The Occurrence of Oil and the Distribution of *Hexagenia* (Ephemeroptera: Ephemeridae) Nymphs in the St. Marys River, Michigan and Ontario[1]

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Abstract. We sampled benthos from the St. Marys River in May 1974 and May 1975 to determine visibly the occurrence of sorpted oil and the distribution of nymphs of the burrowing mayfly *Hexagenia* in the bottom of the Lake George and Lake Nicolet channels. Results of our survey showed that, between 1967 and 1974-75, the occurrence of oil in the substrate of the Lake George Channel had advanced from 16 km to 30 km downstream from the point where oil is discharged at Sault Ste. Marie, Ontario. Absence or low densities of nymphs coincided with the presence of oil in the sediments. In the Lake Nicolet Channel, evidence of oil pollution was meager and the density of *Hexagenia* nymphs was generally high.

As the St. Marys River flows easterly past Sault Ste. Marie, Michigan, and Sault Ste. Marie, Ontario, it divides into the Lake Nicolet Channel west of Sugar Island, and the Lake George Channel north and east of the island (Fig. 1). In a water quality survey of the river conducted in 1967, the Ontario Water Resources Commission (OWRC) found that the water flowing down the Lake Nicolet Channel was pollution free but the water in the Lake George Channel carried a number of industrial wastes including oil, naphthalene, cyanides, and phenol (Veal 1968). In their survey, the OWRC noted that these industrial wastes originated at a steel plant in Sault Ste. Marie, Ontario, and were discharged into the river through a trunk sewer (Figs. 2, 3). The Comission found that the oil component was visible in the substrate as far as 16 km downstream from the point of release at the trunk sewer. The oil had probably reached the bottom by the sorption process discussed by Shelton and Hunter (1974). The presence of oil coincided with the absence of a number of benthic invertebrates, among them the pollution intolerant (Fremling 1970) nymphs of the burrowing mayfly *Hexagenia.*

In 1974-75, seven years after the OWRC survey, we undertook the present study to determine whether changes had occurred in the incidence of oil pollution and the distribution and density of *Hexagenia* nymphs in the two channels of the river system.

MATERIALS AND METHODS

The benthos was sampled with a standard ponar grab (surface area of sample = 0.048 m^2) at stations where the substrate was assumed to be naturally suitable (irrespective of pollution) for inhabitation by *Hexagenia* nymphs (i.e., mud to soft clay). In May 1974, we collected three replicate samples at 23 stations, but at seven stations in the Lake George Channel (solid squares in Fig. 2), the substrate contained a large volume of coarse, partly decomposed detritus which could not be removed from the residue by washing, thus discouraging us from taking more than one sample per station. In May 1975, we increased the number of sampling stations to 81 to better describe and delineate the distribution of

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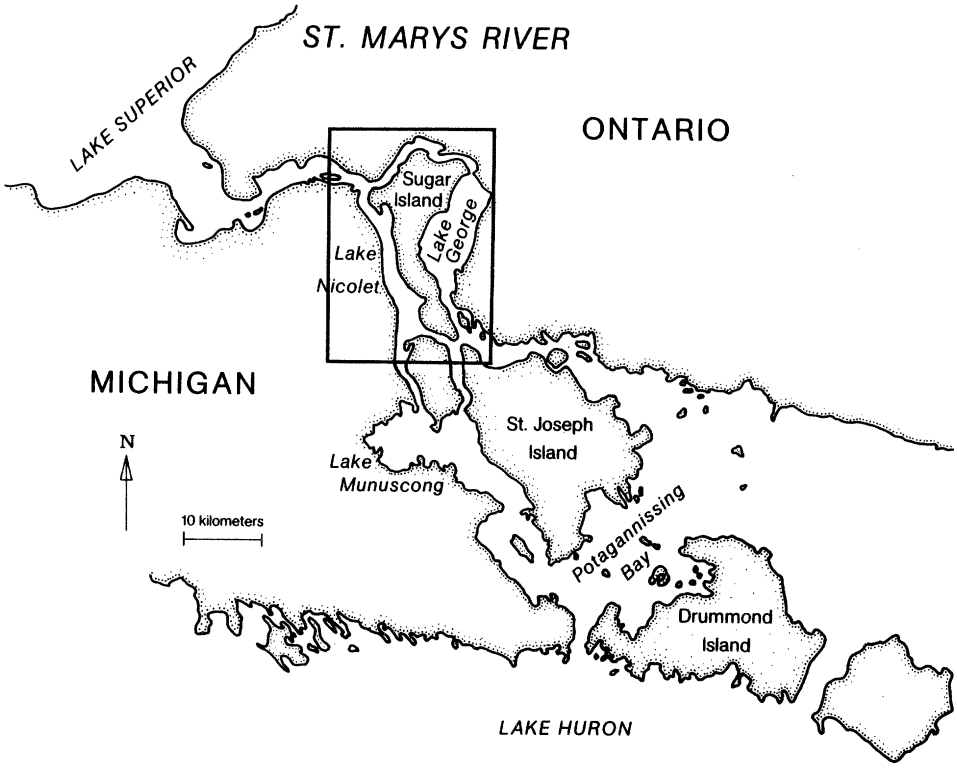

Fig. 1. Section of the St. Marys River surveyed for oil pollution and *Hexagenia* nymphs in 1974-75.

oil and nymphs (Fig. 3). The location of 20 of these stations corresponded to the location of sites that had been sampled by OWRC in 1967. While on station, we examined each sample for visible evidence of oil (as a sludge or film in the substrate) and then washed it through a U.S. Standard No. 30 sieve (0.65-mm mesh openings). The sample residue containing organisms was placed in a jar and preserved in 10% formalin. In the laboratory, *Hexagenia* nymphs were extracted from the residue under 7× magnification.

To test for statistical significance between the mutual presence-absence of nymphs and oil in the substrate, we pooled all counts of nymphs per station for all dates and applied a chi-square test (Conover 1971) to those data.

Results and Discussion

The results of our 1974 survey of the river bottom revealed that oil was present in the substrate of the Lake George Channel, from the station nearest to the point of discharge at Sault Ste. Marie, Ontario, to approximately 30 km downstream in the north end of Lake George (Fig. 2). Correspondingly, *Hexagenia* nymphs were absent in this reach of the river. In 1975, oil was present and nymphs absent at stations previously sampled in 1974, but greater areal coverage in 1975 revealed that few nymphs were present at three stations along the eastern and western margins of northern Lake George (Fig. 3). Oil was found at only one of those three stations. The absence of nymphs in the upper section of the channel in 1974 and 1975 agreed with the findings of OWRC (Veal 1968), except that the Commission found 217 nymphs/m^2 and no oil in the substrate at a station due north of Sugar Island (Fig. 3). OWRC also reported finding no oil anywhere downstream from that station.

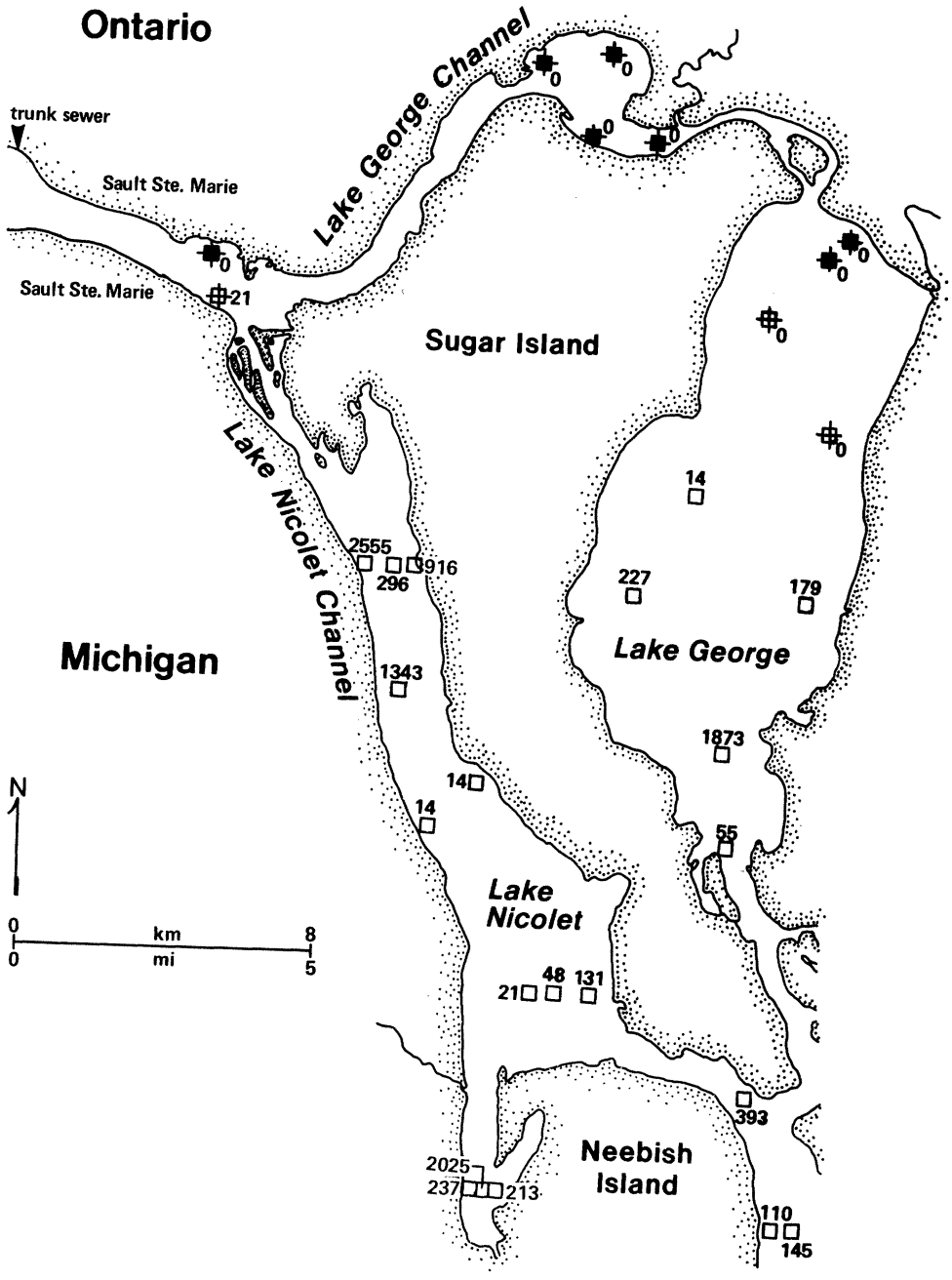

Fig. 2. Location of 30 stations in the St. Marys River sampled in 1974 to test for the presence of oil in the substrate and determine the distribution and density of *Hexagenia* nymphs. Open squares (□) indicate stations where three replicate samples were taken; solid squares (■) indicate stations where only one sample was taken; a cross (+) indicates the visible presence of oil in the substrate; numbers indicate the mean density (no./m^2) of *Hexagenia* nymphs.

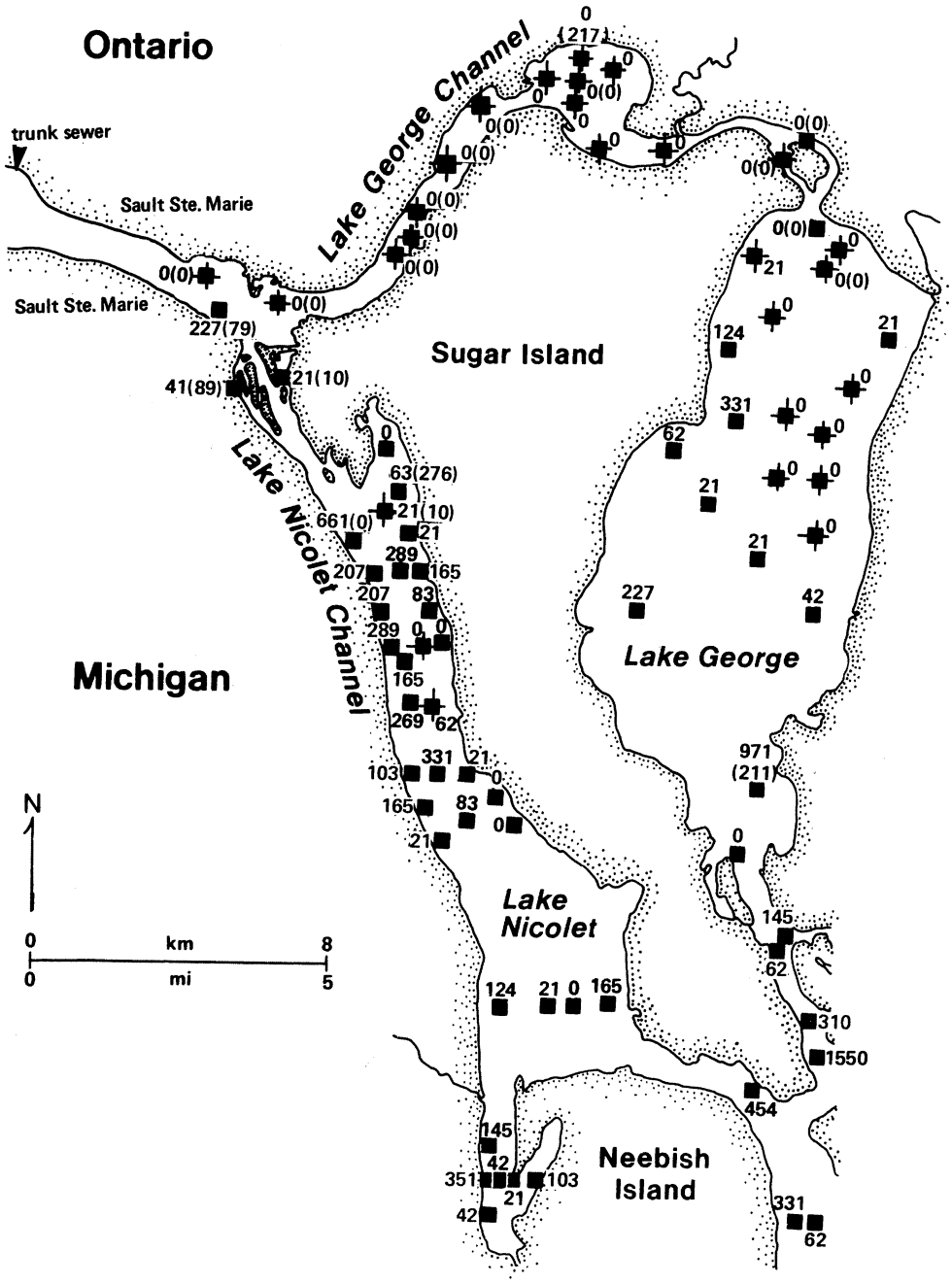

Fig. 3. Location of 81 stations (solid squares, ■) in the St. Marys River sampled in 1975 to test for the presence of oil in the substrate and determine the distribution and density of *Hexagenia* nymphs. A cross (+) indicates the visible presence of oil in the substrate. Unenclosed numbers indicate the density (no./m^2) of *Hexagenia* nymphs in 1975 and numbers enclosed in parentheses indicate the densities (no./m^2) of *Hexagenia* nymphs reported by the Ontario Water Resources Commission in 1967.

In the Lake Nicolet Channel, *Hexagenia* nymphs were found at all stations in 1974 and no visible oil was evident in the substrate except at one station at the head of the channel due east of Sault Ste. Marie, Michigan (Fig. 2). That occurrence of oil may have been

merely transient because no oil was observed there in 1975. Of the 36 stations sampled in the Lake Nicolet Channel in 1975, six yielded no nymphs; oil was present in the substrate at two of these stations (Fig. 3). The absence of nymphs at some stations may be a function of the sandy bottom; sand is known to deter *Hexagenia* inhabitation (Edmunds, Jensen, & Berner 1976; Wright & Mattice 1981). At two other stations, both oil and nymphs were present. In rare instances where nymphs survived in the presence of oil (Fig. 3), the suitability of the habitat may have, nevertheless, been marginal because the density of the nymphs was low (21-62/m^2).

The chi-square test of the relationship between the mutual presence or absence of nymphs and oil over the total study area revealed that, in 1974 and 1975 together, few stations yielded nymphs when oil was present in the substrate, but in the absence of oil, nymphs were found at a large number (about 85%) of stations ($P<0.0001$).

Oil in the Lake George Channel has not been confined to the sorpted form found on the bottom. On a visit to the southern end of Lake George on a calm day in July 1975, the senior author observed, on the lake's surface, a partially windrowed film of oil through which many *Hexagenia limbata* (and *Ephemera simulans*) subimagos were attempting but failing to emerge.

The unsuccessful emergence was witnessed over bottom which, in May 1975, was devoid of oil and supported a substantial population of *Hexagenia* nymphs (227/m^2). Thus, the incidence of oil pollution in the river provides a double threat to mayflies and probably other insects. Not only are the immature forms subjected to the chemical toxicity of the sedimented oil but also, the emerging subimagos must contend with a surface film of oil that presents a physical barrier to emergence.

We have concluded that between 1967 and 1974-75, oil in the bottom of the Lake George Channel, St. Marys River, had advanced from 16 km to more than 30 km downstream from its source. The spread of oil in bottom sediments coincided with the absence of *Hexagenia* nymphs in the northern section of the channel. Thus, continued discharge of oil (and other toxicants) into the river can be expected to accumulate in the substrate and further degrade the benthic community, and the transition (recovery) zone between the presence and absence of nymphs in the bottom of Lake George will probably advance farther downstream. If introduction of industrial wastes into the river ceased, pollutants in the substrate would undergo biodegradation (Emery 1972; Nuefeld & Valiknac 1979; Shelton & Hunter 1974, 1975) and, over time, a benthic habitat suitable to *Hexagenia* could be restored.

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