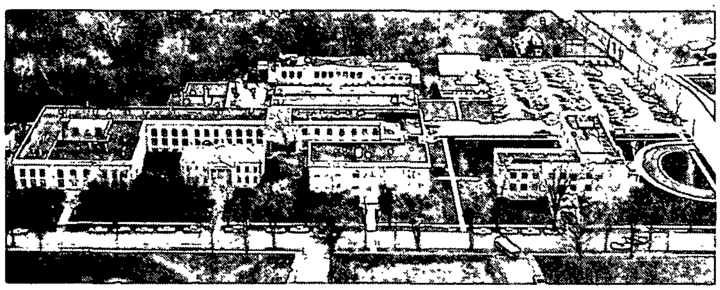

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WATER QUALITY IMPROVEMENTS IN THE LOWER FOX RIVER, WISCONSIN, 1970-1980: AN HISTORICAL PERSPECTIVE

BRUCE E. MARKERT

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WATER QUALITY IMPROVEMENTS IN THE LOWER FOX RIVER, WISCONSIN, 1970-1980: AN HISTORICAL PERSPECTIVE

Bruce E. Markert
Aquatic Biology Group
The Institute of Paper Chemistry
Appleton, Wisconsin 54912

ABSTRACT

Benthic macroinvertebrates were sampled at eleven stations since 1970 in the lower Fox River from Lake Winnebago to Green Bay during the low flow and high temperature period from May through September. Two similar river discharge years (1975 and 1979) were compared to show the water quality changes from the presecondary treatment period (1970-1976) to the postsecondary treatment period (1977-present). During the presecondary period the benthic invertebrate communities were dominated by the pollution associated aquatic worms depicting a severe water quality degradation due to point source discharges. With the advent of secondary treatment, the aquatic worm densities decreased while the more sensitive caddisflies increased denoting improved water quality conditions. The loss of the dense worm population appeared related to the loss of its food source. A strong correlation was present between decreasing current velocity and decreasing Symphitopsyche sp. densities. The data suggest that the water quality of the lower Fox River is less restricted by point source discharges and more restricted by a hypereutrophic lake at its headwaters.

INTRODUCTION

The lower Fox River in its 64 kilometer- (40-miles) reach from Lake Winnebago to Green Bay has along its stretches one of the major industrial complexes in the Midwest. The major water quality changes in this section of the river are created by the 18 pulp and paper mills and 8 municipal treatment systems which discharge wastes into the river. In addition to the numerous point source discharges, the lower Fox River is affected by a hypereutrophic natural lake at its headwaters.

In the 1950's the lower Fox River was labeled as one of ten most polluted rivers in the United States. Studies conducted in the late 50's and 60's by The Institute of Paper Chemistry and the Wisconsin Department of Natural Resources showed that the water quality of the lower Fox River was grossly degraded.

In 1970 a continuous biological monitoring program was initiated and conducted by the Institute to measure the water quality changes within the water column. Because the physical and chemical constituents change rapidly over short periods of time, a biological monitoring program was developed which compared benthic invertebrate communities upstream and downstream from the major discharges. Benthic invertebrates have been one of the most widely used groups of organisms for evaluating the quality of flowing waters[1,2]. Because of their special adaptations to food gathering, reproduction, mobility and respiration particular benthic invertebrates are associated with environmental conditions[3].

STUDY AREA

The Fox River drainage basin is 11,752 km^2 (4520 mi^2) of which the lower Fox River comprises 1,089 km^2 (419 mi^2) or about 6% of the total basin area. Despite the relatively small area, about 83% of the total fall of the river from the headwaters to Lake Michigan occurs in the last 62 km (39 mi) of the stream (Fig. 1). This rapid fall averages 1.3 meters (4.3 feet) per mile in the lower Fox River.

Flows in the lower Fox River are controlled by numerous dams constructed along the rapid sections of the river. River discharge varies from about 28.3 m^3 (1,000 ft^3) per second during the summer months of July, August and September to over 453 m^3 (16,000 ft^3) per second in the spring.

MATERIALS AND METHODS

Eleven sampling stations were chosen to show water quality changes before and after secondary treatment. These stations were selected at locations that would reflect water quality changes due to point source discharges (Fig. 2). Two stations were located above any point source discharge and nine stations below the various discharges. In addition, the stations reflect the different river velocities encountered throughout the lower Fox River. To show the water quality changes which have occurred during the past ten years, two similar river discharge years (1975 and 1979) are presented. The year 1975 depicts the quality of the river prior to secondary treatment and the year 1979 depicts the changes which occurred with the advent of secondary treatment.

Artificial substrate samplers were used constructed of wire barbeque baskets measuring 17.8 x 28 cm and filled with thirty 5-cm diameter unlapped porcelain spheres. The basic basket design was described by Mason[4], and was modified by adding a 35-cm eyebolt through the center and attaching a 0.625 cm thick hardboard plate to the bottom. This modification provides a better attachment for the cable and gives the basket additional support. The sampler was suspended by 0.469 cm plastic-coated steel cable which was looped around a U.S. Coast Guard navigational buoy and through the stabilizing vane. The basket sampler was suspended at the downstream end of the buoy at approximately the 1.2-meter (4-foot) depth.

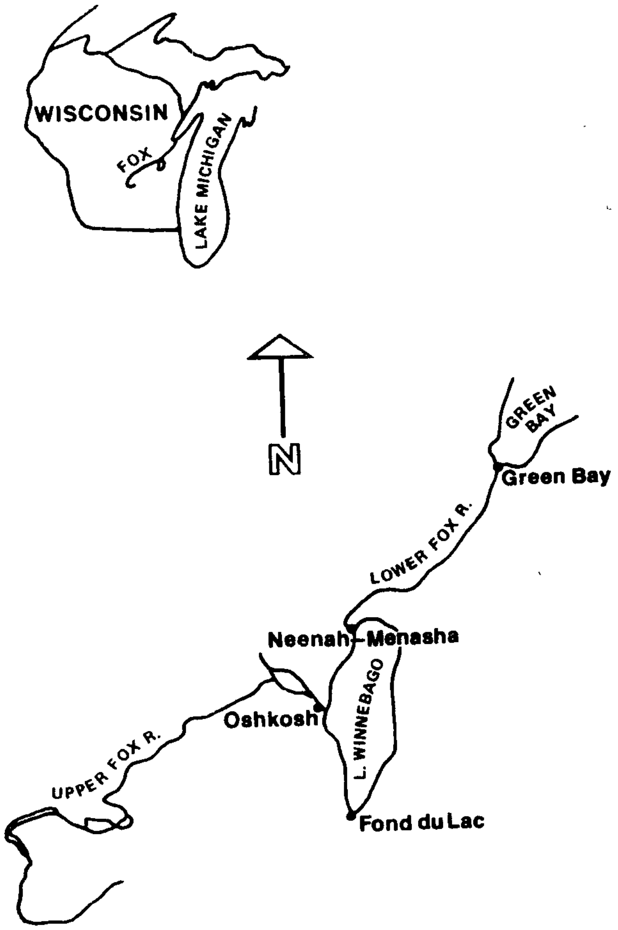


Figure 1. The Upper and Lower Fox River Drainage System

Single artificial substrate samplers were collected from each station following 6-week colonization periods from May through September. Each sampler was harvested by slowly raising the basket to the surface and placing into a wide-mouthed pail. Because the dominant benthic invertebrate communities in the lower Fox River consist of case-making caddisflies and midges, organism loss during sampler retrieval was minimal. After the sampler was collected, the basket was disassembled and separated. The organisms were hand-picked from the balls and basket to include the bottom plate, washed in a U.S. Standard No. 30 sieve (0.595 mm openings) and preserved with buffered 10% formalin. Station current velocities were measured with a Model 201 Marsh/McBirney current meter with the probe placed just above the sampler. Measurements were taken at installation and harvest of the samplers.

Organisms were sorted from the samples under 10X magnification in the laboratory and all animals were enumerated at the generic or specific level, where feasible. Biotic Index (B.I.) was calculated as proposed by Chutter[5].

RESULTS AND DISCUSSION

The average discharge of the lower Fox River was almost identical from June through October in 1975 and 1979.

The dominant benthic invertebrates found on the artificial substrate samplers included worms (Naididae), caddisflies (Symphitopsyche and Cheumatopsyche) and chironomids (Polypedilum and Cricotopus). The majority of naidid worms feed by grazing and have been associated with areas of low dissolved oxygen (DO) for extended periods and high deposition of organic material. For example, Learner, et al.[6] found a ten- to twenty-fold increase of naidid worms downstream from a sewage outfall. This group is usually referred to as pollution-associated. The caddisflies found in the Fox River are mainly filter-feeders and are associated with areas where low DO is not present for extended periods and where low deposition of organic material is present. This group usually represents an enriched but not degraded environment. The chironomids (midges) are both filter-feeders and collector-gatherers. This group has forms found in areas of low DO and forms that are sensitive to low DO's and heavy organic material.

BENTHIC INVERTEBRATE DENSITIES

The fauna from Stations 5 through 11 during the presecondary period (colonizations 2 and 3) was dominated by worms (Naididae) which indicated water quality degradation due to point source discharges (Fig. 3). Low worm densities were observed throughout the river during the first colonization period in 1975 probably due to the higher flows. Low densities were also observed at the two control stations and Stations 3 and 4 during the 2nd and 3rd colonizations.

In general, the release of untreated or partially-treated wastes into a turbulent stream which contains naidid worms usually results in an increase of their abundance. The response observed in the naidid worm densities during the presecondary period appears to be a response to a greater availability of food. The highest worm densities occurred at stations where dense bacterial slime (Sphaerotilus natans) growths were evident. Learner[6] points out that much of the evidence that bacteria are utilized by naidids is circumstantial. However, the success of several Nais sp. in sewage filter beds where they feed on bacterial film suggests that bacteria can be utilized as a food source[6]. The worm populations found in the Fox River in areas with slime growths also suggest that the naidids were feeding on bacteria.

In contrast to the presecondary period the worm fauna during the postsecondary period was low to nonexistent at all stations sampled (Fig. 3). In addition, no slime growths were found at any of the sampled stations during the postsecondary period. The loss of the bacterial slime along with the loss of the dense worm population suggests that the worm decrease occurred due to the loss of their food source.

In direct contrast to the worm abundance, the caddisflies during the presecondary period were dominant from Stations 1 through 5 and were low to nonexistent from Stations 6 through 11 (Fig. 4). The water quality of the lower Fox River during the

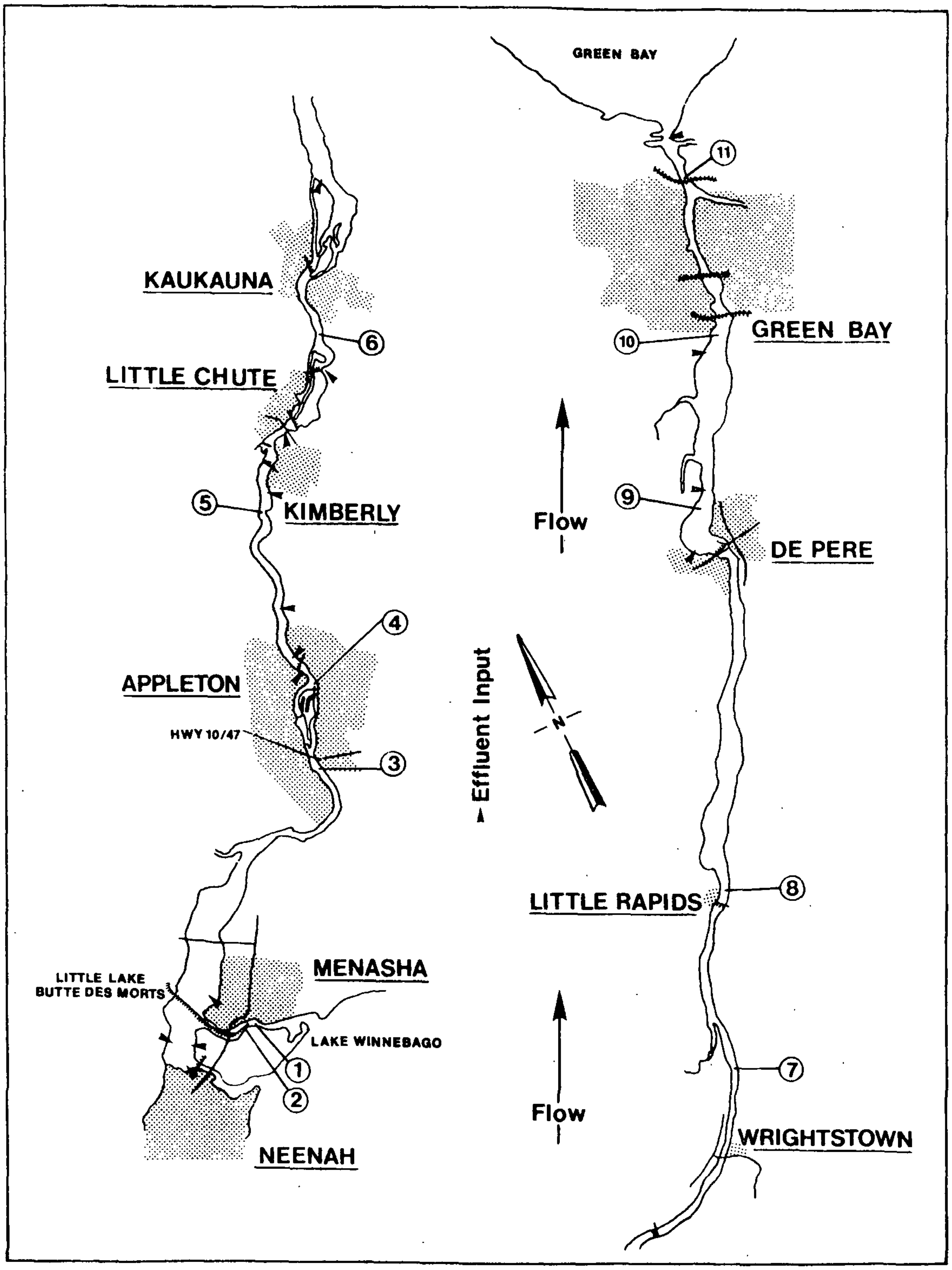
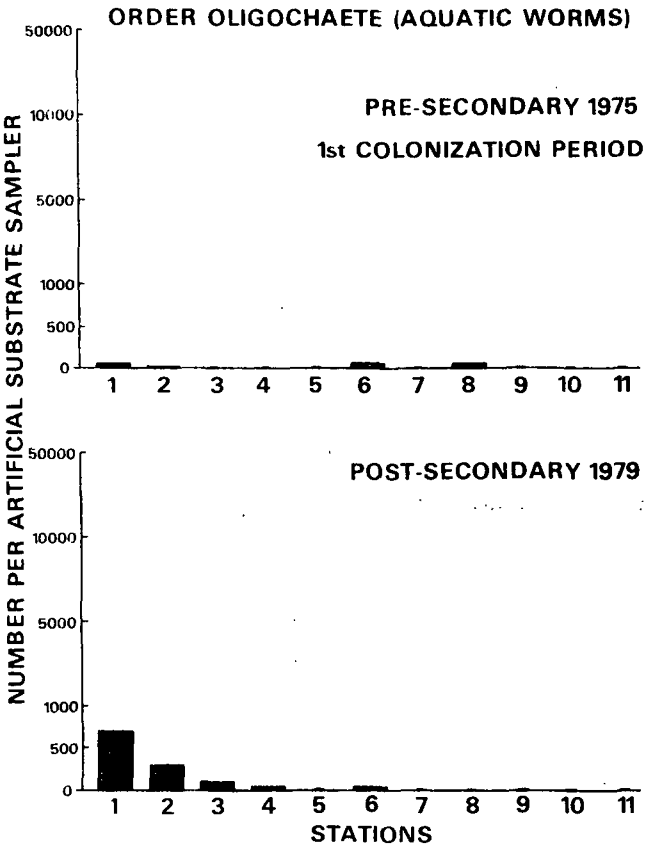
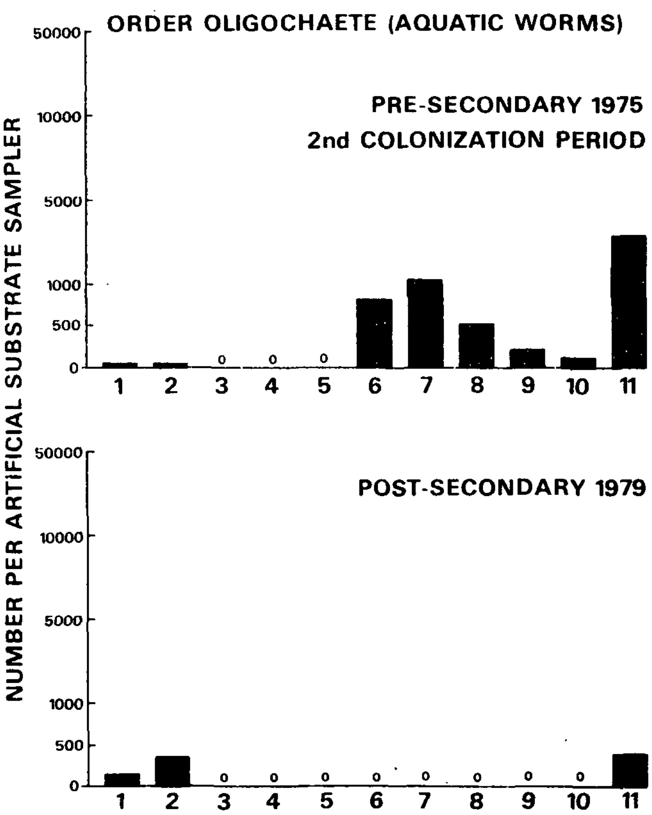


Figure 2. A Map of the Lower Fox River Showing the Sampling Locations and Point Source Discharges

presecondary period was not sufficient to enable the more sensitive caddisfly community to exist in the middle and lower stretches of the Fox River. However, with the advent of secondary treatment the more sensitive caddisfly community was able to populate previously degraded sections of the lower Fox River. The two control stations show quite dramatic density differences and this can be related to the different current velocities found at these two stations.





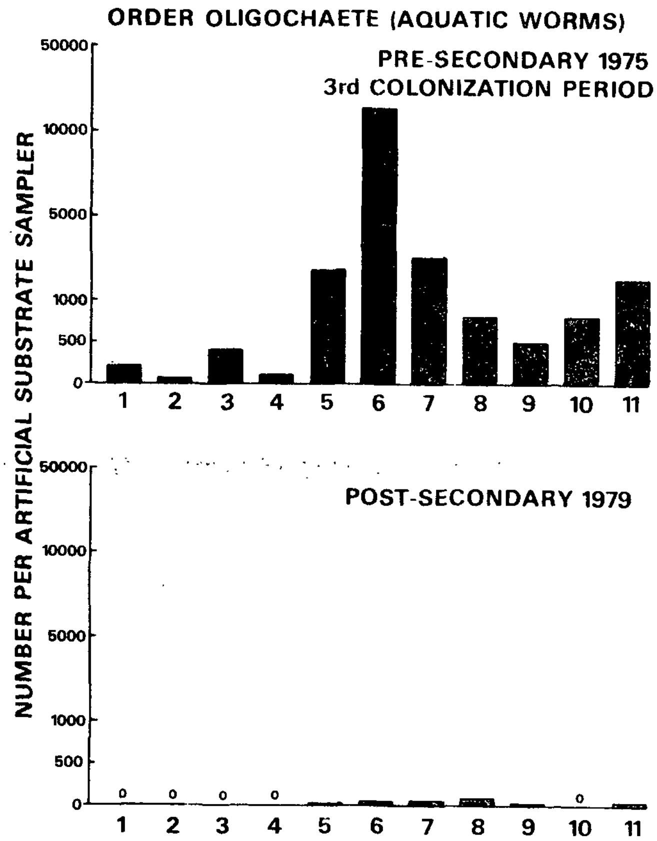
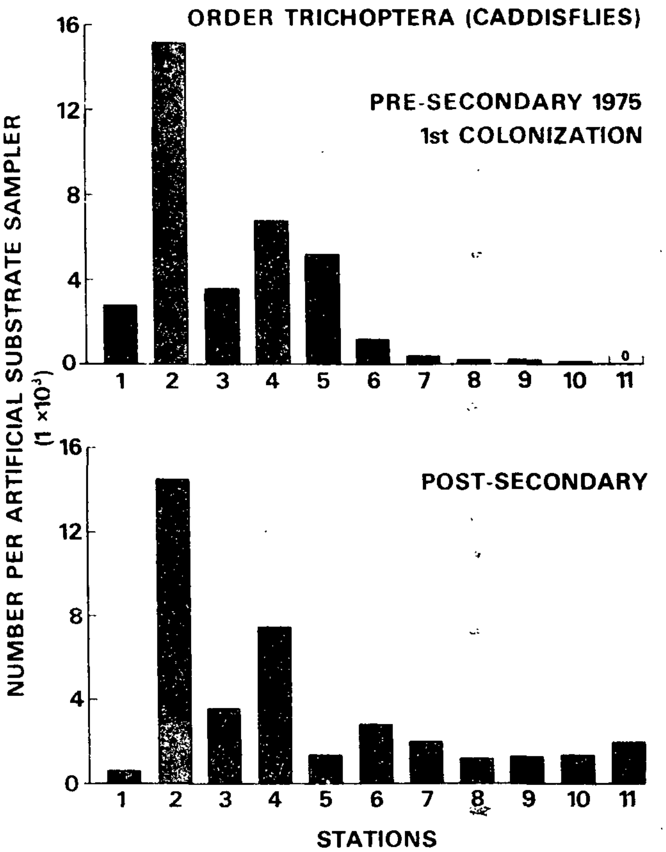


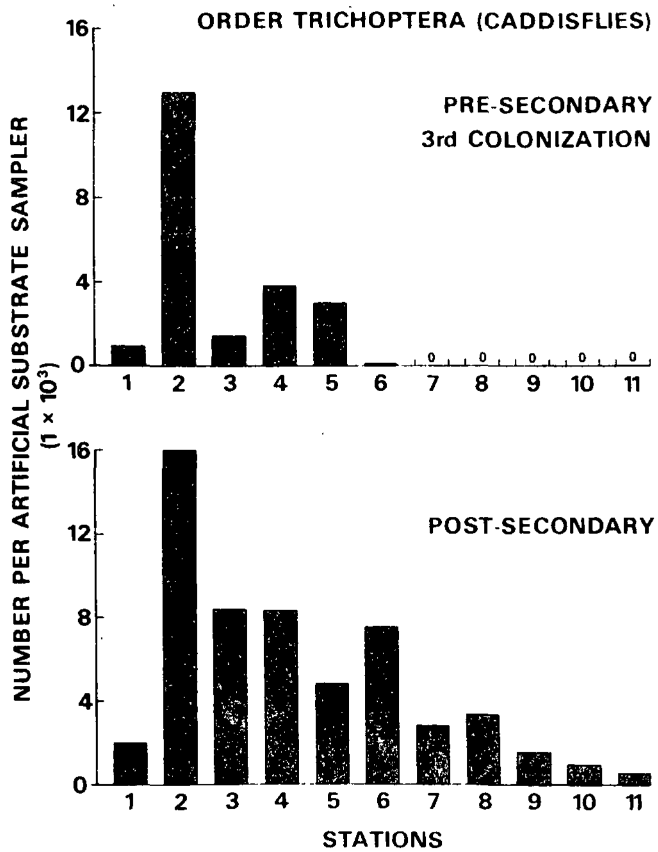
Figure 3. The Total Number of Aquatic Worms (Order Oligochaeta) Found per Artificial Sampler for the Three Colonization Periods During 1975 and 1979

The chironomid (midge) fauna displayed generally higher numbers during the presecondary period with reduced densities during the postsecondary period for all colonizations (Fig. 5). Possibly the increased caddisfly population in recent years has reduced the available habitat for the midges thus reducing their densities.

BIOTIC INDEX (B.I.)

The biotic index for the presecondary period shows quite similar values from Stations 1 to 4, increasing at Station 5 and very high at Stations 6 to 11, expecially during colonizations 2 and 3 (Fig. 6). Chutter[5] interpreted the index values 0-2 denoting clean unpolluted waters, 2-4 slightly enriched, 4-7 enriched and 7-10 polluted. Based on the values observed for the presecondary period, Stations 6 through 11 during the 2nd and 3rd colonizations were polluted. In contrast, the B.I. for the postsecondary period were quite similar for all the stations sampled with somewhat higher values at Stations 1, 9 and 11 (Fig. 6). No values were found between 0-2 and this is understandable because of the hypereutrophic lake at its headwaters.





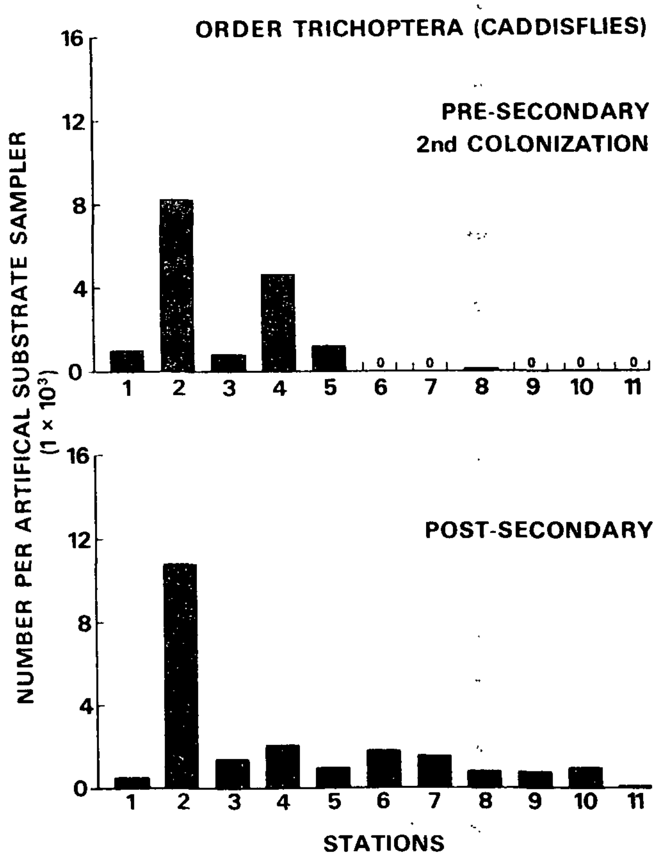


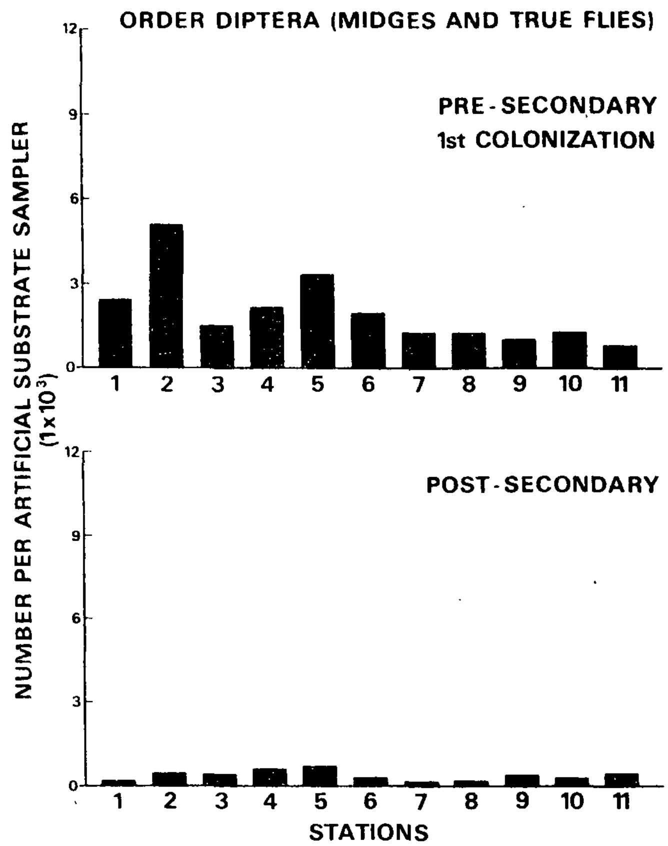
Figure 4. The Total Number of Caddisflies (Order Trichoptera) Found per Artificial Sampler for the Three Colonization Periods During 1975 and 1979

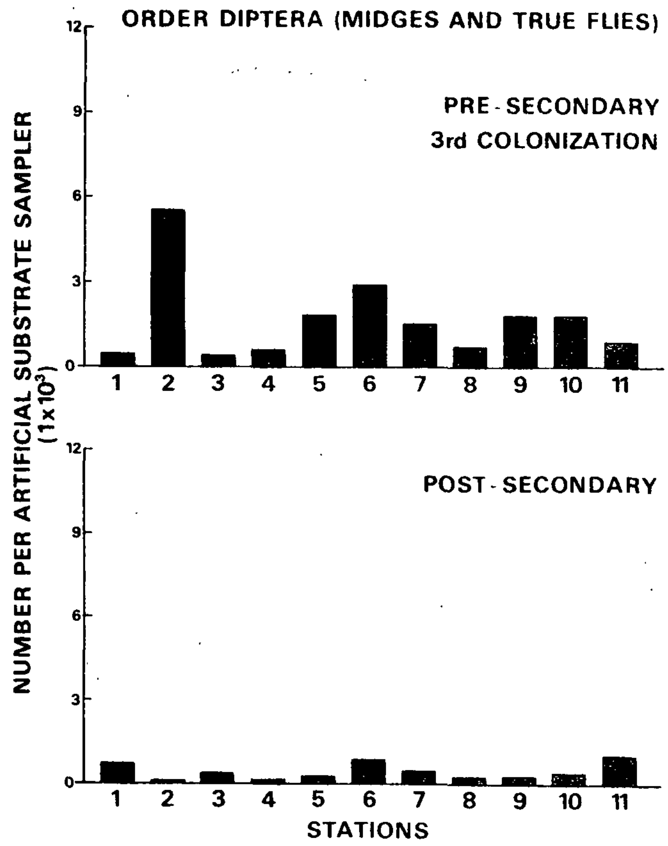
BENTHIC INVERTEBRATE TEMPORAL DISTRIBUTION

In general, two caddisflies were the most abundant organisms in the lower Fox River during the post-secondary period. The "current loving" *Symphitopsyche* sp. dominated the faster water in the upper stretches of the lower Fox River, while *Cheumatopsyche* sp. dominated the slower water in the lower stretches. During the first colonization period the caddisfly, *Symphitopsyche* sp., was the dominant benthic invertebrate from Stations 2 to 8 whereas *Cheumatopsyche* sp. was dominant at the stations closest to Green Bay (Stations 9 to 11) (Fig. 7). During the second colonization period a general decrease was apparent with both dominant caddisflies. This appears to be a natural population decrease due to adult hatching. However, during the third colonization the dominance of *Symphitopsyche* sp. returns in the upper stretches with a subsequent dominance of *Cheumatopsyche* sp. in the lower streteches.

It appears from the data that current velocity may have a profound effect on the distribution of benthic invertebrates found in the lower Fox River's water column. To further understand this relationship, station current velocities and densities of the two dominant caddisflies are compared.

During all three colonizations the *Symphitopsyche* sp. densities demonstrated a strong correlation with current velocity (1st colonization, $r = 0.914$; 2nd colonization, $r = 0.933$; 3rd colonization, $r = 0.970$).





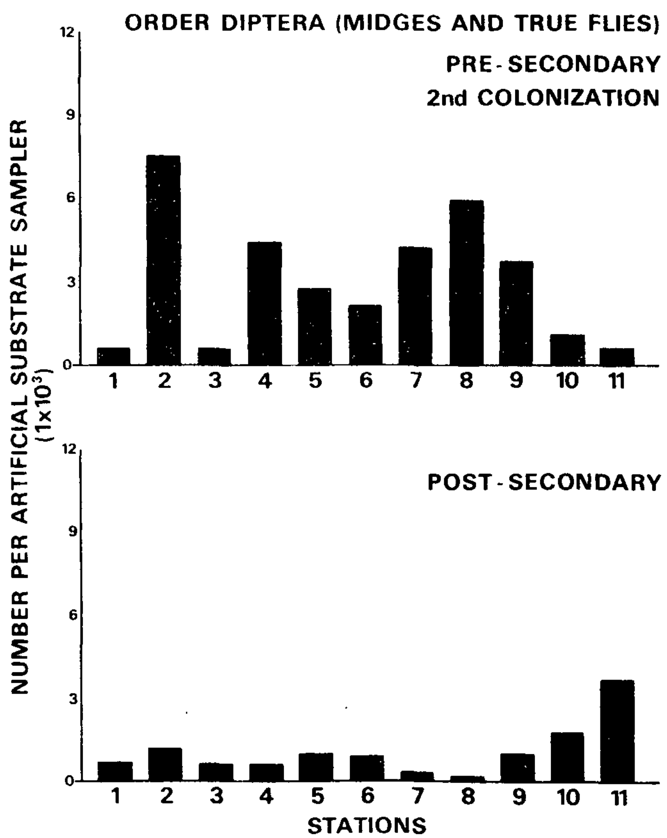


Figure 5. The Total Number of Chironomids (Order Diptera) Found per Artificial Sampler for the Three Colonization Periods During 1975 and 1979

As the current velocity decreased, the Symphitopsyche sp. densities decreased (Fig. 8). In addition, the Cheumatopsyche sp. densities increased in areas where the current velocity was low (< 15 cm/sec). Edington[7] has shown that current velocity has a direct effect on filter-feeding caddisflies. He showed that as current velocities increased so did the densities of certain filter-feeding caddisflies. In the Fox River, the cut-off for optimal current conditions for Symphitopsyche appears to be around 18-20 cm/sec. Edington[7] found the low velocity range of another "current-loving" caddisfly, Hydropsyche instabilis, to be around 15 cm/sec.

Based on the above relationship, it appears that the dominant caddisflies in the Fox River are distributed by current velocity and are not restricted by point source discharges. This is in contrast to pre-secondary conditions when river quality almost exclusively controlled their distribution. In addition, the water quality of the lower Fox River appears to be more affected by the hypereutrophic Lake at its headwaters than by point source discharges.

SUMMARY

1. Benthic invertebrates were collected from May through October from eleven sites on the lower Fox River located in East Central Wisconsin, using an artificial substrate sampler.

2. The monitoring program was initiated in 1970 and is an ongoing annual program. A comparison is

presented showing the water quality conditions prior to secondary treatment of wastes and after the advent of secondary treatment. Similar river discharge years 1975 vs. 1979 were compared.

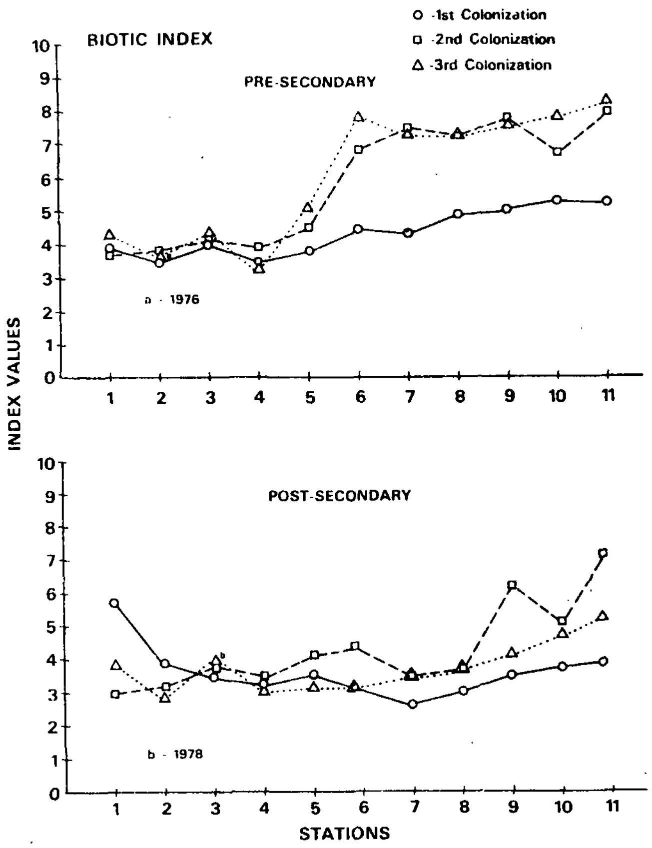


Figure 6. Biotic Index Values for the Benthic Invertebrate Communities Collected During 1975 and 1979

3. Dense populations of aquatic worms dominated the middle and lower stretches of the lower Fox River during the presecondary period showing severe water quality degradation from point source discharges. In addition, the more sensitive caddisfly population was not found in the degraded sections.

4. During the postsecondary period the aquatic worms were not dominant at any of the stations in the lower Fox River, and the caddisfly population became established and dominated the benthic invertebrate densities.

5. The loss of the dense worm population and the increase of the more sensitive caddisfly population denoted a water quality improvement.

6. The heavy accumulation of the bacterial slime, Sphaerotilus natans, during the presecondary period disappeared with the advent of secondary treatment. Thus the loss of the dense worms during the postsecondary appears to be related to the loss of their food source.

7. The relationship between current velocity and Symphitopsyche sp. numbers was strongly correlated. As the current velocity decreased the Symphitopsyche numbers decreased (r = > 0.91).

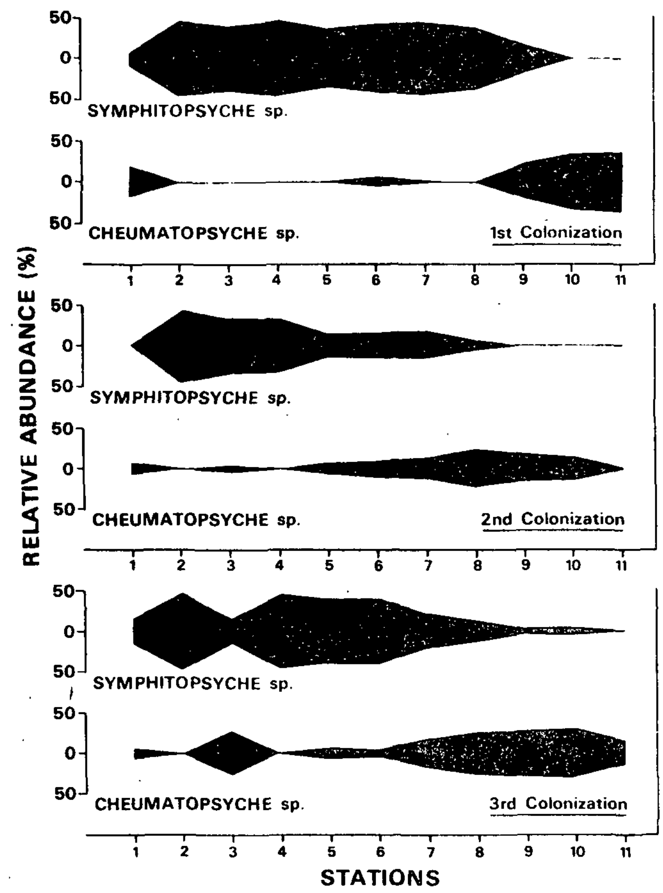


Figure 7. The Relative Abundance of the Two Dominant Benthic Invertebrates Collected During 1979

8. Based on the current velocity and Symphitopsyche sp. relationship, it appears that the water quality of the Fox River is less affected by point source discharges, and more affected by the hypereutrophic lake at its headwaters and the physical changes within the river's morphometry.

ACKNOWLEDGMENTS

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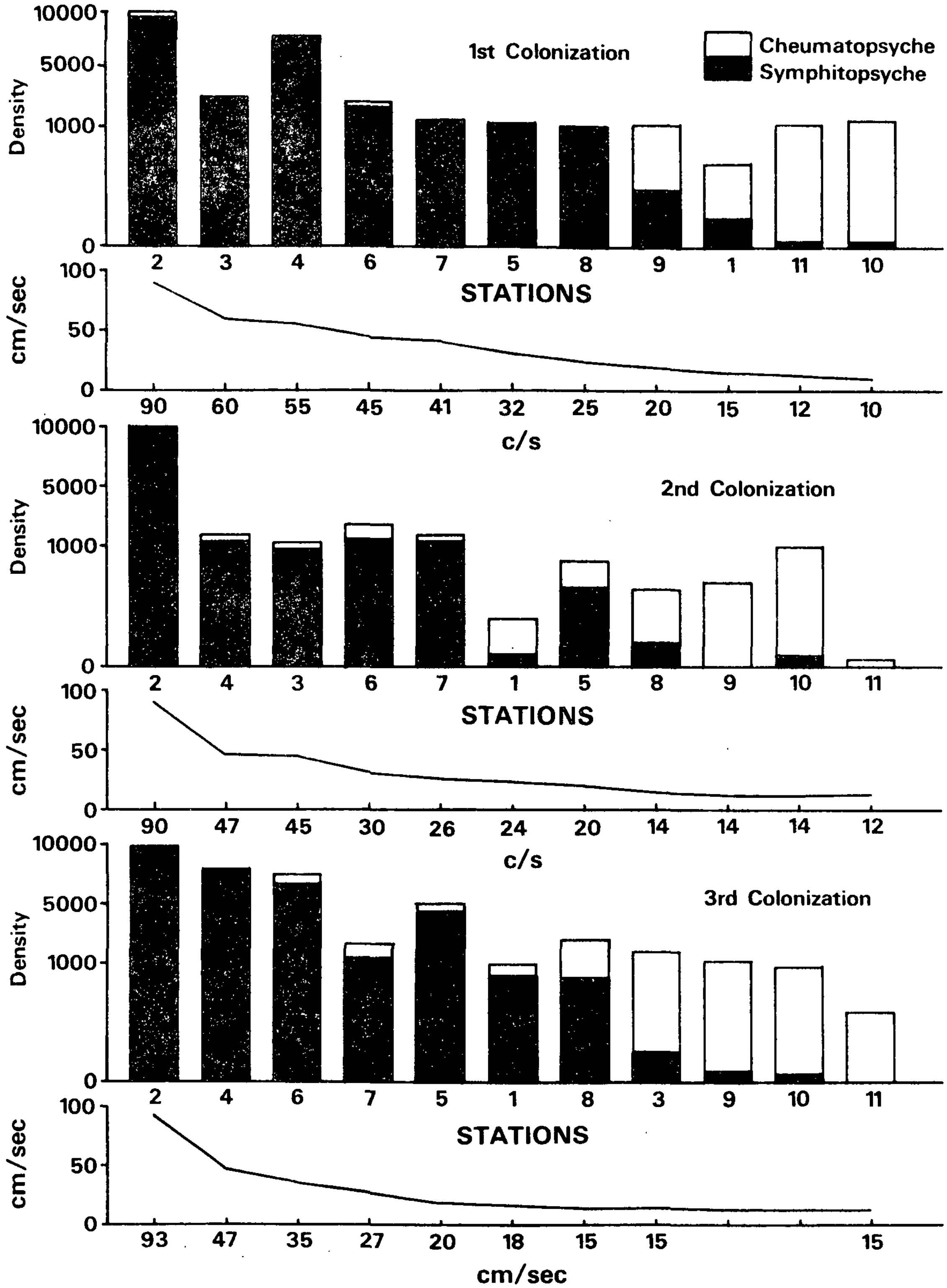

Figure 8. A Comparison Between Total Numbers of the Two Dominant Organisms and Station Current Velocities During 1979

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