EFFECTS OF A MUNICIPAL DISCHARGE ON A MICHIGAN STREAM

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ABSTRACT

EFFECTS OF A MUNICIPAL DISCHARGE
ON A MICHIGAN STREAM

By

Richard L. Mikula

A survey was conducted on a southern Michigan stream during the summer and fall of 1973 to determine the changes in water quality caused by sewage effluent. Changes in water quality were detected by measuring changes in heavy metal concentrations in bottom sediments, primary productivity, phytoplankton communities, fish communities, and macroinvertebrate communities.

Macroinvertebrate and fish communities were drastically altered for over 2.5 miles below the wastewater treatment plant (WWTP). Fish were virtually eliminated and the macroinvertebrate community consisted of large numbers of individuals that were pollution tolerant. Along this portion of stream, turbid and septic smelling water covered a black anaerobic substrate of sludge.

Phytoplankton communities were relatively uniform throughout the stream and were dominated by diatoms tolerant to organic enrichment. Diatoms which are less favored by

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sewage than green and blue-green algae comprised slightly higher concentrations of the algal community above the wastewater treatment plant than below.

Mean primary production, based on chlorophyll a production, experienced a 4-fold increase below the WWTP for at least four miles. Primary production remained approximately 2.5 times larger than the control station for the remaining portion of the stream.

Concentrations of all heavy metals (arsenic, cadmium, chromium, copper, mercury, nickel, zinc) in the organic sediment increased below the WWTP and remained higher than the levels above the WWTP for the remaining portion of the creek.

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INTRODUCTION

A biological and sediment chemistry survey was conducted on Sycamore Creek and three of its tributaries (Willow Creek, Mud Creek, and Vevay Drain) in Ingham County, Michigan, between July 2 and November 8, 1973. This survey was conducted to assess the water quality and habitat of the stream from above Mason to Lansing, Michigan, a distance of approximately twelve miles. There are three known discharges within the study area: Wyeth Laboratory Company in north Mason which discharges cooling water into a storm drain, Mason Wastewater Treatment Plant (WWTP), and Dart Container Company which discharges into Vevay Drain.

BACKGROUND

Sycamore Creek originates approximately 4.5 miles south of Mason and empties into the Red Cedar River in Lansing, Michigan. Total length of Sycamore Creek is approximately 16.5 miles with a drainage basin of 111 square miles. The 7-day, 10-year low flow at the mouth of Sycamore Creek is 3.5 cfs (Knutilla, 1968). Flows are normally much larger than this, exceeding 6.4 cfs 95 percent of the time and 14 cfs 70 percent of the time.

The Michigan Water Resources Commission (MWRC) has conducted two previous surveys in this same area (Basch et al., 1971; Riley, 1972). In March and April, 1971, an *in situ* bioassay was conducted by Basch et al. (1971) to determine the effects on fish of the chlorination operation of the Mason WWTP. Results of this survey showed that chlorinated compounds discharged by the Mason WWTP were toxic to rainbow trout (*Salmo gairdneri*) for at least 0.8 miles downstream and to fathead minnows (*Pimephales promelas*) for at least 250 yards downstream from the WWTP.

Riley (1972) conducted a continuous-flow bioassay to determine the toxic effects of the Dart Container

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Company's effluent to fathead minnows. Bioassay results showed fathead minnows subjected to Dart's effluent could not survive in concentrations greater than 50 percent effluent. The effluent contained oil, high concentrations of total solids (highest level was 3720 mg/l) and pH values ranging from 8.8 to 12.0.

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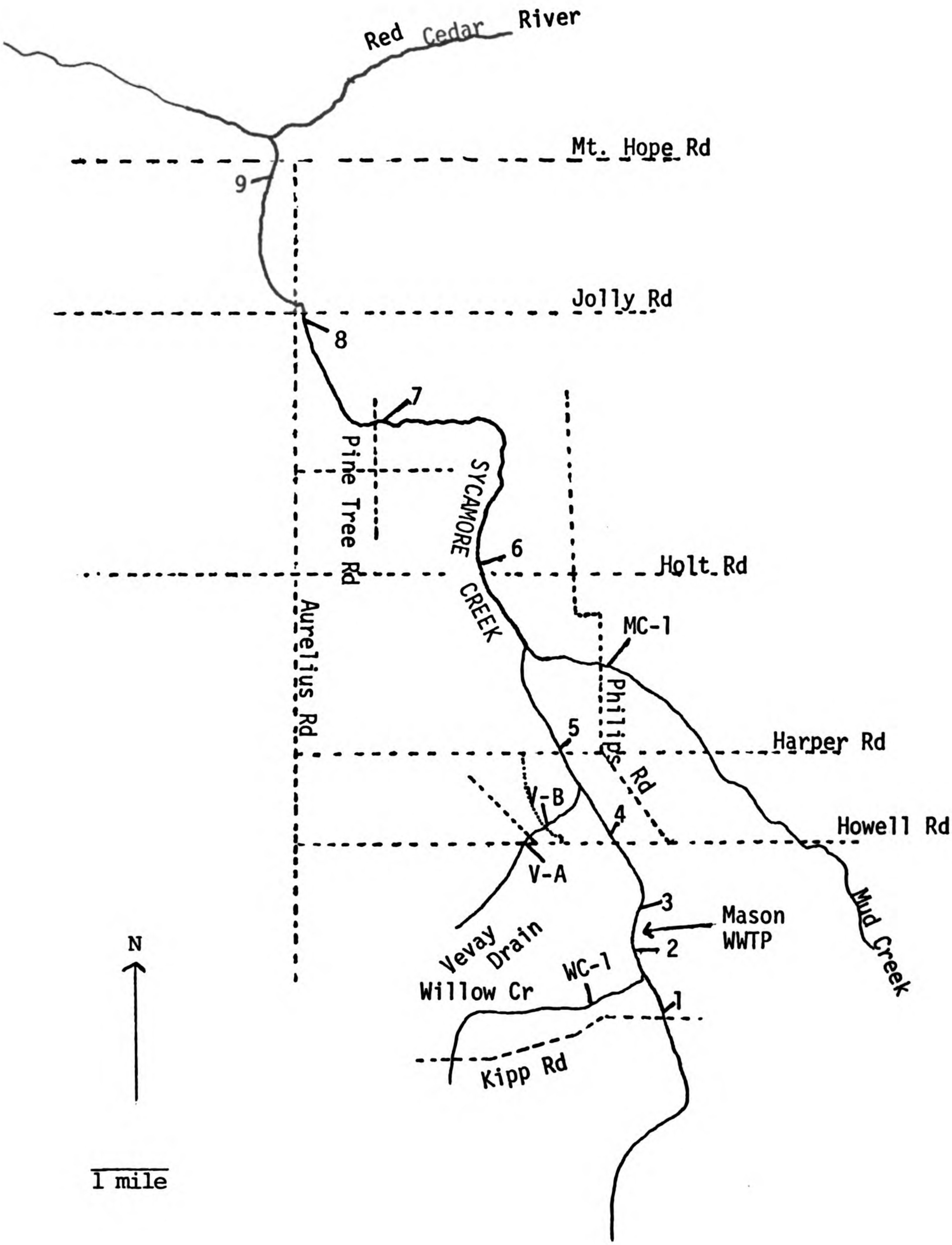
METHODS

To assess habitat and water quality in Sycamore Creek, nine sampling sites were selected (Figure 1). In addition, one site was selected on both Willow and Mud Creeks, and two sites on Vevay Drain to determine the effects of these tributaries on Sycamore Creek. On Vevay Drain sites were selected both above and below the Dart Container Company discharge to determine any water quality degradation in the drain and ultimately in Sycamore Creek. Phytoplankton, periphyton, sediment, fish populations, and macroinvertebrate communities were used to assess the water quality in this survey.

Phytoplankton

Plankton algae in standing water are a reflection of the toxic or nutrient status of the water which they inhabit. This is not true of river algae however, because algae present in river water samples may have come from a considerable distance upstream. Plankton in a stream develops only where the current is reduced, such as along stream margins or in pool areas (Patrick, 1948). Benthic and periphytic algae are often dislodged from their natural

Figure 1. Selected station locations in Sycamore, Mud, and Willow Creeks and Vevay Drain in the vicinity of Mason and Lansing, Ingham County, Michigan. July 2-November 8, 1973.


Red Cedar River
Mt. Hope Rd
9
Jolly Rd
8
7
Pine Tree Rd
SYCAMORE
6
Holt Rd
CREEK
Aurelius Rd
MC-1
Philips Rd
5
Harper Rd
V-B
4
Howell Rd
V-A
3
Mason WWTP
2
Mud Creek
Vevay Drain
WC-1
Willow Cr
1
Kipp Rd
N
1 mile

habitats by river current scouring and appear as "plankton." Therefore, planktonic algae collected at various stations reflect upstream water quality. However, a change in water quality will be reflected by a change in planktonic algae between stations.

One-liter surface water grab samples were taken for plankton analysis at all stations (Figure 1) on July 2 (except stations MC-1 and WC-1); September 6, and November 8, 1973. Samples were preserved with 75 ml of 6:3:1 water-ethyl alcohol-formalin preservative and returned to the MWRC biological laboratory in Lansing, Michigan, for qualitative and quantitative algal analyses. Samples were allowed to settle for 48 hours and then they were drawn down so only the bottom 100 ml remained. This 100 ml concentrate was thoroughly mixed and subsampled. Samples were analyzed utilizing Sedgewick Rafter strip counts. Permanent slides were made for diatom determinations.

After the algae samples were identified and tabulated, a pollution index value (Palmer, 1969) was determined for each station utilizing algae that occurred with a frequency of 50 or more cells per ml.

$$\text{P.I.} = X_1 + X_2 + X_3 + \ldots\ldots\ldots + X_{20}$$

where P.I. = the pollution index value and X_1 through X_{20} equals the numerical values assigned to the twenty most pollution tolerant genera (Palmer, 1969). An index value of 20 or more is evidence of high organic pollution, while a value of 15 to 19 is considered to be probable evidence of high organic pollution (Palmer, 1969). Lower figures indicate organic pollution is not high.

Periphyton

Periphyton is the total assemblage of plants growing on the surfaces of objects submerged in water (Young, 1945). Since periphyton, along with rooted aquatic plants, are considered the most important primary producers in a stream system, changes in periphyton production reflect changes in water quality.

Primary production can be calculated by determining the amount of chlorophyll *a* present in the periphyton growing on the substrate (Hynes, 1970). Chlorophyll *a* is the photosynthetic pigment in fresh water plants and is directly related to the amount of green plant material present. By comparing the amount of chlorophyll *a* produced in a given time period per unit area, the production rates in a stream can be determined.

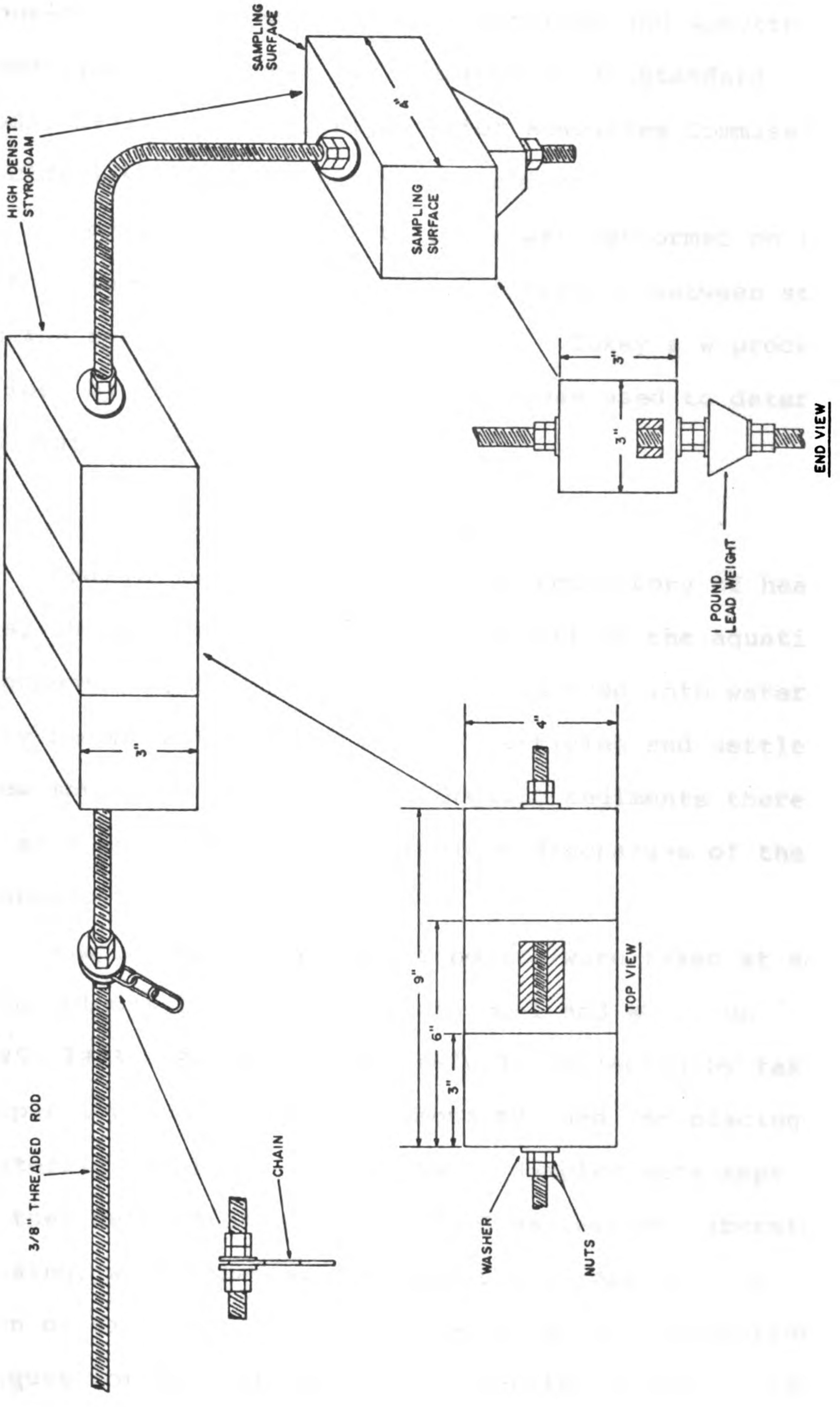
Major factors influencing the amount of production are nutrients, light, turbidity, velocity, temperature, and toxicants. By selecting areas along the stream with similar physical conditions, major changes in productivity can be attributed to changes in nutrient levels within the water and/or presence or absence of toxic substances.

Artificial substrate samplers (Figure 2) used to measure primary production in this survey were constructed by bending a 22-inch length of 3/8-inch threaded rod at a right angle, making one arm about 15 inches long and the other about 7 inches long. Four blocks (3 x 3 x 4 inches) of high density styrofoam were connected to the rod, three on the long arm and one on the short arm. A one-pound lead weight was attached to the rod below the single block of styrofoam. The three blocks on the long side caused the sampler to float while the lead weight pulled the single block down below the water surface, thus providing substrate for periphyton.

After selecting appropriate locations, steel posts were driven into the stream bed for sampler attachment. Six-foot lengths of 1/4-inch chain were used for attachment allowing the samplers to move up and down with water level fluctuation.

Periphyton growing on the submerged block was collected three times at 14-day intervals as recommended by King and Ball (1966). Collections were made August 8, August 22, and September 5, 1973. Thin slices of the 3 x 3 inch ends of the submerged block were cut with a knife and placed into a 250-ml black bottle with 50 ml of 90 percent acetone. The black bottle was required to prevent the breakdown and decay of the chlorophyll *a* while enroute to the laboratory for analysis. Acetone dissolved the styrofoam and served as a chlorophyll extract. The

Figure 2. Artificial substrate utilized to sample periphytic algae at selected locations in Sycamore Creek in the vicinity of Mason and Lansing, Michigan, July 25-September 5, 1973.


SAMPLING SURFACE
HIGH DENSITY STYROFOAM
4"
SAMPLING SURFACE
3"
3"
END VIEW
1 POUND LEAD WEIGHT
3"
4"
9"
6"
3"
TOP VIEW
3/8" THREADED ROD
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acetone-chlorophyll extracts were sonified and spectrophotometrically analyzed for chlorophyll a (Standard Methods, 1971) by the Michigan Water Resources Commission pesticide laboratory in Lansing, Michigan.

Two-way analysis of variance was performed on the data to determine if significant differences between stations and sampling dates had occurred. Tukey's w-procedure, described by Steel and Torrie (1960), was used to determine which stations differed.

Sediments

Organic sediments are a major repository of heavy metals, chlorinated hydrocarbons, and oil in the aquatic environment. These materials, if discharged into water quickly become attached to organic particles and settle out in slow moving or still water. Organic sediments therefore serve as a useful monitor of previous discharges of these substances.

Samples of the organic deposits were taken at each station (Figure 1) except stations MC-1 and WC-1, on July 25, 1973. Samples were carefully collected by taking the upper layer of organic sediment by hand and placing it in a sterile Whirl-Pak plastic bag. Samples were kept cool until they were returned to the MWRC wastewater laboratory in Lansing, where they were frozen until analyzed. A portion of each sample was analyzed by atomic absorption techniques for the following heavy metals: arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc. The remainder of each sample was analyzed for chlorinated hydrocarbon pesticides, phthalates, polychlorinated biphenyls (PCB's) and oil by using standard gas chromatography procedures. Sediment pH was also determined.

Fish Populations

On September 7, 1973, resident fish populations were examined at six selected locations (SC-1, SC-2, SC-5, SC-6, SC-7, and SC-8) on Sycamore Creek (Figure 1). Fish collections were made with a backpack electrofishing unit utilizing a 12-volt battery. Stunned fish were collected with nets and placed in a bucket until shocking was completed. Each area of stream, approximately 2000 square feet, was shocked for 45 minutes. Species identifications and tabulations were made on site with the exception of a few species which were labeled, preserved with 150 ml of a formalin solution (37% formaldehyde, 63% water and methanol), and returned to the MWRC biology laboratory in Lansing, Michigan, for identification.

The collected fish were categorized into the following trophic levels defined by Willson (1972):

Class 1 — These fish are nondifferentiating bottom feeders. They live, grow, and multiply in clean water areas and will also thrive in waters of degraded quality. In low water quality areas the variety of macroinvertebrates is low but total numbers are very high. The straining of food organisms from sludge deposits is easy and large quantities of food are available at little expense in energy.

Group 1: Fish in this group are moderate to large in size. They suck or rasp off bottom animals such as midges and aquatic worms from rocks, sand and bottom ooze, expelling substrate materials and consuming the animals. Examples of fish in this group are carp, suckers, sheepshead, and bullheads.

<u>Class II</u> These fish species are differentiating predators and are generally associated with clean water environments. They live, grow, and multiply best when a diverse macroinvertebrate food supply is available.

Group 2: Fish in this group are small in size and as a result are restricted to feeding on smaller macroinvertebrates. They are generally classed as forage species. Examples of fish in this group are minnows, darters, shad, shiners, and chubs.

Group 3: Fish in this group are moderate to large in size and are capable of utilizing the entire macroinvertebrate community in addition to fish in group 2 and fry of groups 3 and 4. Examples of fish in this group are crappies, bluegills, sunfish, perch, and catfish.

Group 4: Fish in this group are large in size and utilize fish from groups 1, 2, 3, and 4 as their principal food source. They may also utilize larger macroinvertebrates from the benthic community, but fish comprise the major portion of food intake. Examples of fish in this group are pike, bass, bowfin, and burbot.

By categorizing fish into the above discrete trophic levels it is possible to utilize fish community structures in evaluating existing water quality conditions (Willson, 1972). A weighed trophic index (T.I.) is used in this evaluation. T.I. = x(1) + x(2) + x(3) + x(4), where x = the number of fish species in a trophic group, and 1, 2, 3, and 4 = the trophic group numbers. Thus, species most dependent upon higher water quality conditions and a stable balanced community are given greater weight than those capable of withstanding degraded water quality and the resulting community imbalance. Higher trophic index values will therefore reflect more stable community structures and higher water quality conditions with lower trophic index values reflecting reduced water quality conditions.

Macroinvertebrates

Aquatic macroinvertebrates and their community structures are useful in evaluating water quality. Since these animals spend their entire life or parts of their life cycle (eggs, larvae, and/or pupae) in the water, they can reflect long term water quality conditions to which they have been exposed.

Generally, a natural unpolluted stream will support many different species but only a few individuals per species due to competition for food and living space (Gaufin and Tarzwell, 1956). In polluted streams many taxa are eliminated, but those that remain usually occur in high numbers due to lack of competition.

Qualitative macroinvertebrate samples were taken at all stations (Figure 1) on September 4-5, 1973. Samples were collected with triangular dip nets and by hand picking from all habitats found at the station site. Time of collecting was approximately 30 minutes or until no new species were found with additional sampling. Samples were placed in quart jars, labeled, preserved with 100 ml of a formalin solution (37% formaldehyde, 63% water and methanol), and returned to the MWRC biology laboratory in Lansing, Michigan.

Quantitative samples were taken with modified Hester-Dendy artificial substrate samplers at all stations (Figure 1) except stations V-A and V-B. On July 25, 1973, two samplers were suspended with wire in the water column, approximately 6-8 inches from the bottom. These samplers consisted of a five-inch eyebolt and 8 circular plates of 1/8 inch tempered hardboard with a diameter of 2 3/4 inches (Figure 3). Small hardboard spacers (3/4" x 3/4" x 1/8") were positioned so that 1/8, 1/4, and 3/8 inch spaces existed between the plates. Plates and spacers were held in place by a washer and hex nut. Each sampler had 0.061 square meters of surface area available for colonization by macroinvertebrates.

On September 5, 1973, following six weeks of exposure, the substrates were carefully removed from the water by placing a #10 sized can with a U.S. Standard #30 mesh screened bottom below the sampler and slowly bringing it up around the sampler. The wire suspending the sampler was cut and the sampler and material in the bottom of the can were placed in a quart jar, labeled, and preserved by

Figure 3. Circular Hester-Dendy artificial substrate sampler colonized by macroinvertebrates in Sycamore, Mud, and Willow Creeks, vicinity of Mason and Lansing, Ingham County, Michigan, July 25-September 5, 1973.

covering the sampler with 95 percent methyl alcohol. Samplers were returned to the MWRC biology laboratory in Lansing, disassembled, and the individual sampling components scraped with a putty knife into a container with a U.S. Standard #30 mesh screen bottom. After sieving and washing, the remaining material was placed in labeled vials containing 75 percent ethyl alcohol.

Macroinvertebrates from both the qualitative and quantitative samples were identified and tabulated. Each identified taxon was assigned a tolerance status suggested by the United States Environmental Protection Agency (Anon., 1973).

Tolerance status refers to the animal's relative ability to withstand and/or respond to adverse environmental conditions. Individual tolerances are generally derived from an animal's reaction to organic wastes and attendant oxygen depletion or modification of bottom deposits.

Tolerance status is generally defined by the Michigan Water Resources Commission as:

> Intolerant--organisms whose growth and development are dependent upon a narrow range of environmental conditions. They are rarely found in areas of organic enrichment. They cannot adapt to adverse situations and are replaced by less sensitive organisms if the quality of their environment is degraded.

> Facultative--organisms with the ability to survive over a wide range of environmental conditions. They possess "medium" tolerance and often respond positively to moderate organic enrichment but cannot tolerate severe environmental stresses.

<u>Tolerant</u>--organisms that can grow and develop within a wide range of environmental conditions. They are often found in water of poor quality. These species are generally insensitive to a variety of environmental stresses.

Benthic communities can be compared at the various stations by calculating a biotic index (Beck, 1955) which weights the number of species according to their tolerance. The biotic index (BI) is calculated by doubling the number of intolerant species and adding this to the number of facultative species (BI = 2I + F). Values for the biotic index normally range between zero and 40, with polluted streams usually having values less than 10 (Beck, 1955). Biotic indices were calculated for both the qualitative and quantitative samples.

In addition to the tolerance status, the diversity of the animals present in a given benthic community is significant. Species diversity was determined for the quantitative samples using Shannon's formula as described by Patten (1962):

$$\bar{d} = -\sum_{i=1}^{s} n_i/N \log_2 n_i/N$$

where "N" is the total number of organisms, "n_i" is the number of individuals per species, and "s" is the number of species. The value of $\bar{d}$ ranges from zero to any positive number. Wilhm (1970) states that $\bar{d}$ rarely exceeds nine and is generally between three and four in clean water and less than one in polluted stream areas.

When degradation is at slight to moderate levels, $\bar{d}$ lacks the sensitivity to demonstrate differences. Differences can often be detected by calculating equitability at each station. The equitability formula (Lloyd and Ghelardi, 1964) used was:

$$e = \frac{s'}{s}$$

where s = number of taxa in the sample, and s' = the number of species expected from a community that conforms to the MacArthur's model in Lloyd and Ghelardi (1964). Streams unaffected by oxygen demanding wastes generally have "e" values ranging from 0.6 to 0.8 while streams with even slight levels of degradation have "e" values generally below 0.5 (Anon., 1973).

RESULTS

Habitat

Station habitat descriptions, locations, and observations are shown in Table 1. From these data the immediate deleterious effects of the Mason WWTP are apparent. Sand and gravel, the usual substrate occurring in Sycamore Creek, was covered with black anaerobic sludge for a distance of greater than 2.5 miles below the WWTP. Clear water above the WWTP became turbid and had a septic smell for a distance greater than 2.5 miles below the WWTP.

Phytoplankton

Data from the three sampling runs are presented in Appendix A, Tables 1, 2, and 3. July algal abundances ranged from 680 (SC-5) to 1419/ml (SC-6). Organisms per ml decreased from 1206 above the Mason WWTP to 904 immediately below the WWTP at station SC-3. Decreases in algal counts continued downstream to station SC-6, where the highest counts occurred (1419/ml). Diatoms comprised over 93 percent of the algal communities at each station except station SC-9 where diatoms made up 87 percent of the community. Green (Chlorophyta) and blue-green (Cyanophyta)

TABLE 1.--Station location and habitat descriptions for sampling sites on Sycamore, Willow, and Mud Creeks and Vevay Drain in the vicinity of Mason and Lansing, Michigan, July 25 to November 8, 1973.

Station Number	Station Location	Flow ft/sec	Average Width (ft)	Average Depth (ft)	Substrate	Vegetation	Other Observations
SC-1	Kipp Road South of Mason	1.0	8.0	1.0	Gravel and sand	Sparse emergent grasses; shrubs and trees abundant on stream banks	Water was clear; numerous minnows (Cyprinidae) were observed
WC-1	Upstream from U.S. 27	0.6-1.0	7.0	1.0	Sand with small amounts of gravel	No aquatic macrophytes; tall grass and shrubs on stream banks	Water was clear
SC-2	E. cemetery entrance above Mason WWTP	1.0-2.0	10.0	1.5	Sand, gravel, and rock	No aquatic macrophytes; grass, shrubs, and trees on stream banks	Water was clear; minnows and suckers (Castostomidae) were observed
SC-3	100 feet below Mason WWTP	0.4-1.0	12.0	2.5	Sparse sand and gravel; huge deposits of sludge	Sparse emergent grasses; grass, shrubs, and trees on stream banks	Water was grayish-white in color; water and sludge had septic odor; minnows were observed
SC-4	Howell Road (0.7 miles below Mason WWTP)	0.5	18.0	3.0	Sand covered with huge deposits of sludge	Emergent grasses and _Typha_; grass and shrubs on stream banks	Water was grayish-white in color; water and sludge had septic odor
V-A	Hogsback Road above Dart Container Company	1.0	4.0	1.0	Sand, gravel, and sediment	No aquatic macrophytes; grass and shrubs on stream banks	Water was clear; oil released when sediment was disturbed; periphytic growth abundant
V-B	Dart Road below Dart Company	1.0	4.0	1.5	Sand, gravel, and sediment	No aquatic macrophytes; grass and shrubs on stream banks	Water was clear; oil on water and in sediment periphyton abundant

TABLE 1.--Continued.

Station Number	Station Location	Flow ft/sec	Average Width (ft)	Average Depth (ft)	Substrate	Vegetation	Other Observations
SC-5	Harper Road (2.5 miles below Mason WWTP	0.5	20.0	4.0	Sand and gravel covered with sludge	Emergent grasses; grass on stream banks	Water grayish-white in color; traces of oil in the sediment
MC-1	Phillips Road	0.6-1.0	10.0	1.5	Sand and logs	Watercress (*Nasturtium officinale*) present in areas of the stream	Water was clear; minnows were observed
SC-6	Holt Road (4.0 miles below Mason WWTP)	0.6-1.0	25.0	4.0	Sand, gravel, silt, and a few rocks	No aquatic macrophytes; shrubs and grass grew on stream banks	Water was clear; water and silt had a slight septic odor to them
SC-7	Pine Tree Road (7.5 miles below Mason WWTP)	1.0-2.0	25.0	3.0	Sand, gravel, and rocks; small deposits of sediment along edges	No aquatic macrophytes; shrubs and trees grew on banks	Water was slightly turbid
SC-8	Jolly Road (9.5 miles below Mason WWTP)	1.5	30.0	2.5	Sand, gravel, and rocks; sediment along the edges	Emergent grasses; grass grew on the stream banks	Water was clear; minnows were observed
SC-9	Mt. Hope Rd. (11.0 miles below Mason WWTP)	0.8	20.0	4.0	Sand, rock, and sediment	Emergent grasses; grass and shrubs on stream bank	Water was slightly turbid; oil in the sediment, periphytic growth abundant

algae combined, comprised less than 5.0 percent of the algal communities at all stations except station SC-9, where these groups comprised 10 percent of the community. Flagellates comprised less than 3.0 percent of the algal communities. Palmer's pollution index ranged from 6 to 9 (Appendix A, Table 1).

September algal abundances ranged from 961 (SC-1) to 2792/ml (SC-6) in the main stream. Diatoms comprised over 90 percent of the algae except for stations SC-4 (70%) and MC-1 (84%). Green and blue-green algae combined, comprised less than 6.0 percent of all samples. Flagellates comprised less than 4.0 percent of the algal communities except at stations SC-4 (25%) and MC-1 (15%). Palmer's index values ranged from 6 (SC-5) to 11 (SC-4) in the mainstream. Vevay Drain had an index value of 3 below Dart Container Company.

November algal abundances ranged from 95 (SC-1) to 432/ml (SC-4). Diatoms comprised over 90 percent of the algal community at all stations, except stations SC-3 (33%), SC-4 (79%), and SC-8 (88%). Green and blue-green algae comprised less than 5.0 percent of the algal communities, except at stations SC-2 (9%) and SC-8 (8%). Flagellates comprised less than 6.0 percent of the algal communities except at stations SC-3 (62%) and SC-4 (16%). Palmer's pollution index ranged from 3 to 6.

Nitzchia and *Navicula*, ranked by Palmer (1969) as the sixth and seventh genera most tolerant to pollution, were dominant at all stations on all sampling dates. *Navicula* was generally more abundant than *Nitzchia* at most stations and sampling dates except in September when *Nitzchia* was more abundant than *Navicula* at stations SC-4 and SC-5.

Euglena, the most tolerant genus to organic pollution (Palmer, 1969) occurred in low numbers (0-36 per ml) at all stations and sampling dates except at station SC-4 where there were 260 per ml in September. In November, *Euglena* was virtually absent. It was observed at stations SC-4 and V-B in the qualitative scan, but was only found at station SC-8 in the quantitative count (1 per ml).

Periphyton

Periphyton data are presented in Appendix B, Table 1. The over-all mean standing crops of periphyton at stations 1, 5, 6, 7, and 8 were 1.70, 6.75, 6.72, 3.90, and 4.61 ug/cm^2 of chlorophyll *a*, respectively. Periphyton standing crop was approximately 4 times greater at stations SC-5 and SC-6 below the Mason WWTP than above Mason at station SC-1.

Two-way analysis of variance showed a significant (95%) difference of periphyton standing crop between the stations (Appendix B, Table 2). Data analysis using Tukey's w-procedure showed periphyton standing crops at stations SC-5 and SC-6, below the Mason WWTP, were significantly (90%) greater than the periphyton standing crop at station SC-1 above Mason (Appendix B, Table 3).

Sediments

Heavy metal concentrations found in organic sediments from Sycamore Creek and Vevay Drain are given in Appendix C, Table 1. Mean concentrations of all metals except cadmium were higher than Michigan background levels (Hesse and Evans, 1972). Cadmium was below the limits of detectability (0.2 mg/kg) at all stations except stations SC-3 and SC-9 which had respective wet weight values of 0.8 and 0.6 mg/kg.

Mean arsenic (3.3 mg/kg) and mercury (3.2 mg/kg) concentrations were 1.7 and 11.0 times greater than the respective mean background levels plus two standard derivations. Other metal concentrations exceeded background levels by factors ranging between the above extremes.

Chromium, copper, lead, mercury, nickel, and zinc concentrations increased between stations SC-1 and SC-2. Lead was the only metal which increased substantially between these stations (29.7 to 102.8 mg/kg). All metal concentrations increased between station SC-2 above the Mason WWTP and station SC-3 below the WWTP. The extremes were arsenic and nickel which increased 1.9 times (2.1 to 4.1 mg/kg and 19.3 to 36.0 mg/kg, respectively) and copper which increased 5.5 times (27.8 to 153.2 mg/kg). Concentrations of all metals, with the exception of copper, which remained about the same, decreased between stations SC-3 and SC-4, but were still higher than levels found at stations SC-1 and SC-2 above the Mason WWTP. Metal concentrations generally declined in a downstream direction to Pine Tree Road (SC-7). Below this station all metal concentrations increased. Substantial increases in lead (50.4 to 360.4 mg/kg) and zinc (137.6 to 303.3 mg/kg) occurred between stations SC-8 and SC-9.

With the exception of cadmium which was below the limit of detectability, metal concentrations in Vevay Drain below Dart Container Company were approximately double those found above Dart Container Company. These levels were substantially lower than the levels found in Sycamore Creek (SC-4) above the confluence of the two streams.

No unusually high concentrations of chlorinated hydrocarbon pesticides, polychlorinated biphenyls (PCB's) and phthalates (DEHP) were found in any of the organic sediment samples (Appendix C, Table 2). Sixty-two percent of the concentrations of the above substances were below the limits of detectability. The phthalate concentration (5.2 ppm) below the Mason WWTP at station SC-3 was high for streams but was average for values detected below Michigan WWTPs (Hesse, 1973).

The highest oil concentration (841 ppm) was found below Mason at station SC-2 above the Mason WWTP. Oil concentrations increased from 412 to 648 ppm below Dart Container Company in Vevay Drain.

Sediment pH in Sycamore Creek and Vevay Drain ranged from 6.8 to 7.4 (Appendix C, Table 2).

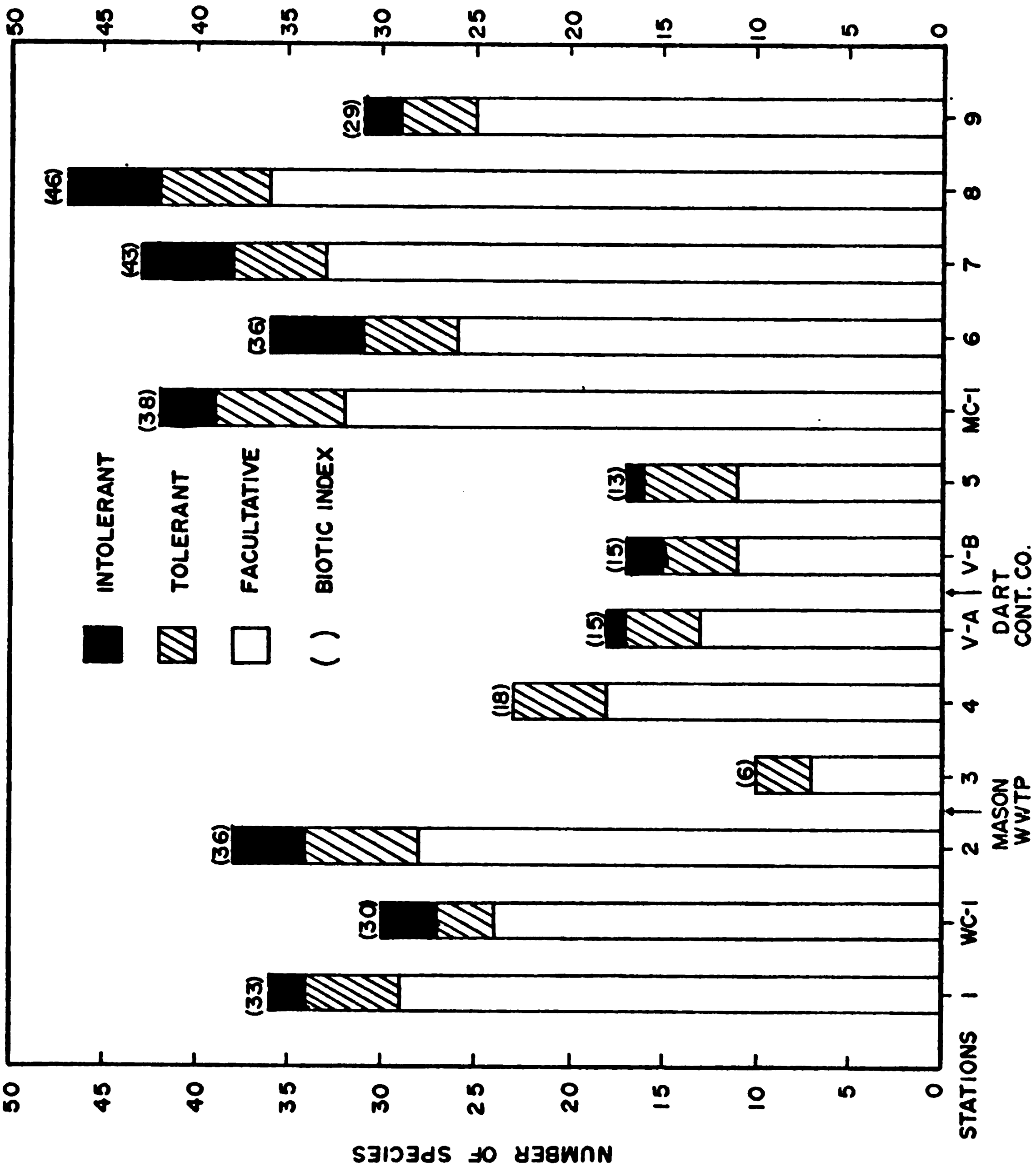
Fish Populations

Data from electofishing are presented in Appendix D, Table 1. Fish populations were adversely effected below the Mason WWTP discharge. The number of species decreased from 10 at station SC-2 immediately above the WWTP to 1 at station SC-5, 2.5 miles below the WWTP. Fish numbers corresponding to the above stations also decreased from 78 to 6, respectively. Fish populations partially recovered at station SC-6 where 6 species and 18 individuals were collected. Station SC-7 had the highest quality population of fish with 58 individuals and 13 species, including 2 species in group 4. Station SC-7 had the highest trophic index value (28) while station SC-5, 2.5 miles below the Mason WWTP had the lowest trophic index value (2).

Macroinvertebrates

Qualitative sample data are presented in Appendix D, Table 2. As illustrated in Figure 4, macroinvertebrates decreased in number of species from 38, with 4 intolerant forms, above the Mason WWTP (SC-2) to 9 species, with no intolerant forms, immediately below the WWTP (SC-3). Biotic indices for these stations decreased from 36 to 6, respectively. Species numbers increased at station SC-4 to 23, with 5 tolerants and no intolerants. Two tolerant taxa (Oligochaeta, *Chironomus* sp) made up over 85 percent of the

Figure 4. Total number of species, proportion of each tolerance group, and biotic index determined from qualitative samples collected in Sycamore Creek, Willow Creek, Mud Creek, and Vevay Drain in the vicinity of Mason and Lansing, Ingham County, Michigan, Sept. 4-5, 1973.


INTOLERANT
TOLERANT
FACULTATIVE
BIOTIC INDEX
NUMBER OF SPECIES
STATIONS
1
WC-1
2
MASON WWTP
3
4
V-A
DART CONT. CO.
V-B
5
MC-1
6
7
8
9
(33)
(30)
(36)
(6)
(18)
(15)
(15)
(13)
(38)
(36)
(43)
(46)
(29)
0
5
10
15
20
25
30
35
40
45
50

individuals collected at station SC-4. Seventeen species with one intolerant, were collected at station SC-5, 2.5 miles below the WWTP.

Number of species and biotic index increased substantially between stations SC-5 and SC-6 (Figure 4). Thirty-six species were collected at station SC-6, resulting in a biotic index of 36. Forty-two species were collected in Mud Creek (MC-1) which enters Sycamore Creek between stations SC-5 and SC-6. Stations SC-7 and SC-8 continued to show improvement with station SC-8 being the highest quality water and habitat found (47 species, BI=46). Species dropped substantially between stations SC-8 and SC-9. Thirty-one species were collected at station SC-9, giving a biotic index of 29.

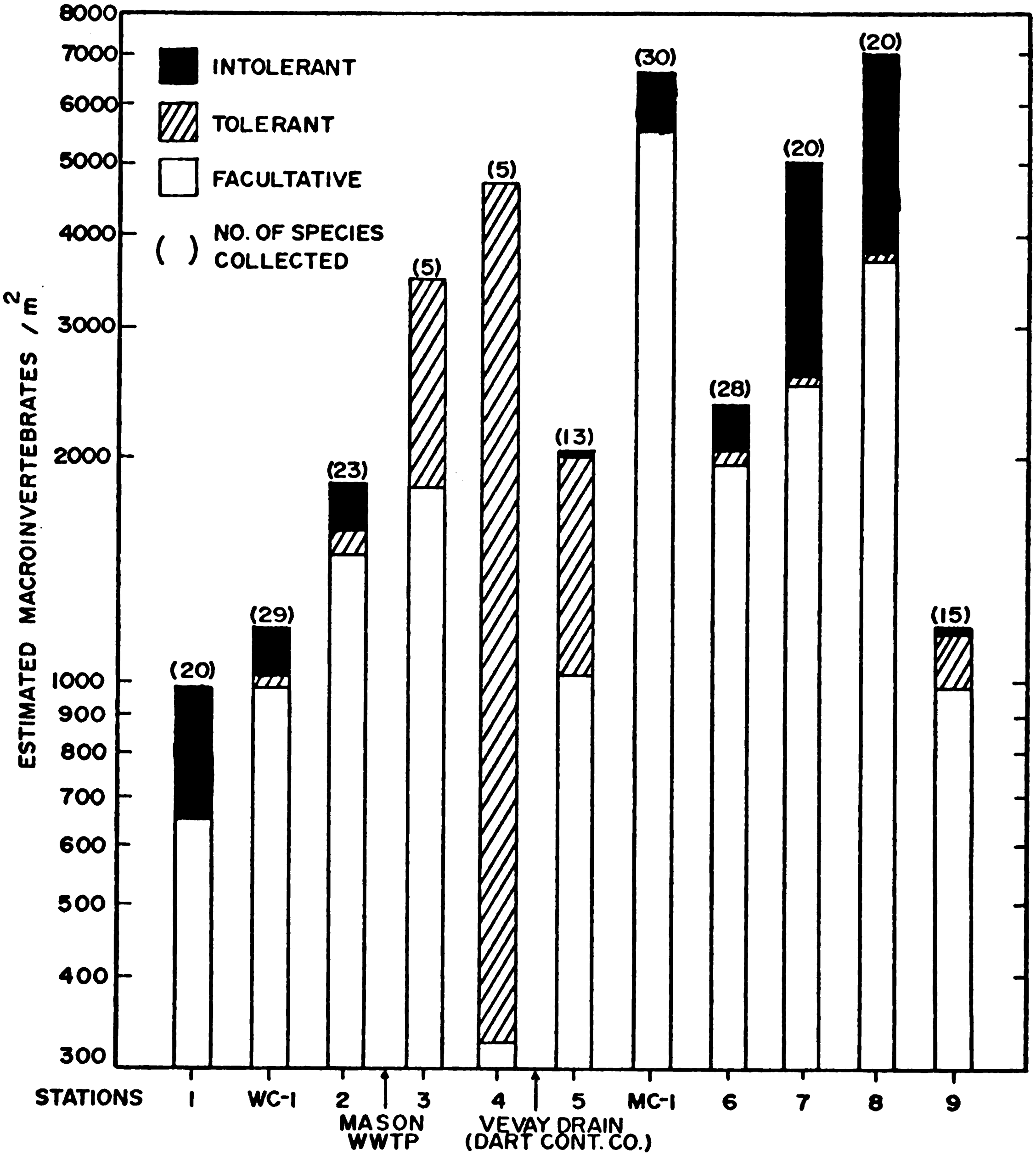
Quantitative data from Hester-Dendy artificial substrates are given in Appendix D, Table 3 and summarized in Appendix D, Table 4. Total number of macroinvertebrate species decreased from 23 at station SC-2 above the WWTP to 5 species at stations SC-3 and SC-4 below the WWTP. Species numbers increased to 13 at station SC-5 and to 28 at SC-6. The highest number of species were collected in the tributaries at stations WC-1 (29 species) and MC-1 (30 species).

Mean numbers of macroinvertebrate species were significantly (95%) lower at stations SC-3 and SC-4 immediately below the Mason WWTP (Appendix D, Table 7). Mean number of macroinvertebrate species was 16.5 at station SC-2 immediately above the WWTP and decreased to 4.5 and 4.0 at stations SC-3 and SC-4 respectively (Appendix D, Table 5). Midges (Chironomidae) comprised 100 percent of the individuals at station SC-3 (Appendix D, Table 4). One midge species (Chironomus sp) comprised over 95 percent of the individuals at station SC-4.

As illustrated in Figure 5, estimated number of macroinvertebrates per square meter increased substantially between stations SC-1 (983 individuals) and station SC-4 (4713 individuals). Estimated number of macroinvertebrates per square meter decreased substantially at station SC-5 (2058 individuals) but the number of species increased from 5 to 13 between stations SC-4 and SC-5, respectively. Number of macroinvertebrates increased in a downstream direction below station SC-5 and SC-8 where the highest numbers were collected. At station SC-8, estimated number per square meter was 7036. Of the total number of individuals at station SC-8, 40 percent were sensitive mayflies (Ephemeroptera) and 48 percent were caddisflies (Trichoptera). Estimated number of macroinvertebrates per square meter substantially decreased at station SC-9 to 1386 with all mayflies and nearly all caddisflies eliminated (Appendix D, Table 4). Midges comprised 96.5 percent of the organisms (Appendix D, Table 4).

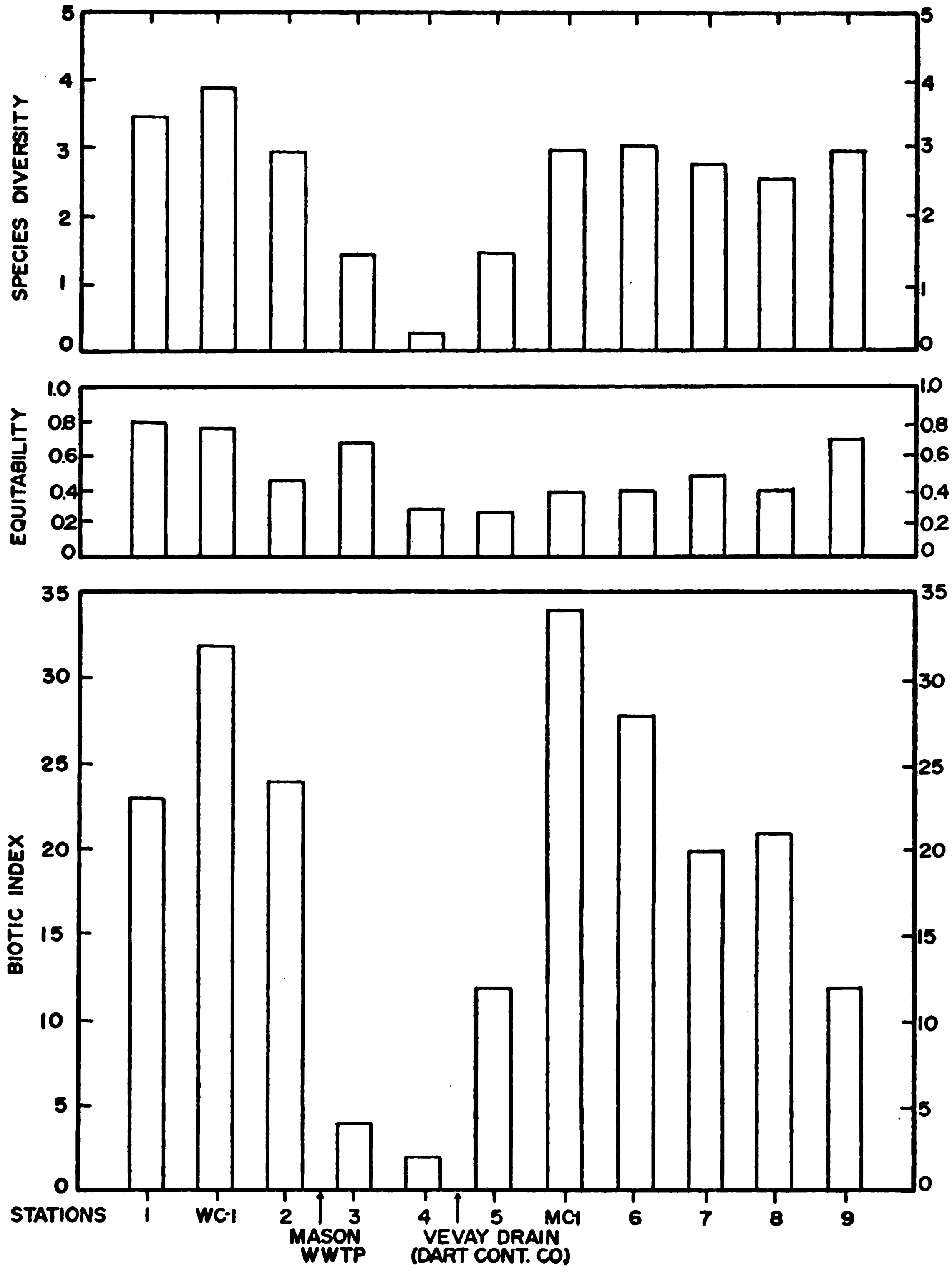
Species diversity values were lowest at stations SC-3, SC-4, and SC-5 below the Mason WWTP (Figure 6). These stations had respective species diversity values of

Figure 5. Estimated number of organisms/m^2, proportion of each tolerant group, and the number of species collected on circular Hester-Dendy artificial substrate samplers placed in Sycamore, Willow, and Mud Creeks in the vicinity of Mason and Lansing, Ingham County, Michigan, July 25-September 5, 1973.



8000
7000
6000
5000
4000
3000
2000
1000
900
800
700
600
500
400
300
ESTIMATED MACROINVERTEBRATES / m2
INTOLERANT
TOLERANT
FACULTATIVE
( ) NO. OF SPECIES COLLECTED
(20)
(29)
(23)
(5)
(5)
(13)
(30)
(28)
(20)
(20)
(15)
STATIONS
1
WC-1
2
3
4
5
MC-1
6
7
8
9
MASON WWTP
VEVAY DRAIN (DART CONT. CO.)

Figure 6. Species diversity, equitability, and biotic index values determined from colonization of organisms on circular Hester-Dendy artificial substrate samplers placed in Sycamore, Willow, and Mud Creeks in the vicinity of Mason and Lansing, Ingham County, Michigan, July 25-September 5, 1973.


SPECIES DIVERSITY
EQUITABILITY
BIOTIC INDEX
STATIONS
1
WC-1
2
3
4
5
MC1
6
7
8
9
MASON WWTP
VEVAY DRAIN (DART CONT. CO)

1.4, 0.3, and 1.5 (Appendix D, Table 6) and were significantly (95%) lower than all other stations (Appendix D, Table 8). Station SC-4 was significantly (95%) lower than stations SC-3 and SC-5. All other species diversity values ranged from 2.6 to 3.9.

High equitability values (>0.75) were found above Mason at stations SC-1 and WC-1. Equitability values decreased to 0.45 at station SC-2 immediately above the Mason WWTP. Stations SC-4 and SC-5 below the Mason WWTP had equitability values of 0.28, the lowest values found. Stations MC-1, SC-6, SC-7, and SC-8 had equitability values ranging from 0.38 to 0.47. Station SC-9 had an equitability value of 0.69, which is a substantial increase from station SC-8 (0.41).

Biotic index values (Figure 6) were highest in the tributaries. Willow Creek had a value of 32 and Mud Creek a value of 34. Station SC-2 immediately above the Mason WWTP had a biotic index value of 24 while stations SC-3 and SC-4 below the WWTP had values of 4 and 2, respectively. Station SC-6 below the confluence of Mud Creek had a biotic index value of 28, due to insect drift from Mud Creek and an increase in water quality as a result of higher quality dilution water entering via Mud Creek. Biotic index values decreased from 21 at station SC-8 to 12 at station SC-9.

DISCUSSION

Phytoplankton data did not decisively show changes in water quality in relation to the Mason WWTP. Although algal densities fluctuated, community structure was generally uniform throughout and dominated by diatoms tolerant of organic enrichment. Diatoms, which are less favored by sewage than green and blue-green algae (Wager and Schumacher, 1970) comprised slightly higher concentrations of the algal community above the Mason WWTP than below the WWTP in July and September. In November, substantial decreases in diatoms at stations SC-3 and SC-4 below the WWTP occurred.

Increased primary production below the Mason WWTP indicated increased nutrients in the stream. For at least 4 miles below the WWTP production was 4 times greater than above. Below this 4-mile stretch, production was at least 2 times greater than above the WWTP. When there is an excessive amount of primary production, fish and macroinvertebrates mortality may occur because of severe oxygen depletion and excess carbon dioxide (Hite, 1973). As can be seen in Figure 5, this did not occur in Sycamore

Creek. The number of macroinvertebrates per unit area generally increased in a downstream direction to station SC-8, where the highest numbers occurred.

All metal concentrations increased between station SC-2 above the Mason WWTP and station SC-3 directly below the WWTP. Metal concentrations generally declined in a downstream direction below SC-3 to SC-7, a distance of 7.5 miles. Concentrations at this point were still higher than those found above Mason at station SC-1. Below station SC-7, all metal concentrations increased from unknown sources.

With the exception of cadmium, mean metal concentrations in the organic sediments were higher than Michigan background levels (Hesse and Evans, 1972). Sediment metal concentrations above the Mason WWTP were higher than those found in nonindustrial streams in Illinois and metal concentrations below the WWTP were substantially higher than those found in the Illinois River (Mathis and Cummings, 1973).

Lethal metal concentrations are extremely difficult to determine because of limited work in this area and because lethal concentrations vary with pH, temperature, water hardness, and other chemical parameters (Doudoroff and Katz, 1953). Synergistic effects with other metals also vary the lethal levels of metals (Doudoroff, 1952).

Mathis and Cummings (1973) found that metal concentrations in the sediment were three to four orders of magnitude greater than concentrations in the water. Assuming this same relationship for Sycamore Creek, the nickel concentration at station SC-3 and SC-4 would be approximately equal to the concentrations found by Garton (1968) to be detrimental to aquatic macroinvertebrates. Also, assuming this same relationship, concentrations of arsenic, cadmium, copper, and zinc at stations SC-3 and SC-4 range from one to two orders of magnitude lower than concentrations permitted in drinking water (McKee and Wolf, 1963). Chromium and mercury concentrations at stations SC-3 and SC-4 were equal to those concentrations permitted in drinking water, while lead was approximately one order of magnitude higher than permitted (McKee and Wolf, 1973). When lead concentrations decreased to permissible drinking water standards (SC-6, SC-7, and SC-8) the macroinvertebrate communities improved (Appendix D, Tables 2 and 3). When the lead concentrations again exceed the permissible drinking limits at station SC-9, the macroinvertebrate community declines again. Lead may not be the major factor causing the macroinvertebrate responses, but it is worth considering.

Fish data indicated reduced water quality below the Mason WWTP. Fish were virtually eliminated for 2.5 miles below the WWTP. Six fish of one species (*Umbra limi*) were collected at station SC-5. Fish habitat was ideal in the vicinity of station SC-5, characterized by fallen logs, deep holes, and isolation from human populations, but high quality fish communities were absent.

Chlorine was probably the primary waste product of the Mason WWTP which eliminated the fish. Zillich (1972) indicates that free chlorine concentrations greater than 0.05 mg/l are lethal to many fish species. Basch and Truchan (1974) found that continuous exposure to chlorine concentrations greater than 0.02 mg/l could be detrimental to intolerant warmwater fish. Basch et al. (1971) found the average chlorine residual of the Mason WWTP's effluent to be 2.64 mg/l. They also found chlorine concentrations of 0.046 and 0.013 mg/l at stations SC-4 and SC-5 respectively. No chlorine concentrations were measured during this survey. However, there are four reasons why chlorine might have been the primary factor for the absence of fish: (1) The chlorine concentrations measured by Basch et al. (1971) were probably diluted by high stream flows while concentrations during this survey were probably less diluted because of low stream flows. (2) Fish in warmer water could be effected by lower chlorine concentrations than fish in cooler waters (Gordon, 1974) (Basch et al. conducted survey in the spring). (3) Prior to the time of fish sampling, mechanical failures occurred within the WWTP (Marquardt, 1974)[1] so possibly more chlorine was added to the effluent due to the increased volume of raw sewage. (4) Possibly

[1]James Marquardt, Operator of Mason WWTP, Personal Communication, Feb. 7, 1974.

the chlorine concentrations were not lethal to the fish, but stressed them so they avoided the four mile stretch of stream below the Mason WWTP.

Other possible factors effecting the fish population are: (1) Low oxygen concentrations. (2) Concentrations of heavy metals in the water and sediment. (3) Little food was available to fish that hunt by sight because the dominant macroinvertebrates were Oligochaetes and *Chironomus* which burrow into the sediment.

Macroinvertebrate data indicated reduced water quality below the Mason WWTP. The number of species and the number of intolerant individuals were greatly reduced or eliminated for a distance of at least 2.5 miles. Substantial improvements occurred in the macroinvertebrate community at station SC-6, a distance of 4 miles below the WWTP. At this point sludge was no longer present and Mud Creek's high quality water had diluted the poor quality water of Sycamore Creek.

Sludge was probably the dominant factor involved in altering the macroinvertebrate community. Ellis (1936) states that silt alters aquatic communities through screening out light, changing heat radiation, and retaining organic materials and other substances which create unfavorable conditions. Gaufin (1958) also found that the settling of fine solids form a blanket over the stream bottom, thus reducing the number of available habitats.

Factors discussed in eliminating the fish population could also have been involved in altering the macroinvertebrate community.

The immediate effects of the macroinvertebrate community caused by the Mason WWTP were similar to the effects of other wastewater treatment plants (Mackenthum, 1969; Olive and Dambach, 1973; Gaufin and Tarzwell, 1956). Mackenthum (1969) found that organic pollutants in the absence of toxic materials cause dramatic increases in the densities of oligochaetes and chironomids. Olive and Dambach (1973) found that these organisms (oligochaetes and chironomids) accounted for over 90 percent of the invertebrate community. These two groups made up over 90 percent of the invertebrates collected at stations SC-3 and SC-4 in both the qualitative and quantitative samples (Appendix D, Tables 2 and 3). Gaufin and Tarzwell (1956) found that there were usually one-third to one-sixth as many species below a sewage plant than above and that these organisms (Hemiptera, Diptera, Coleoptera) usually have special respiratory modifications that permit them to survive in poorly oxygenated waters. The organisms found below the Mason WWTP were chiefly in these insect orders (Appendix D, Tables 2 and 3). The dominant organism at stations SC-3, SC-4, SC-5 was *Chironomus* which possess hemoglobin that acts in both the transportation and storage of oxygen (Walshe, 1950).

This survey showed reduced water quality below the Mason WWTP which had substantial degrading effects on the stream biota and general stream aesthetics for at least 2.5 miles. Lesser effects occurred for an additional 1.5 miles.

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LITERATURE CITED

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APPENDICES

APPENDIX A

PHYTOPLANKTON DATA

Table A1. Phytoplankton densities in Sycamore Creek and Vevay Drain in the vicinity of Mason and Lansing, Ingham County, Michigan, July 2, 1973. Data expressed in organisms/ml.

Stations:	1	2	3	4	V-A	V-B	5	6	7	8	9
Algal Taxa / Station Location:	Kipp Rd Above Mason	E. Cemetery Entrance above Mason WWTP	100 ft Below Mason WWTP	Howell Road	Vevay Drain Above Dart Company	Vevay Drain Below Dart Company	Harper Road	Holt Road	Pine Tree Road	Jolly Road	Mt. Hope Road
Bacillariophyceae (Diatoms)											
Achnanthes sp.	42	62	83	83	151	169	39	55	94	104	86
Amphora sp.	8	36	29	47	8	18	26	39	29	10	8
Caloneis sp.	3	13	5		8			8	3		
Cocconeis sp.	13	36	13	47	16	8	26	62	39	23	16
Cyclotella sp.	29	26	44	44	44	42		23	23	70	55
Cymatopleura sp.	+	3						8	5		3
Cymbella sp.		8		18	8			16	10		8
Diatoma sp.	3				8			8			
Fragilaria sp.		8	13	10		26	26	70	99	10	
Gomphonema sp.	23	36	29	55	31	62	13	62	70	57	39
Gyrosigma sp.			29	10				23		3	5
Melosira sp.	3				8	21	18		34	23	13
Meridion sp.	26	8		29	23	18	8	78	34	10	8
Navicula sp.	562	549	400	255	556	504	234	546	356	525	343
Neidium sp.			3	3			3				
Nitzschia sp.	159	278	109	164	127	107	143	164	182	239	179
Rhoicosphenia sp.	10	44	13	18		96	23	23	29		
Stauroneis sp.		8	13								
Stephanodiscus sp.								23	21		13
Surirella sp.	11	8	13	18	8				10		16
Synedra sp.	8	36	70	18	83	107	26	70	10	10	8
Undetermined centrics								18			
Undetermined pennates		31	29	29	31	26	52	55	10	23	
Chlorophyta (Greens)											
Ankistrodesmus sp.		5			3		5	5	8	16	5
Closterium sp.		3									3
Coelastrum sp.										3	
Crucigenia sp.					3	3	3				
Micractinium sp.						3					
Oocystis sp.											3
Scenedesmus sp.		3		21		8	23	21	23	26	42
Undetermined coccoid						3					8
Undetermined filamentous		5						3			5
Cyanophyta (Blue-greens)											
Agmenellum sp.											10
Undetermined coccoid											13
Undetermined filamentous	3		3								5
Flagellates											
Dinobryon sp.					3				3		
Euglena sp.	5						3	10	8	10	3
Peridinium sp.			3								
Phacus sp.					3		3	5			
Trachelomonas sp.	5					8	3	16	13	18	3
Undetermined			3				3	8			21
Total Number of Organisms	913	1206	904	869	1122	1229	680	1419	1113	1180	921
Percent Diatoms	98.58	98.68	99.01	97.59	98.93	97.97	93.68	95.21	95.06	93.82	86.87
Percent Greens	0	1.33	0	2.42	0.54	1.39	4.56	2.05	2.79	3.82	7.17
Percent Blue-greens	0.33	0	0.34	0	0	0	0	0	0	0	3.04
Percent Flagellates	1.10	0	0.67	0	0.54	0.65	1.77	2.75	2.16	2.38	2.94
Species Diversity ($\bar{d}$)	2.06	2.70	2.93	3.32	2.59	2.93	3.16	3.45	3.41	2.71	3.20
Pollution index	6	6	8	7	8	9	6	9	7	8	7

Table A2. Phytoplankton densities in Sycamore Creek, Willow Creek, Mud Creek, and Vevay Drain in the vicinity of Mason and Lansing, Ingham County, Michigan September 5, 1973. Data expressed in organisms/ml.

Stations:	1	WC-1	2	4	V-A	V-B	5	MC-1	6	7	8	9
Algal Taxa / Station Location:	Kipp Rd. Above Mason	Upstream from US-127	E. Cemetery Entrance above Mason WWTP	Howell Road	Vevay Drain Above Dart Company	Vevay Drain Below Dart Company	Harper Road	Phillips Road	Holt Road	Pine Tree Road	Jolly Road	Mt. Hope Road
Bacillariophyceae (Diatoms)												
Achnanthes sp.	18	49	91	10	49	36		42	62	16	177	42
Amphora sp.	5	31	83	5	13				83	120	120	21
Asterionella sp.												
Caloneis sp.									3	+		
Cocconeis sp.	36	44	101		8			153	109	208	120	21
Cyclotella sp.		39	62	+	47	17	1	31	47	75	112	112
Cymatopleura sp.			3					3				
Cymbella sp.		13	18	5								
Fragilaria sp.		26	18		13							21
Gomphonema sp.	60	26	55	10	49	12	31	13	49	75	88	65
Gyrosigma sp.			3				16		13	44	29	10
Melosira sp.	13	5		13	5		6		18			26
Meridion sp.	18				21			57	62		29	
Navicula sp.	491	468	1011	218	471	191	190	660	879	637	592	671
Neidium sp.	3		5						3	16		
Nitzchia sp.	257	99	346	452	70	30	507	520	1271	889	1214	598
Rhoicosphenia sp.	5		18	18			16		62		29	21
Stephanodiscus sp.									8			8
Surirella sp.	5											10
Synedra sp.	5	5	10	5	57	12	31		49	16	29	21
Undetermined centrics									23			
Undetermined pennates	36	36	29	10			96	13			89	21
Chlorophyta (Greens)												
Ankistrodesmus sp.			3					3		3	8	3
Closterium sp.											3	
Oocystis sp.										5		
Pediastrum sp.								3		3		
Scenedesmus sp.			5	6		3	8	3	8	8	21	36
Undetermined coccoid							8	3		3	3	3
Undetermined filamentous							3					3
Cyanophyta (Blue-greens)												
Anacystis sp.										3		
Oscillatoria sp.				5								
Undetermined coccoid	3			3								
Undetermined filamentous		3		36	3		31		3		5	
Flagellates												
Euglena sp.	3			260			36	18	8	31	13	5
Pandorina sp.					5	1		196	21			
Phacus sp.		3						13		8	3	3
Trachelomonas sp.		3			5		3	8	8	5	5	
Undetermined	3			8	10	3		36	3	10		3
Total Number of Organisms	961	850	1861	1064	826	305	983	1775	2792	2175	2689	1724
Percent Diatoms	99.07	98.95	99.57	70.12	97.22	97.71	90.95	84.06	98.18	96.37	97.74	96.76
Percent Greens	0	0	0.43	0.57	0	0.99	1.94	0.68	0.29	1.02	1.31	2.61
Percent Blue-Greens	0.32	0.36	0	4.14	0.37	0	3.16	0	0.11	0.14	0.19	0
Percent Flagellates	0.63	0.71	0	25.19	2.43	1.32	3.97	15.27	1.44	2.49	0.78	0.64
Species Diversity ($\bar{d}$)	2.17	2.44	2.30	2.29	2.38	1.87	2.34	2.54	2.38	2.48	2.64	2.52
Pollution index	7	6	8	11	10	3	6	7	9	8	8	8

+Alga observed in qualitative scan but not during actual counting procedure.

Table A3. Phytoplankton densities in Sycamore Creek, Willow Creek, Mud Creek, and Vevay Drain in the vicinity of Mason and Lansing, Ingham County, Michigan, November 8, 1973. Data expressed in organisms/ml.

Algal Taxa / Stations:	1	MC-1	2	3	4	V-B	5	MC-1	6	7	8	9
Station Location:	Kipp Rd. Above Mason	Upstream from US-127	E. Cemetery Entrance above Mason WWTP	100 ft. below Mason WWTP	Howell Road	Vevay Drain	Harper Road	Phillips Road	Holt Road	Pine Tree Road	Jolly Road	Mt. Hope Road
Bacillariophyceae (Diatoms)												
Achnanthes sp.		13		10	+	5	21	13	10	12		3
Amphora sp.		44	5	4	8	5	13	10	13	5		5
Caloneis sp.						5						3
Cocconeis sp.		18	5		5		3	36	4	3		3
Cyclotella sp.		10	3	4	96	4	3	10	14	7		4
Cymatopleura sp.		3										
Cymbella sp.		5					3	3	10			
Diatoma sp.								5		3		
Fragilaria sp.	5	5			13	1	8	21				
Gomphonema sp.		13	3	1	13		26	18	23	12		
Gyrosigma sp.			1				3	3				
Melosira sp.			1			4	3	8	9			
Meridion sp.						5	3	3				
Navicula sp.	57	200	61	70	198	88	125	146	101	91	86	69
Nitzschia sp.	18	26	5	29	5	42	49	91	40	77	51	79
Rhoicosphenia sp.							5					
Stephanodiscus sp.											7	
Surirella sp.				1			5	3				3
Synedra sp.				2	5	10	13		7			3
Undetermined centrics		3		4								
Undetermined pennates	10	26	3	5		10	13	5	27	5	12	
Chlorophyta (Greens)												
Ankistrodesmus sp.					3						1	
Crucigenia sp.											9	4
Scenedesmus sp.					5						1	
Undetermined coccoid			1							1		
Undetermined filamentous		3						3	3	5	1	
Cyanophyta (Blue-greens)												
Anabaena sp.	5											
Undetermined filamentous		3	8	18	10	1	3	3	3		3	5
Flagellates												
Euglena sp.					+	+					1	
Dinobryon sp.					3		3		1			
Trachelomonas sp.			+					+	7	1	4	1
Undetermined				242	68				7		1	
Total Number of Organisms	95	372	96	390	432	180	302	381	279	222	177	182
Percent Diatoms	94.74	98.39	90.63	33.34	79.40	99.45	98.02	98.43	92.48	96.85	88.14	94.51
Percent Greens	0	0.81	1.05	0	1.86	0	0	0.79	1.08	2.71	6.78	2.20
Percent Blue-greens	5.27	0.81	8.34	4.62	2.32	0.56	1.00	0.79	1.08	0	1.70	2.75
Percent Flagellates	0	0	0	62.06	16.44	0	1.00	0	5.38	0.45	3.39	0.55
Species Diversity ($\bar{d}$)	1.67	2.46	2.06	1.86	2.35	2.36	2.97	2.84	3.14	2.28	2.12	2.11
Pollution index	3	3	3	3	4	3	6	6	3	6	6	6

+ Alga observed in qualitative scan but not during actual counting procedure.

APPENDIX B

PERIPHYTON DATA

TABLE B1.--Periphyton standing crop collected every two weeks in Sycamore Creek, Ingham County, Michigan, July 25-September 5, 1973. All values expressed as ug/cm^2 of chlorophyll a.

Collection Date	Station:	1			5			6			7			8		
	Samples:	A	B	$\bar{X}$	A	B	$\bar{X}$	A	B	$\bar{X}$	A	B	$\bar{X}$	A	B	$\bar{X}$
Aug. 8, 1973		1.87	2.05	1.96	27.65*	6.03	6.03	6.22	7.81	7.02	6.83	7.30	7.07	4.65	5.64	5.15
Aug. 22, 1973		1.51	1.23	1.37	6.97	2.54	4.76	6.22	8.96	7.59	2.42	2.39	2.41	5.86	2.32	4.09
Sept. 5, 1973		2.35	1.19	1.77	10.58	8.31	9.45	6.32	4.76	5.54	2.30	2.12	2.21	-	-	4.59**
	Grand mean			$(\bar{\bar{X}})$=1.70			$\bar{\bar{X}}$=6.75			$\bar{\bar{X}}$=6.72			$\bar{\bar{X}}$=3.90			$\bar{\bar{X}}$=4.61

*Not figured in mean

**Artificial value used for two-way analysis of variance. Values obtained by methods in Biometry (1969) by Sokal and Rohlf, pp. 337-340.

TABLE B2.--Two-way analysis of variance for adjusted* periphyton primary production in Sycamore Creek, Ingham County, Michigan, July 25-September 5, 1973.

Source	D.F.	Sum of Squares	Mean Squares	F
Station	4	53.6952	13.4237	4.303**
Dates	2	4.9169	2.4584	0.778
Error	7	24.9589	3.1198	
Total	13	83.5710	19.4477	

*Table adjusted for missing value for station SC-8 according to methods in Biometry (1969) by Sokal and Rohlf, pp. 337-340.

**Significant at 5% level

TABLE B3.--Comparisons of differences between mean standing crop from Sycamore Creek, July 25-September 5, 1973. Data expressed in ug/cm^2 of chlorophyll *a*.

Station	1	7	8	6	5
Station Mean*	1.70	3.90	4.61	6.72	6.75

*Means not connected by the same line are significantly different at 10% level.

APPENDIX C

ORGANIC SEDIMENT CONCENTRATIONS

Table C1. Heavy metal concentrations found in bottom sediments of Sycamore Creek and Vevay Drain, Ingham County, Michigan, July 25, 1973. All values expressed in mg/kg, dry weight*.

	Metals							
Stations:	Arsenic	Cadmium*	Chromium	Copper	Mercury	Nickel	Lead	Zinc
SC - 1	2.1	<0.2	8.9	17.0	1.7	14.4	29.7	161.4
SC - 2	2.1	<0.2	11.6	27.8	1.8	19.3	102.8	171.3
SC - 3	4.1	0.8	31.8	153.2	6.3	36.0	270.3	450.5
SC - 4	4.0	<0.2	27.8	161.4	5.8	26.9	233.2	403.6
V - A	1.7	<0.2	5.4	12.6	1.0	9.2	23.8	67.9
V - B	2.7	<0.2	10.8	37.0	2.2	17.3	43.2	167.6
SC - 5	4.7	<0.2	23.7	113.7	5.2	26.5	151.7	360.2
SC - 6	4.9	<0.2	18.6	42.2	3.6	26.5	58.8	225.5
SC - 7	2.5	<0.2	10.9	18.6	2.2	14.8	24.6	92.9
SC - 8	4.6	<0.2	20.2	33.0	3.0	22.9	50.4	137.6
SC - 9	3.0	0.6	24.6	57.1	2.2	27.6	360.4	303.3
Mean	3.3	-	17.7	61.2	3.2	22.0	122.6	231.1
Range	1.7-4.9	<0.2-0.8	5.4-31.8	12.6-161.4	1.0-6.3	9.2-36.0	24.6-270.3	67.9-450.5
Mean + 2 Std. Dev.	5.7	-	35.0	171.2	6.8	37.4	355.3	489.4
1971 Michigan Background Levels								
Mean	0.4	4.2	1.6	-	0.19	-	36.9	31.3
Range	0.0-2.0	0.0-11.0	0.0-5.0	-	0.12-15.0	-	1.0-96.0	4.0-210.0
Mean + 2 Std. Dev.	2.0	11.0	3.9	-	0.29	-	99.0	53.0

* Cadmium expressed in mg/kg wet weight.

TABLE C2.--Concentrations of chlorinated hydrocarbon pesticides, polychlorinated biphenyls, phthalates, and oil found in the bottom sediments of Sycamore Creek and Vevay Drain, Ingham Co., Michigan, July 25, 1973. All values expressed in mg/kg. pH values expressed in standard units.

Parameter	Station:	1	2	3	4	V-A	V-B	5	6	7	8	9
	Location:	Above Mason at Kipp Rd.	E. Cemetery Entrance	100 ft. Below Mason WWTP	Holt Rd.	Hogsback Rd.	Dart Rd.	Harper Rd.	Holt Rd.	Pine Tree Rd.	Jolly Rd.	Mt. Hope Rd.
Chlorinated Hydro-carbon Pesticides												
Total DDT		<0.001	0.068	0.111	0.065	<0.001	<0.001	0.051	0.020	<0.001	<0.001	0.688
DDE		<0.001	0.019	0.025	0.012	<0.001	<0.001	0.012	0.005	<0.001	<0.001	0.510
TDE		<0.001	0.024	0.053	0.027	<0.001	<0.001	0.023	0.008	<0.001	<0.001	0.078
OP-DDT		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
PP-DDT		<0.001	0.025	0.033	0.026	<0.001	<0.001	0.016	0.007	<0.001	<0.001	0.100
Dieldrin		<0.001	<0.001	0.004	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	0.006
Chlorodane		<0.001	0.240	0.350	0.120	<0.001	<0.001	0.055	<0.001	<0.001	<0.001	0.310
Polychlorinated Biphenyls												
PCB as 12.54		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Phthalates as:												
DEHP		<0.5	<0.5	5.2	3.3	<0.5	<0.5	1.7	0.6	<0.5	0.5	2.8
Oil		400	841	577	290	412	648	369	133	92	98	110
pH		6.8	7.1	7.3	7.2	7.1	7.2	6.9	7.3	6.8	7.4	7.2

APPENDIX D

FISH AND MACROINVERTEBRATE DATA

TABLE D1.--Summary of fish data collected by electrofishing at selected stations from Sycamore Creek, Ingham Co., Michigan, September 7, 1973.

Stations:	1	2	5	6	7	8
Fish Species (common and scientific names) / Station Location:	Upstream from Kipp Rd.	Upstream from E. Cemetery Entrance	Upstream from Harper Rd.	Upstream from Holt Rd.	Upstream from Pine Tree Rd.	Upstream from Jolly Rd.
Class I						
Group 1						
Redhorse sucker (*Moxostoma* sp.)					1	1
Hognose sucker (*Hypentelium nigricans*)						1
White sucker (*Catostomus commersoni*)	18	18		2	8	3
Black bullhead (*Ictalurus melas*)	1				1	
Yellow bullhead (*I. natalis*)					4	4
Class II						
Group 2						
Blackside darter (*Percina maculata*)		1			3	2
Johnny darter (*Etheostoma nigrum*)	2	5		1	4	11
Rainbow darter (*E. caeruleum*)	1	4			1	
Creek Chub (*Semotilus atromaculatus*)	29	2				
Central mudminnow (*Umbra limi*)	1	11	6	2		1
Blacknose dace (*Rhinichthys atratulus*)	1	5				
Shiners (*Notropis* sp.)					2	
Common shiner (*N. cornutus*)		7				
Golden shiner (*Notemigonus crysoleucas*)						1
Fathead minnow (*Pimephales promelas*)					5	3
Group 3						
Green sunfish (*Lepomis cyanellus*)		11		5	2	17
Pumpkinseed (*L. gibbosus*)	1			1		
Rockbass (*Ambloplites rupestris*)		14		7	24	5
Group 4						
Largemouth bass (*Micropterus salmoides*)					2	
Northern pike (*Essox lucius*)					1	
Total number of species	8	10	1	6	13	11
Total number of individuals	54	78	6	18	58	49
Trophic index values	15	21	2	14	28	20

Table 22. Aquatic macroinvertebrates taken in qualitative collections from Sycamore Creek, Willow Creek, Mud Creek, and Vevay Drain, Ingham County, Michigan, September 4-5, 1973.

Tolerance Status	Scientific Name	1 Kipp Rd. Above Mason	WC-1 Upstream from US - 127	2 Cemetery Entrance Above Mason WWTP	3 100 Ft. below WWTP	4 Howell Rd.	V-A Above Dart Container Co.	V-B Below Dart Container Co.	5 Harper Rd.	MC-1 Phillips Rd.	6 Holt Rd.	7 Pine Tree Rd.	8 Jolly Rd.	9 Mt. Hope Rd.
	Turbellaria (flatworms).													
F	Planariidae						9					2		16
T	Oligochaeta (aquatic earthworms)		3		51	·100	3	2	2	2	7		1	7
	Hirudinea (leeches)													
T	Batrachobdella picta		2						1				1	
T	Erpobdellidae		1					2						
T	Erpobdella triannulata	2		2										
T	Glossiphonia complanata	1		1						1				
T	Helobdella stagnalis											2		
	Gastropoda (snails, limpets)													
F	Amnicola integra											5	1	3
F	A. limosa											2		12
F	Campeloma decisum		1	9				13		2				
F	Ferrissia sp.		3							1			10	
F	Goniobasis livescens											2	1	
T	Helisoma antrosus	1		15						1			1	
F	Lymnaea sp.	2												
T	Physa sp.	60		13		5	1	16		3		3	2	5
F	Pleurocera acuta									5				
F	Vivipara maleatus													3
	Pelecypoda (clams)													
F	Pleurobema sp.		1											
F	Sphaerium sp.	1	5	46			4	12		21			1	3
F	Villosa sp.		1											
	Isopoda (sow bugs)													
T	Asellus sp.			2	11	34	3		3	1	5	4	1	11
	Amphipoda (scuds)													
I	Gammarus sp.	>100	>100	94						20	1	5	6	
F	Hyalella azteca					1	2		34	85	106	50	18	> 100
	Decapoda (crayfish)													
F	Cambarus sp.							1						
F	Orconectes propinquus	9		20		3				1			2	
F	O. virilis		1	6		2		19	3		2	2	2	
	Plecoptera (stoneflies)													
I	Acroneuria sp.									3		6	6	
	Ephemeroptera (mayflies)													
F	Baetis sp.	20	6	1						7	9	37	36	
F	Caenis sp.		1	1										
I	Ephemera varia			1										
I	Heptagenia											1		
I	Hexagenia												1	
F	Pseudocloeon punctiventrus										1			
I	Stenonema bipunctatum	25	2	1										
I	Stenonema sp.		4	3				1		14	37	41	20	21
I	Siphlonurus sp.						13	4	14		4	3	2	9
	Odonata (dragonflies, damselflies)													
F	Aeshna sp.				3									
F	Agrionidae			1	1		23	8	71	25	20	5	1	26
F	Boyeria sp.	1	8	1						1			4	
F	Calopteryx maculatum	21		6		3		5		43	2		11	2
F	Dromogomphus sp.		1				1				1			
F	Plathemis sp.							3						
	Hemiptera (true bugs)													
F	Belostoma fluminea	1		1		4		1	1		1	5	4	1
F	Corixidae		1	1		9	3		2	51	116	61	18	20
F	Gerris remigus			2	1									
F	Mesovelia mulsanti											1		
F	Mesovelia sp.													1
F	Metrobates sp.												1	
F	Notonecta unifasciata			5				2	2	1				
F	Plea sp.										4			
F	Potamobates sp.	4		1										
F	Ranatra fusca	1		3		1			4		2	3		
F	Ranatra sp							6						10
F	Rheumatobates sp.											2		
F	Saldidae		1											
	Megaloptera (alderflies, fishflies)													
F	Chauliodes pectinicornis					2								
F	Nigronia serricornis												3	
F	Sialis mohri												2	
F	Sialis sp.			2						2				

Table D2. (Continued)

Tolerance Status	Scientific Name / Location:	1 Kipp Rd. Above Mason	WC-1 Upstream from US - 127	2 E. Cemetery Entrance Above Mason WWTP	3 100 Ft. below WWTP	4 Howell Rd.	V-A Above Dart Container Co.	V-B Below Dart Container Co.	5 Harper Rd.	MC-1 Phillips Rd.	6 Holt Rd.	7 Pine Tree Rd.	8 Jolly Rd.	9 Mt. Hope Rd.
	Trichoptera (caddisflies)													
I	Agraylea sp.										1			
F	Cheumatopsyche sp.	112	20							8	22	23	25	7
F	Hydropsyche bifida group	17									1	5	3	
F	H. betteni	73		1						2	2	6	3	
F	H. simulans	35	26	3						10	3	12	12	3
F	Hydropsyche sp.							1						
F	Leptocella diarina												1	
F	Polycentropus sp.									1				
F	Psychomyiid Genus A									1				
I	Pycnopsyche sp.										1			
	Coleoptera (beetles)													
F	Berosus sp.					1								3
F	Deronectes sp.					1				1			1	
F	Dineutus sp.												2	
F	Dubiraphia	6	9	2			1			24	21	8	5	1
F	Dytiscidae										2			
F	Ectoparia sp.	1		2								1		
F	Galerucella sp.					2								
F	Gyrinus sp.		1											
F	Haliplus sp.					1			1					
F	Hydrovatus sp.					1					1			
F	Ilybius sp.					1								
F	Laccophilus sp.					1	1				1	1		
F	Macronychus glabratus	1								2		3	13	
F	Optioservus sp.	12	2	1										
F	Peltodytes sp.						2			1	3	1		17
F	Sperchopsis tesselatus	1												
F	Stenelmis sp.	4	1	2								2		1
F	Tropisternus sp.					6			3		8	1		
	Diptera (flies)													
F	Antocha saxicola											1		
T	Culex sp.					1			4					
F	Dicranota sp.	2												
F	Limnophila sp.												4	
F	Odontomyia sp.											1		
F	Paradixa sp.											1		
F	Pedicia sp.	1												
F	Simuliidae	1	1							7			4	
T	Stratiomys sp.										1			
F	Tabanus sp.			1						1		1		
F	Tipula sp.	2		10			1			1				
	Chironomidae (midges)													
F	Pupae*				4	4			2	4	2	1		
F	Ablabesmyia sp.													1
F	Brillia sp.	2												
T	Chironomus sp. (gills)	1		4	>100	>500	2	3	41	1	3	4	13	11
F	Cladotanytarsus sp.	1	3	1			1			2	3		2	
F	Clinotanypus sp.								1	1	1			
F	Cricotopus bicinctus										2		1	
F	Cricotopus sp.											1		
F	Cryptochironomus sp.		1				6						1	2
F	Dicrotendipes sp.												1	
F	Einfeldia sp.				1									1
F	Endochironomus nigricans						1			1				
F	Lymnophyes sp.	1												
F	Micropsectra sp.		1											
F	Microtendipes sp.	1								4				
F	Natarsia sp.				2	4								
F	Paratanytarsus sp.											1		
F	Pentaneura sp.									1		1		
F	Pentaneurini	1												
F	Polypedilum fallax			5	33					2				
F	Polypedilum sp.	4	9								4	3	1	1
T	Procladius sp.									2	2	1	2	19
F	Psectrotanypus sp.					16			1					
F	Rheocricotopus sp.			1							6			
F	Thienemannimyia group		2	1						1		1	1	1
F	Tribelos sp.												3	3
													1	
	Total number of species	36	30	38	9	23	18	17	17	42	36	43	47	31
	Number of intolerant species	2	3	4	0	0	1	2	1	3	5	5	5	2
	Number of facultative species	29	24	28	6	18	13	11	11	32	26	33	36	25
	Number of tolerant species	5	3	6	3	5	4	4	5	7	5	5	6	4
	Biotic index (BI)	33	30	36	6	18	15	15	13	38	36	43	46	29

* Not included in species determinations

Table D3. Estimated macroinvertebrate numbers per square meter in Sycamore, Willow, and Mud Creeks, Ingham County, Michigan, based upon colonization of Hester-Dendy artificaial substrate samplers, July 25-September 5, 1973.

--	Stations:	1		MC-1		2		3		4		5		MC-1		6		7		8		9	
Tolerance Status	Scientific Name / Location:	Above Mason at Kipp Rd		Upstream from US-127		E. Cemetery Entrance		100 ft. below Mason WWTP		Howell Rd.		Harper Rd.		Phillips Rd.		Holt Rd.		Pine Tree Rd.		Jolly Rd.		Mt. Hope Rd.	
	Sample	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
	Turbellaria (flatworms)																						
F	Planariidae																		16				
T	Oligochaeta (aquatic earthworms)									16	32					16							16
	Gastropoda (snails, limpets)																						
F	*Ferrissia* sp.				16	97	65							16	16	16				16			
T	*Physa* sp.					16																	16
	Isopoda (sow bugs)																						
T	*Asellus* sp.										113												
	Amphipoda (scuds)																						
I	*Gammarus* sp.	291	194	16	48	81	129								32	16							
F	*Hyalella azteca*			242	16														16	178	129		
	Plecoptera (stoneflies)																						
I	*Acroneuria* sp.																				16		
	Ephemeroptera (mayflies)																						
F	*Baetis* sp.				16									484	307	48	81	1420	323	1017	1727		
F	*Caenis* sp.						16																
I	Leptophlebiidae			16																			
I	*Stenonema bipunctatum*	16	65	16		32									32								
I	*Stenonema* sp.	81	48	65	178	16	16					16		662	81	145	145	1146	1243	1081	1759		
	Odonata (dragonflies, damselflies)																						
F	Agrionidae	16					16					16					65						48
F	*Boyeria* sp.														16								
F	*Calopteryx maculatum*						32							48		32	16				16		
	Hemiptera (true bugs)																						
F	*Microvelia* sp.		16																				
	Megaloptera (alderflies, fishflies)																						
F	*Nigronia serricornis*																			16			
	Trichoptera (caddisflies)																						
F	*Cheumatopsyche* sp.	16		194	32	145	32							694	4777	936	1404	1953	1340	2663	2647		
F	*Cyrnellus* sp.	16																					
F	*Hydropsyche bifida* group					65								16	178	16	81	32	32	129	97		
F	*H. betteni*													194	81			65	258	32	81		
F	*H. simulans*															32	32						
F	*Hydropsyche* sp.					16								1114	1259			242	613	581	516		
I	*Platycentropus*													16									
F	*Polycentropus*				97											32							
F	*Psychomyiid* Genus A				48										16								
I	*Ochrotrichia* sp.																						16
	Coleoptera (beetles)																						
F	*Ancyronyx variegata*																	16					
F	*Dubiraphia* sp.		16	32											16					65			
F	*Macronychus glabratus*					65								97	161	16	16	113	65	258	468		
F	*Optioservus* sp.			16																			
	Diptera (flies)																						
F	Heleidae		16									16			16		16						
F	Empididae						16																
F	Simuliidae														81	16		113	16				
	Chironomidae (midges)																						
F	*Pupae**		16	65		48	48	258	404	16		65	97		65	16	32	16		16	16	48	16
F	*Ablabesmyia* sp.				48	16	16									32						32	161
F	*Brillia* sp.				16																		
T	*Chironomus* sp (gills)			16	16	32	81	791	1033	4164	4858	662	726			48	48	65		16		129	161
F	*Cladotanytarsus* sp.	16	226	194			16							16	1065	16	48	129	339	129	48		
F	*Clinotanypus* sp.											16	16										
F	*Coelotanypus* sp.												16										
F	*Corynoneura* sp.	145	48	32										16	210								
F	*Cricotopus* sp.	16	32		16											65	48						
F	*C. bicinctus*	16	32			48	113	16								16	65	32	16			16	32
F	*Cryptochironomus* sp					16																	
F	*Dicrotendipes* sp.					16	16															274	355
F	*Einfeldia* sp.				16			452	387			904	1356			32							
F	*Endochironomus* sp.	16																					
F	*Eukiefferiella* sp														16								
F	*Labrundinia* sp.													16									
F	*Lauterbornia* sp.		48																				
F	*Limnophyes* sp.	48	32	48											32								
F	*Micropsectra* sp.			48																			
F	*Microtendipes* sp/			97	32										32								
F	*Natarsia* sp										16												
F	*Parachironomus* sp.											16											
F	*Paracladopelma* sp.															16		16				48	16
F	*Paralauterborniella* sp.				16															48			
F	*Pentaneura* sp.													16			16	81	97		16	16	
F	*Polypedilum fallax*	145	178	436	226	742	936	1824	1808				16		178	210	113	16	16	32		355	404
F	*Polypedilum* sp.			16			65	16	16					16	468	32	48	65	81			48	48
T	*Procladius* sp.											65										16	16
F	*Psectrocladius* sp	16	16	129											97	32							32
F	*Psectrotanypus* sp									65	145	16	65										
F	*Rheocricotopus* sp.	32				48								129	291	161	145		16	113	97		
F	Tanypodinae												16					16					
F	*Thienemanniella* sp			32											178	65	32			32	16		
F	*Thienemannimyia* group	32	65	145		210	97					16		32	16	113	113					258	194
F	*Tribelos* sp.				16																		
	Total number of species/station	20		29		23		5		5		13		30		28		20		20		15	
	Estimated total number of organisms/m^2/station	983		1354		1709.5		3502.5		4712.5		2058		6649.5		2369.5		5011.5		7035.5		1385.5	

* Not included in species calculations

TABLE D4.--Summary of macroinvertebrate data from Hester-Dendy artificial substrate samplers placed in Sycamore, Willow, and Mud Creeks, Ingham Co., Michigan, July 25-September 5, 1973.

Stations:	1	WC-1	2	3	4	5	MC-1	6	7	8	9
Station Locations:	Above Mason at Kipp Rd.	Upstream from U.S. 127	E. Cemetery Entrance	100 ft. below Mason WWTP	Howell Rd.	Harper Rd.	Phillips Rd.	Holt Rd.	Pine Tree Rd.	Jolly Rd.	Mt. Hope Rd.
Total number of species	20	29	23	5	5	13	30	28	20	20	15
Number of mayfly species	2	4	3	0	0	1	3	2	2	2	0
Number of caddisfly species	2	3	3	0	0	0	6	4	4	4	1
Number of midge species	11	17	10	5	3	10	13	14	9	7	11
Number of other species	5	5	7	0	2	2	8	8	5	7	3
Percent mayfly species	10.0	13.8	13.0	0	0	7.6	10.0	7.1	10.0	10.0	0
Percent caddisfly species	10.0	10.3	13.0	0	0	0	20.0	14.3	20.0	20.0	6.7
Percent midge species	55.0	58.6	43.5	100.0	60.0	76.9	43.3	50.0	45.0	35.0	73.3
Percent other species	25.0	17.2	30.4	0	40.0	15.4	26.7	28.6	25.0	35.0	20.0
Estimated number of organisms/m^2	983	1354	1709.5	3502.5	4712.5	2058	6649.5	2369.5	5011.5	7035.5	1385.5
Number of mayflies/m^2	105	145.5	40	0	0	8	783	209.5	2066	2792	0
Number of caddisflies/m^2	16	185.5	129	0	0	0	4172.5	1266.5	2267.5	3373	8
Number of midges/m^2	587.5	830	1282	3502.5	4632	2034	1444.5	781	500.5	289.5	1337.5
Number of others/m^2	274.5	193	258.5	0	80.5	16	249.5	112.5	177.5	581	40
Percent number of mayflies	10.7	10.8	2.3	0	0	0.4	11.8	8.8	41.2	39.7	0
Percent number of caddisflies	1.6	13.7	7.6	0	0	0	62.8	53.5	45.3	47.9	0.6
Percent number of midges	59.8	61.3	75.0	100.0	98.3	98.8	21.7	33.0	10.0	4.1	96.5
Percent number of other individuals	27.9	14.3	15.1	0	1.7	0.8	3.8	4.8	3.5	8.3	2.9
Species diversity ($\bar{d}$)/station	3.5	3.9	2.9	1.4	0.3	1.5	3.0	3.1	2.8	2.6	2.9
Equitability (e)/station	0.80	0.76	0.45	0.67	0.28	0.28	0.38	0.42	0.47	0.41	0.69
Biotic index (BI)/station	23	32	24	4	2	12	34	28	20	21	12

TABLE D5.--Number of species collected on circular Hester-Dendy artificial substrates in Sycamore, Willow, and Mud Creeks in the vicinity of Mason and Lansing, Ingham County, Michigan, July 25-September 5, 1973.

Station:	1	WC	2	3	4	5	MC	6	7	8	9
Species in Sample A	16	19	17	5	3	10	17	25	17	17	10
Species in Sample B	15	17	16	4	5	7	26	19	16	14	14
Mean	15.5	18.0	16.5	4.0	4.0	8.5	21.5	22.0	16.5	15.5	12.0

TABLE D6.--Species diversity ($\bar{d}$) of macroinvertebrates collected on circular Hester-Dendy artificial substrates in Sycamore, Willow, and Mud Creeks in the vicinity of Mason and Lansing, Ingham County, Michigan, July 25-September 5, 1973.

Station:	1	WC	2	3	4	5	MC	6	7	8	9
($\bar{d}$) of Sample A	3.15	3.51	2.92	1.44	0.15	1.63	2.79	3.27	2.56	2.66	2.60
($\bar{d}$) of Sample B	3.33	3.36	2.51	1.40	0.42	1.32	2.75	2.71	2.76	2.46	2.96
Average ($\bar{d}$) of Samples*	3.24	3.43	2.71	1.42	0.29	1.48	2.77	2.99	2.66	2.56	2.78

*This is not the same as ($\bar{d}$)/station

TABLE D7.--Comparisons of differences between mean number of macroinvertebrate species collected on Hester-Dendy artificial substrates in Sycamore, Willow, and Mud Creeks in the vicinity of Mason and Lansing, Ingham County, Michigan, July 25-September 5, 1973.

Station	4	3	5	9	1	8	2	7	WC	MC	6
Mean Number of Species	4.0	4.5	8.5	12.0	15.5	15.5	16.5	16.5	18.0	21.5	22.0

*Means not connected by the same line are significantly different at 5% level.

TABLE D8.--Comparisons of differences between species diversities of macroinvertebrates collected on Hester-Dendy artificial substrates in Sycamore, Willow, and Mud Creeks in the vicinity of Mason and Lansing, Ingham County, Michigan, July 25-September 5, 1973.

Station	4	3	5	8	7	2	MC	9	6	1	WC
Average ($\bar{d}$)	0.29	1.42	1.48	2.56	2.66	2.71	2.77	2.78	2.99	3.24	3.43

*Means not connected by the same line are significantly different at 5% level.