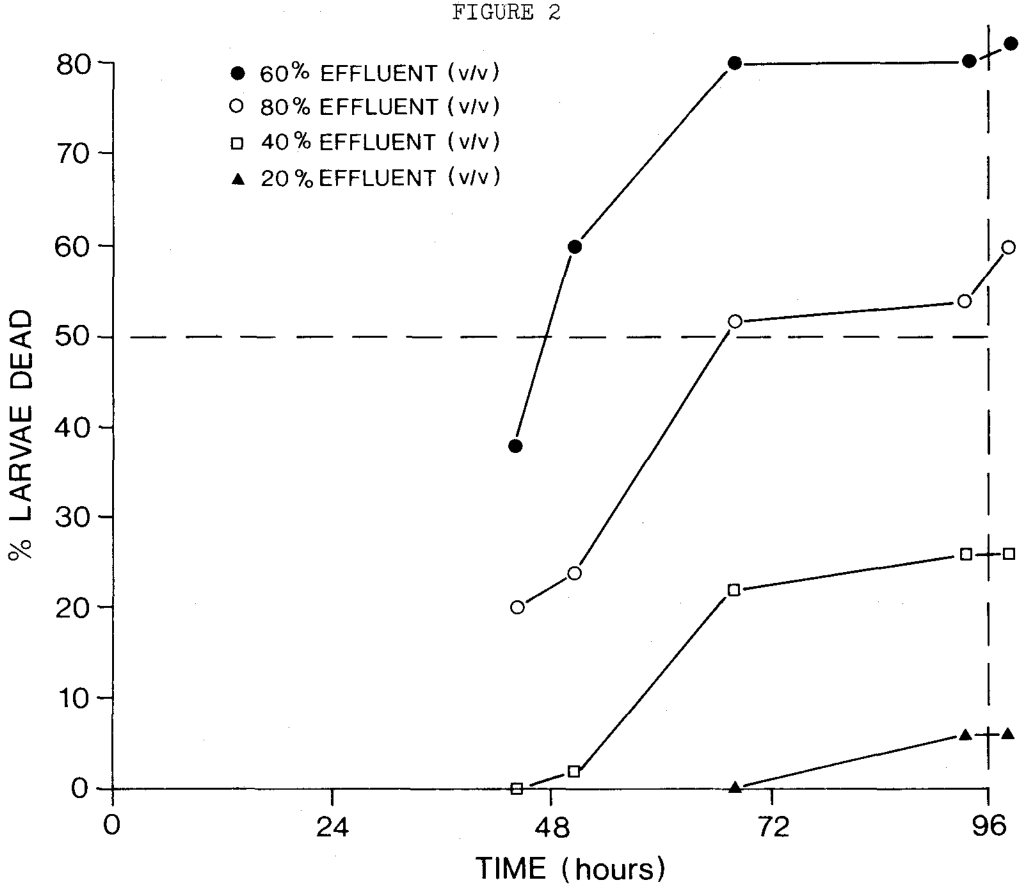
The three most common zooplankters (COOLEY 1977) found in Schindler trap samples (Daphnia retrocurva, Bosmina longirostris, and Diacyclops bicuspidatus thomasi) while constituting an average abundance of ≈ 1800 plankters/m^3 per species contributed only 3% of the total stomach content. The most common plankter, B. longirostris, contributed just 0.3% to stomach contents yielding an electivity index close to -1 for all three dominant zooplankton species. The indicator k (ZAIKA and OSTROVSKAYA 1973) denotes the ratio of the number of larvae with at least one food item in the stomach to the total number of larvae and, as such, is an indicator of prey use. The ratio of smelt larvae with food to larval abundance, whether applied to a specific prey or to the whole food spectrum was never equal to 1 (Table 2).

Bioassay testing

The first bioassay, logarithmic dilution series, demonstrated simply that test specimens survived the 96 h exposure at all dilute concentrations - the lethal level lying somewhere between 10% v/v (10^{-1}) and full concentration. There were no survivors in the raw effluent after 12 h. Only 8% of the larvae in 10% concentration effluent died during the 96 h exposure. After the first 12 h, 99% of all larvae survived.

The second bioassay, arithmetic dilution series, resulted in an anomaly (Fig. 2) in that there were more survivors in the 80% than in 60% effluent, i.e. 50% mortality occurred between 44 h and 50.5 h in 60% effluent and between 50.5 h and 68 h in 80% effluent.

FIGURE 2



Cumulative mortality of larval fish during static bioassay at 4 effluent dilutions.

Analyses of the raw effluent showed the following chemical and physical differences, before dilution, between bioassay types:

	Log dilution	Arithmetic dilution	
Sol. nitrogen	50	35	ppb
Particulate nitrogen	0.17	5.07	ppm
Sol. phosphorus	44	70	ppb
Dis. organic carbon	124	80	ppm
Particulate carbon	14.24	81.09	ppm
Sodium	138	85	ppm
SO_4	180	154	ppm
Total P	140	310	ppb
pH	10.48	9.98	
Conductivity	743	607	mhos

DISCUSSION

Larval fish were caught in quantity in surface waters of Nipigon Bay nearshore areas. The presence of smelt, almost exclusively, in an area highly influenced by the pulp and paper mill was, however, unexpected. Also, no difference in length or in food selection between larvae in influenced and uninfluenced areas was found. Consequently, larval fish distribution and habits were either unaffected by the mill effluent or captures in the effluent were transients.

Bioassays indicated that the acutely lethal concentration (LC50) of the effluent was approximately 60% for the larval fish community normally exposed to the effluent. The variability in effluent constituents (see text table) emphasizes, however, the changing nature of the wastewater and its subsequent effect. Nevertheless, from bioassay and analysis of plume chemistry (MINNS 1977) concentrations in Nipigon Bay did not appear to approach acutely lethal levels.

Although data are scant, it appears that larval smelt strongly select for zooplankton species. Food was similar in composition and quantity at Cook Pt. and near the discharge (COOLEY 1977); thus, factors other than pulp and paper mill effluent likely governed feeding. WONG and WARD (1972) found early stages select for prey size, but it seems unusual for predators to select less abundant, small zooplankton.

Since neither long term effects nor all species present in the bay have been examined, the effect of the pulp and paper mill discharge on fish early life history is still largely unknown. Also data were limited. However, from bioassay and field collection, it appears that conditions in Nipigon Bay are not acutely lethal.

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