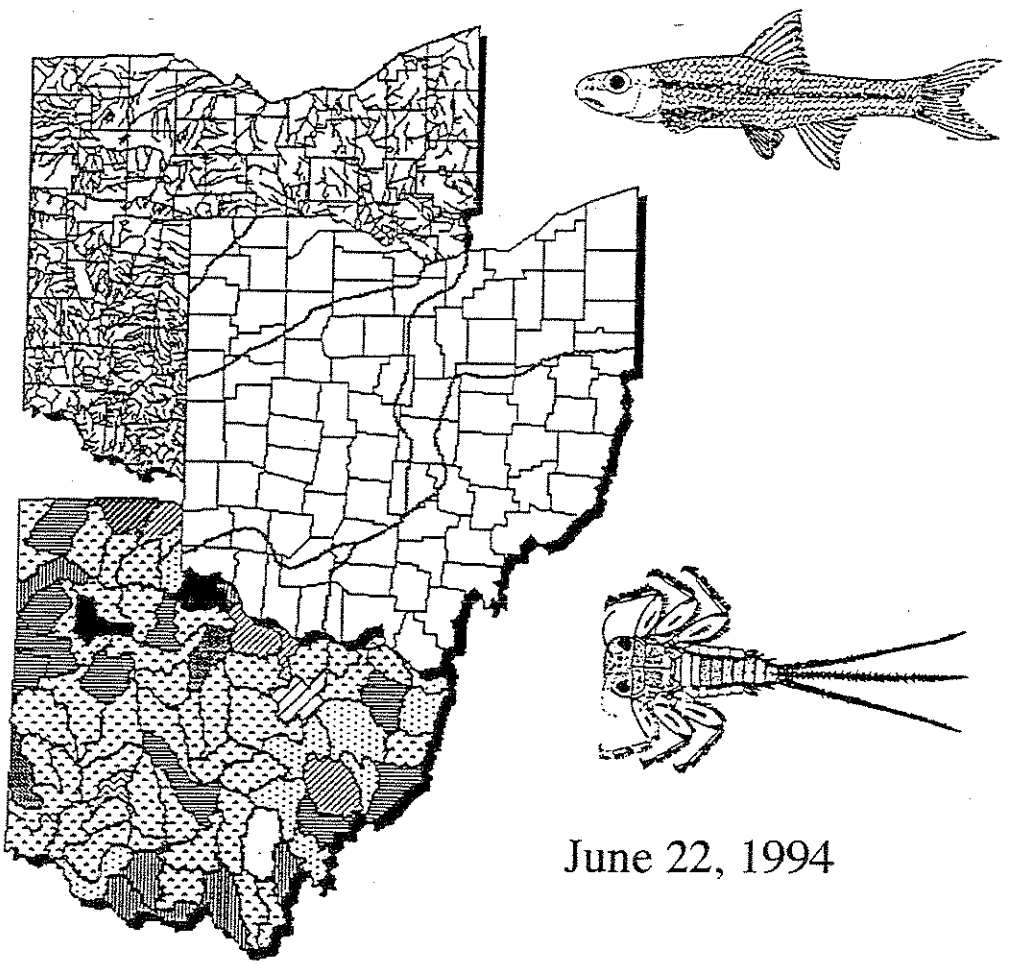
State of Ohio
Environmental Protection Agency

Ecological Assessment Section
Division of Water

Biological and Water Quality Study of the River Styx

Medina and Wayne Counties (Ohio)



June 22, 1994

P.O. Box 163669, 1800 WaterMark Dr., Columbus, Ohio 43216-3669

Biological and Water Quality Study of the River Styx

Medina and Wayne Counties, Ohio

1994

Ohio EPA Technical Report SWS/1994-6-8

prepared by

State of Ohio Environmental Protection Agency
Division of Surface Water
Water Quality Section
Northeast District Office
2110 East Aurora Road
Twinsburg, Ohio 44087

TABLE OF CONTENTS

List of Tables

List of Figures

NOTICE TO USERS

Ohio EPA adopted biological criteria into the Ohio Water Quality Standards (WQS; Ohio Administrative Code 3745-1) regulations in February 1990 (Effective May 1990). These criteria consist of numeric values for the Index of Biotic Integrity (IBI) and Modified Index of Well-Being (MIwb), both of which are based on fish, and the Invertebrate Community Index (ICI), which is based on macroinvertebrates. Criteria for each index are specified for each of Ohio's five ecoregions, and are further organized by organism group, index, site type, and aquatic life use designation. These criteria, along with the chemical and whole effluent toxicity evaluation methods, figure prominently in the assessment of Ohio's surface water resources.

Several documents support the adoption of the biological criteria by outlining the rationale for using biological information, the specific methods by which the biocriteria were derived and calculated, the field methods by which sampling must be conducted, and the process for evaluating results. These documents are:

Ohio Environmental Protection Agency. 1987a. Biological criteria for the protection of aquatic life: Volume I. The role of biological data in water quality assessment. Division of Water Quality Monitoring & Assessment, Surface Water Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1987b. Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters. Division of Water Quality Monitoring & Assessment, Surface Water Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1989a. Addendum to Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters. Division of Water Quality Planning & Assessment, Ecological Assessment Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1989b. Biological criteria for the protection of aquatic life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities. Division of Water Quality Planning & Assessment, Ecological Assessment Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1990c. The use of biological criteria in the Ohio EPA surface water monitoring and assessment program. Division of Water Quality Planning & Assessment, Ecological Assessment Section, Columbus, Ohio.

Rankin, E.T. 1989. The qualitative habitat evaluation index (QHEI): rationale,methods, and application. Division of Water Quality Planning & Assessment, Ecological Assessment Section, Columbus, Ohio.

These documents and this document can be obtained by writing to:

Ohio EPA - DSW
Ecological Assessment Section
1685 Westbelt Drive
Columbus, Ohio 43228
(614) 777-6264

Acknowledgements

The following Ohio EPA staff are acknowledged for their significant contribution to this report.

Study Area Description - Steve Tuckerman
Pollutant Loadings - Steve Tuckerman
Ambient Chemical Quality - Steve Tuckerman
Biological Assessment:
Macroinvertebrate Community - Jeff DeShon
Fish Community - Steve Tuckerman
Data Management - Dennis Mishne, Ed Rankin
Reviewer - Chris Yoder

This evaluation and report would not have been possible without the additional assistance of the study team and the Ohio EPA Northeast District Office Division of Surface Water staff for assistance in the field and the chemistry analyses provided by the Ohio EPA Division of Environmental Services. Special Thanks to Rob Lang, Debra Hembree and David Stroud for their assistance in data collection.

The River Styx near Rittman on August 11, 1993. The stream discoloration is a result of a treatment plant upset from the Packaging Corporation of America (PCA) 001 outfall. The top photograph was taken from near Salt Street in Rittman looking North. Note the channelized stream and poor riparian habitat. The bottom photograph was taken from Salt Street looking South . The clear water discharges of the Rittman WWTP (left) and PCA 002 (right) can be seen mixing with the turbid River Styx waters.

Biological and Water Quality Survey of the River Styx
(Medina and Wayne Counties, Ohio)

Ohio Environmental Protection Agency
Division of Water Quality Planning and Assessment
1800 WaterMark Drive
Columbus, Ohio 43266-0149

Introduction

The 1993 River Styx study area consisted of the River Styx mainstem from the mouth to upstream from the Wadsworth wastewater treatment plant (WWTP) at river mile (RM) 3.5. Three facilities with a total of 6 NPDES permitted outfalls discharge within the study area. Significant land uses in the River Styx watershed include agriculture, industry and small urban development.

Specific objectives of this evaluation were to:

1) Collect biological, chemical and physical water resource information from the River Styx, upstream and downstream from the Rittman WWTP, Wadsworth WWTP and Packaging Corporation of America (PCA) outfalls;

2) Evaluate current aquatic life use attainment status near the mouth of the River Styx;

3) Assess any water quality trends in the River Styx against the results of a 1983 Ohio EPA survey, and;

4) Expand Ohio EPA's data base for long term reporting purposes.

The findings of this evaluation may factor into regulatory actions taken by Ohio EPA (*e.g.* NPDES permits, Director's Orders), the Ohio Water Quality Standards (OAC 3745-1), and eventually be incorporated into the State Water Quality Management Plans, the Ohio Nonpoint Source Assessment, and the biennial Water Resource Inventory (305[b] report).

Summary

River Styx

A total of 3.5 miles of the River Styx were assessed as part of the 1993 sampling effort. Based upon the performance of the fish and macroinvertebrate communities and the Erie/Ontario Lake Plain (EOLP) ecoregion biocriteria, 0.6 mile of the River Styx was in FULL attainment of the modified warmwater habitat (MWH) aquatic life use (17% of the study area); and 2.9 miles were in **NON** attainment of the MWH aquatic life use (83% of the study area). Full attainment occurred upstream of the major wastewater discharges in the basin with significant degradation of the aquatic community observed beginning downstream from the Wadsworth WWTP. Progressive degradation of the aquatic community occurred all the way to the confluence with Chippewa Creek corresponding with additional point source discharges. Aquatic life use attainment status and biocriteria scores for all sampling locations are presented in Table 1.

Table 1. Aquatic life use attainment status and biocriteria scores for the River Styx study area

RIVER MILE Fish/Invert.	IBI	Modified Iwb	ICI[a]	QHEI[b]	Attainment Status[c]	Comment
River Styx						
	Erie Ontario Lake Plain – MWH Use Designation – Existing					
3.5	**27**	7.9	F	41	Full	UST Wadsworth WWTP
2.8	**26**	5.9*	**P***	43.5	**NON**	DST Wadsworth WWTP
0.75	**23***	**4.1***	**P***	34.5	**NON**	DST PCA 001, 003, 004
0.1	**17***L	**4.3***	**P***	35	**NON**	DST PCA 002 and Rittman WWTP

Ecoregion Biocriteria:

Erie Ontario Lake Plain (EOLP)

INDEX - Site Type	WWH	EWH	MWH[d]
IBI - Headwaters	40	50	24
Mod. Iwb - Wading	7.9	9.4	6.2

[d] - Modified Warmwater Habitat for channel modified areas.

* - significant departure from biocriteria; poor and very poor results are underlined.

ns - nonsignificant departure from biocriteria for WWH or EWH (4 IBI or ICI units; 0.5 Iwb units).

a - Narrative evaluation used in lieu of ICI where quantitative sampling was not done (E=Exceptional; G=good; MG=Marginally good; F=Fair; P=Poor; VP=Very Poor).

b - Qualitative Habitat Evaluation Index (QHEI) values based on the new version (Rankin 1989).

c - Attainment status based on one organism group is parenthetically expressed.

L - IBI is low end adjusted

Wastewater discharges adversely affect the water quality and aquatic communities in the River Styx. These discharges account for approximately 97% of the stream flow in this study segment during Q_7-10 conditions. This information was calculated from United States Geologic Service (USGS) water yield from a basin measurement site in Chippewa Creek at nearby Sterling and average annual WWTP discharges reported to Ohio EPA. Attainment status was degraded from FULL attainment upstream from the Wadsworth WWTP to **NON** attainment downstream from the Wadsworth WWTP, PCA 001, 002, 003 and 004 outfalls and the Rittman WWTP discharges. The Wadsworth WWTP discharge had a significant adverse impact on River Styx fish and macroinvertebrate communities due to organic enrichment and probable chlorine and ammonia-N toxicity. PCA 001 had a significant impact on the biologic communities due to organic enrichment. Complex toxic effects were indicated downstream from the PCA 002 and Rittman WWTPs. Rittman and PCA outfall 002 are too close together to separate individual effects of the discharges. However, two bioassay tests performed on the PCA 001 discharge in 1988 and the low percentage of industrial flow to the Rittman WWTP indicate the probable source is from a PCA discharge.

1983-1993 Trend Assessment

Fish and aquatic macroinvertebrate communities in the River Styx have not significantly changed from 1983 to 1993 and continue to perform below ecoregional expectations for the modified warmwater habitat use designation. However, water quality of the River Styx for most parameters sampled appears to have improved from 1983 to 1993. These improvements in water quality are a direct result of improvements at the waste water treatment facilities in the basin. The greatest improvement in water quality from 1983 to 1993 was achieved downstream from PCA and the Rittman WWTP. In contrast with improvements in other parameters, an increase in phosphorus concentration was indicated downstream from the Wadsworth WWTP.

Evaluated Point Sources

Wadsworth WWTP (RM 3.34)

One exceedence of the MWH criteria for ammonia–N was documented downstream from the Wadsworth WWTP. Loss of relatively intolerant fish and macroinvertebrate species was also documented downstream from the Wadsworth discharge, although the fish community still met the MWH Index of Biotic Integrity (IBI) criteria. Very low fecal coliform and *E. coli* bacteria counts downstream from the discharge indicate in–stream chlorine toxicity from the Wadsworth effluent. In–stream phosphorus concentrations have increased from 1983 to 1993 downstream from the Wadsworth discharge. Toxicity was found in two of three bioassay tests performed on this discharge.

Packaging Corporation of America–Paperboard Division (PCA) (RM 0.92, 0.74, 0.8)

The River Styx fish community was in **NON** attainment of the Modified Index of Well Being (MIwb) for MWH streams downstream from the PCA 001 discharge. An instantaneous temperature measurement above the daily average water quality criteria was documented downstream from the 002 outfall. No other water quality criteria exceedences (except for bacteria counts) were noted downstream from the PCA outfalls. In–stream temperature, chemical oxygen demand (COD), total zinc and total arsenic values increased downstream from the PCA outfalls. NPDES permit limits for PCA are based upon USEPA categorical standards for the pulp and paper industry and allow relatively high concentrations of pollutants. Periodic upsets and biotoxicity (two of four tests) have also been documented at the facility. Cumulative stressors such as these are the likely reason for the poor biologic performance in the River Styx downstream from the PCA discharges.

Rittman WWTP (RM 0.74)

Both fish and qualitative macroinvertebrate communities declined significantly downstream from the Rittman WWTP. However, the Rittman discharge is directly across the stream from the PCA 002 discharge. It is not known if the Rittman discharge, the PCA discharges, or non–point source contaminants are the cause(s) of the decline in the aquatic communities. The biologic signature downstream of the discharges is indicative of complex toxicity. Rittman is not likely the source of the indicated toxicity since less than ten percent of the influent flow to the plant is from industrial sources.

Conclusions

River Styx

- The River Styx was fully meeting the MWH criteria upstream from the Wadsworth WWTP.

- The River Styx from RM 2.75 to the mouth was in **NON** attainment of Ohio's biocriteria. This **NON** attainment segment was located downstream from Wadsworth, PCA and Rittman WWTP discharges.
- The Wadsworth WWTP discharge was responsible for ammonia–N water quality criteria exceedences in the River Styx.
- Organic enrichment from WWTP discharges to the River Styx is the primary cause of **NON**–attainment in the basin.
- Fish and macroinvertebrate communities in the River Styx showed a complex toxicity signature downstream from PCA and Rittman discharges.
- Area of Degradation Value (ADV) statistics increased from 1983 to 1993 indicating reduced performance of the aquatic communities from 1983 to 1993.

Recommendations

Status of Aquatic Life Uses

Ohio EPA is under obligation by a 1981 public notice to review and evaluate all aquatic life use designations outside of the WWH use prior to basing any permitting actions on the existing, unverified use designations. The River Styx is currently classified as a Modified Warmwater Habitat Stream from River Mile (RM) 3.9 to the mouth. Because of extensive channelization of the River Styx in 1980 and the prospect that it will be maintained in this condition, the Modified Warmwater Habitat use designation is still appropriate.

River Styx

- Investigate the reason(s) for degraded fish and macroinvertebrate populations near the mouth of the River Styx.
- Perform a temperature survey on the river near the mouth.
- Perform bioassay tests on the PCA 002 (cooling water pond) and Rittman WWTP discharges.

Status of Non-Aquatic Life Uses

- The River Styx is currently classified as agricultural and industrial water supply and primary contact recreation. These uses are appropriate and should be maintained.

Other Recommendations

- Re–evaluate the need to maintain a dredged channel.
- Encourage riparian habitat enhancement along the River Styx from RM 3.9 to the mouth.

Future Monitoring Needs

- Evaluate the impacts of nonpoint source pollution in previously unmonitored stream segments in the upper River Styx Basin.
- Investigate chlorine concentrations in the River Styx immediately downstream from the Wadsworth WWTP and monitor impacts of scheduled dechlorination at the Wadsworth WWTP.
- Investigate in–stream toxicity indicated in the River Styx upstream from the major dischargers in the basin.
- Investigate high bacteria levels in the River Styx in and upstream from the current study area.

Study Area

The River Styx is a subbasin of Chippewa Creek, tributary to the Tuscarawas River (Fig. 1). The basin drains 28.55 square miles in northeast Ohio (Ohio Department of Natural Resources, 1954)

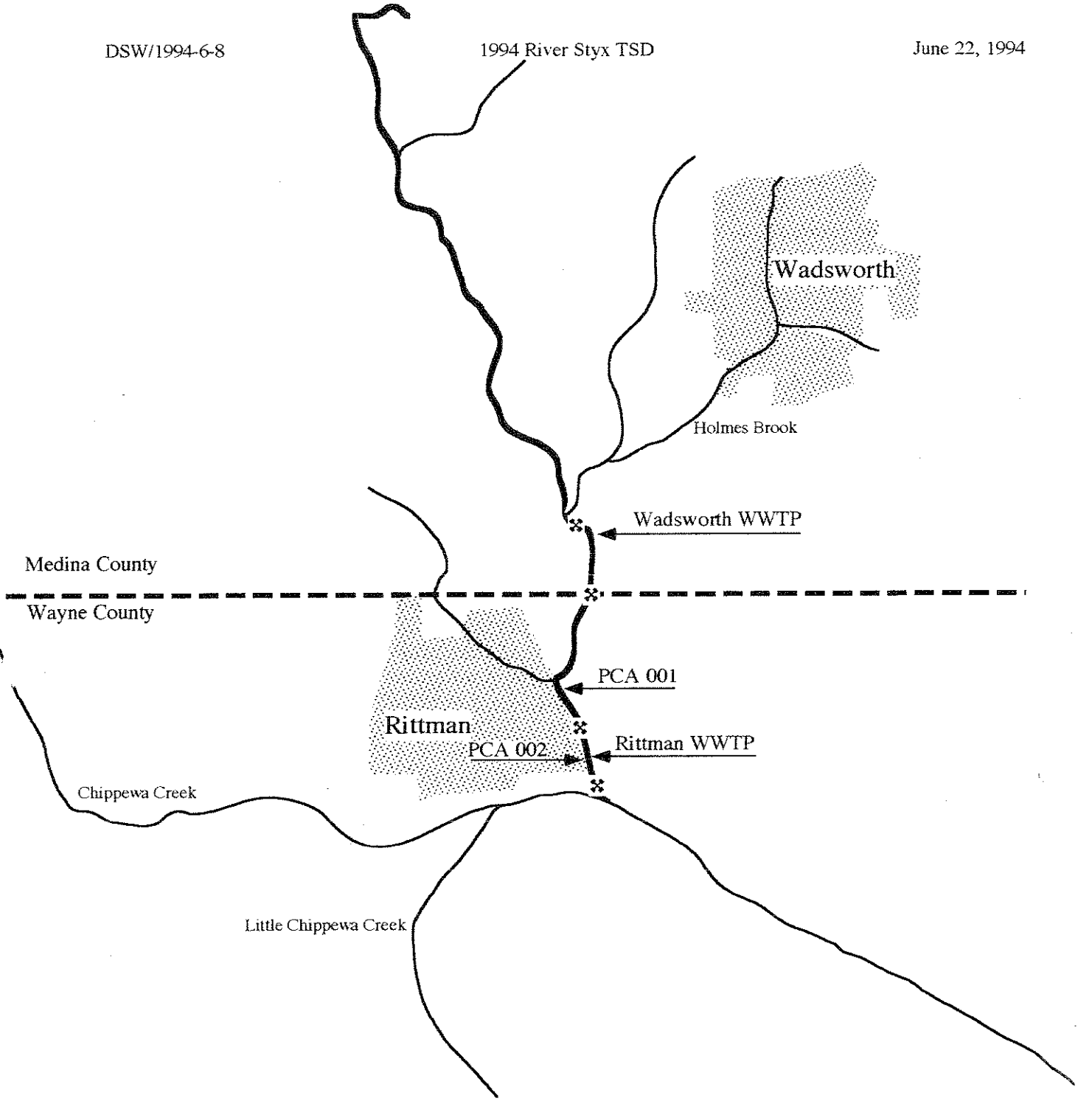


Figure 1. The River Styx study area showing principal streams and tributaries, population centers, pollution sources, and sampling locations.

with the basin headwaters in Medina County. The River Styx flows in a southerly direction through glaciated topography to Chippewa Creek near the town of Rittman. The largest tributary to the River Styx is Holmes Brook which enters the river at River Mile 3.6, immediately upstream from the study area. Table 2 presents the general characteristics of the stream in the study area and point sources evaluated in this report. Table 3 lists the permitted wastewater discharges in the basin and Table 4 shows the sampling locations for this study.

Table 2. Stream characteristics and significant identified pollution sources in the River Styx study area.

Stream Name	Length (Miles)	Avg Fall (Feet/Mile)	Drainage (Square Miles)	Non Point Source Pollution Categories	Point Sources Evaluated
River Styx	10.1	6.7	28.55	Agriculture	PCA 001
				Urban	PCA 002
				Industrial	Wadsworth WWTP
				Waste Disposal	Rittman WWTP

Land use in the northern half of the River Styx watershed is dominated by rural/suburban communities and agriculture. The lower portion of the River Styx Harbor becomes more urbanized with an increasing number of commercial and industrial properties (Ohio EPA, 1990). The River Styx from RM 3.9 to the mouth was dredged in 1975 and 1980 (personal communication, SWCD, 1994) by the Muskingham River Conservancy District. "Maintenance" of the dredged portion of the channel is performed as needed. This dredged section is currently classified in Ohio Water Quality Standards (WQS) with the MWH use designation. Land uses within the southern portion of the basin are predominated by disturbed lands such as disposal areas and lagoons. Non-point sources in this segment include abandoned salt lagoons, sludge lagoons and flyash disposal areas.

The River Styx Basin is located in the Erie/Ontario Lake Plain (EOLP) ecoregion. The EOLP is characterized by glacial plains interspersed with higher remnant beach ridges, drumlins, glacial till ridges, ground moraines, till plains, and outwash terraces. Local relief is greater in the Erie/Ontario Lake Plain ecoregion (northeast Ohio) than in the neighboring Huron/Erie Lake Plain (northwest Ohio) and Eastern Corn Belt Plain (central and western Ohio) ecoregions, but less than the relief found in the Western Allegheny Plateau (southeast Ohio) ecoregion (U.S. EPA 1988). Soils within the basin are predominantly Fitchville Associations which are lacustrine silts characterized as nearly level to moderately steep and somewhat poorly drained to moderately drained (USDA 1977, 1984).

Table 3. 1993 Wastewater Dischargers to the River Styx

Municipal Discharges

Entity	County	Permit#	Stream	RM	Flow MGD
Public/Semi-public Dischargers					
RITTMAN WWTP	WAYNE	3PC00010	RIVER STYX	0.74	1.6 MGD
WADSWORTH WWTP	MEDINA	3PD00022	RIVER STYX	3.34	3.6 MGD

Industrial Discharges

Entity	County	Permit #	Stream	RM	Flow MGD	Type
PACKAGING CORPORATION OF AMERICA 001	WAYNE	3IA00003	RIVER STYX	0.92	2.5	P, CS, B
PACKAGING CORPORATION OF AMERICA 002	WAYNE	3IA00003	RIVER STYX	0.74	1.7	C
PACKAGING CORPORATION OF AMERICA 003	WAYNE	3IA00003	RIVER STYX	0.8		CS
PACKAGING CORPORATION OF AMERICA 004	WAYNE	3IA00003	RIVER STYX	0.8		CS
ADVANCED ELASTOMER	MEDINA	3IR00043	UT TO RIVER STYX	3.9/0.1	0.139	C,NC,S
OHIO BRASS	MEDINA	3IN0037	UT TO RIVER STYX	4.0/1.05/0.6	0.002	CS.NC, S, P
GOLDSMITH & EGGLETON	MEDINA	3IR00053	UT TO HOLMES BROOK	3.6/0.36/2.1/ 0.5/0.31	0.058	P, NC

C = COOLING WATER
P = PROCESS WASTEWATER
C = NON-CONTACT COOLING WATER
CS = CONTAMINATED STORM WATER
B = BOILER BLOWDOWN
S = SANITARY

Table 4. Sampling locations (effluent sample - E, water chemistry - C, sediment - S, benthos - B, fish - F, fish tissue - FT, WLA Modeling - M) in the River Styx study area, 1993.

Stream/ River Mile	Type of Sampling	Latitude/Longitude	Landmark	USGS 7.5 min. Quad
River Styx				
3.5	C, F, B	41.0048/81.7657	Upstream Wadsworth WWTP	Seville
3.34	E		Wadsworth 001 Effluent	Rittman
2.8	C, F, B	40.9957/81.7633	Wall Road	Rittman
0.92	E		PCA 001 Effluent	Rittman
0.75	C, F, B	40.9672/81.7703	Salt Road	Rittman
0.74	E		Rittman 001 Effluent	Rittman
0.01	C, F, B	40.9619/81.7653	At Mouth	Rittman

Methods

All chemical, physical, and biological field, laboratory, data processing, and data analysis methods and procedures adhere to those specified in the Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices (Ohio Environmental Protection Agency 1989c) and Biological Criteria for the Protection of Aquatic Life, Volumes II-III (Ohio Environmental Protection Agency 1987b, 1989a, 1989b), and The Qualitative Habitat Evaluation Index (QHEI): Rationale, Methods, and Application (Rankin 1989) for aquatic habitat assessment.

Attainment/nonattainment of aquatic life uses is determined by using biological criteria codified in Ohio Administrative Code (OAC) 3745-1-07, Table 7-17. The biological community performance measures that are used include the Index of Biotic Integrity (IBI) and the Modified Index of Well-being (MIwb), both of which are based on fish community characteristics, and the Invertebrate Community Index (ICI) which is based on macroinvertebrate community characteristics. IBI and ICI are multi-metric indices patterned after an original IBI described by Karr (1981) and Fausch et al. (1984). The MIwb is a measure of fish community abundance and diversity using numbers and weight information; it is a modification of the original Index of Well-Being applied to fish community information from the Wabash River (Gammon 1976, Gammon *et al.* 1981).

Performance expectations for the basic aquatic life uses (Warmwater Habitat [WWH], Exceptional Warmwater Habitat [EWH], and Modified Warmwater Habitat [MWH]) were developed using the regional reference site approach (Hughes *et al.* 1986; Omernik 1988). This fits the practical definition of biological integrity as the biological performance of the natural habitats within a region (Karr and Dudley 1981). Attainment of an aquatic life use is FULL if all three indices (or those available) meet the applicable criteria, PARTIAL if at least one of the indexes does not attain and performance does not fall below the fair category, and **NON** if all indices either fail to attain or any index indicates poor or very poor performance.

Physical habitat was evaluated using the Qualitative Habitat Evaluation Index (QHEI) developed by the Ohio EPA for streams and rivers in Ohio (Rankin 1989). Various attributes of the available habitat are scored based on their overall importance to the establishment of viable, diverse aquatic faunas. Evaluations of type and quality of substrate, amount of instream cover, channel morphology, extent of riparian canopy, pool and riffle development and quality, and stream gradient are among the metrics used to determine the QHEI score which generally ranges from 20 to 100. The QHEI is used to evaluate the characteristics of a stream segment, not just the characteristics of a single sampling site. As such, individual sites may have much poorer physical habitat due to a localized disturbance yet still support aquatic communities closely resembling those sampled at adjacent sites with better habitat, provided water quality conditions are similar. QHEI scores from hundreds of segments around the state have indicated that values higher than 60 are generally conducive to the establishment of warmwater faunas while those scores in excess of 75-80 often typify habitat conditions which have the ability to support exceptional faunas.

During this survey, macroinvertebrates were sampled with a standard dip net for a qualitative assessment of the available natural substrates. Macroinvertebrate sites in the study area were evaluated using an assessment tool currently in the developmental phase. This method utilizes the qualitative, natural substrate collections available from each site and relies on tolerance values derived for each macroinvertebrate taxon collected. These tolerance values, unlike other tolerance values used in common indices (e.g., the Hilsenhoff Biotic Index), utilizes the abundance data for a given taxon collected with artificial substrates at sites around Ohio. To determine the tolerance value of a given taxon, ICI scores at all locations in the ecoregion where the taxon has been collected with artificial substrates are weighted by the abundance data of that taxon at those sites. The mean of the weighted ICI scores for the taxon results in the tolerance value of that taxon. Thus, a taxon's tolerance value represents its relative level of tolerance on the ICI's 0 to 60 scale. High tolerance values are calculated for the more intolerant taxa which tend to reach their greatest abundance at undisturbed sites (i.e., sites with highest ICI scores). Conversely, the more pollution tolerant taxa attain their greatest abundances at highly disturbed sites with low ICI scores, which results in a lower tolerance value. For the qualitative macroinvertebrate collections in the River Styx study area, the median tolerance value, based on all tolerance values of the organisms collected at a site, resulted in what has been termed the Qualitative Community Tolerance Value (QCTV). The 25th percentile median QCTV values for sites in the EOLP ecoregion that have met the macroinvertebrate ICI criteria is 35.7. The 75th percentile median QCTV values for sites in the EOLP ecoregion that have not met the macroinvertebrate ICI criteria is 31.7. Therefore, median QCTV greater than 35.7 reflect conditions where ICI values would be expected to meet or exceed biocriterion while median QCTV less than 31.7 reflect conditions where ICI values would not be expected to meet biocriterion. Though only in the developmental stage, the QCTV shows potential as a method to supplement existing assessment methods using the qualitatively collected macroinvertebrate information.

Fish were sampled two times with pulsed DC electrofishing gear using the wading method (200 meter zones). Chemical/physical and biological sampling locations are listed in Table 3. An Area Of Degradation Value (ADV; Rankin and Yoder 1992) was calculated for the study area based on the longitudinal performance of the biological communities. The ADV portrays the length or "extent" of degradation to aquatic communities and is simply the distance that the biological index (IBI, MIwb, and ICI) departs from the stream criterion or the upstream level of performance. The magnitude of impact refers to the vertical departure of each index below the criterion. The total ADV is the area beneath the ecoregional criterion when the results for each index are plotted against river mile. This is also expressed as ADV/mile to normalize comparisons between segments and other areas.

Results and Discussion

Pollutant Loadings: 1983-1993

Wadsworth WWTP

The Wadsworth WWTP (RM 3.34) is an activated sludge plant with settling, phosphorus removal and chlorination. The average design flow of the plant is 3.6 MGD with a peak flow of 5.8 MGD. Installation of dechlorination equipment at the WWTP is scheduled for 1994. Less than ten percent of the plant flow is derived from industrial sources. Figure 2 illustrates loadings trends of the Wadsworth WWTP from 1983 to 1993. Total Kjeldahl nitrogen (TKN) loadings and temperature have not changed appreciably in the last ten years. Total suspended solids (TSS) and five–day carbonaceous biochemical oxygen demand ($cBOD_5$) loadings appear to be increasing slightly. These increases may be attributable to slightly increased flows treated at the plant since 1988. Current total zinc loadings have increased since 1989 but are less than loadings reported in 1987. Wadsworth WWTP has a prolonged history of total copper concentration violations of their NPDES permit. The copper violations have been reduced since the Wadsworth WWTP permit limits were raised from 14 to 50 $\mu g/l$. Slight acute toxicity was found in testing of the effluent in June 1987. Twenty four hour composite samples, grab samples and mixing zone samples were acutely toxic when sampled in April 1993. The effluent was not acutely toxic in samples collected in August 1993.

Compliance history of Wadsworth WWTP (number of months reporting violations at least once during that month)

1993: *TSS* - 1; *O&G* - 1; *Cu* - 11; *Hg* - 2; *Ni* - 12
1992: *Cu* - 12; *Cd* - 1; *Zn* - 1
1991: *Cu* -12; *Hg* - 5; *Ni* - 1; NH_3 - 2; Cl_2 - 2; *Cr* - 1
1990: *Cu* - 12; *Hg* - 4; Cl_2 - 1; *pH* - 1; *D.O.* - 1
1989: *Cu* - 12; *Hg* - 3; *Cr* - 1
1988: *Cu* - 5; NH_3 - 3
1987: *Cu* - 11; *Zn* - 1
1986: *Cu* - 1; NH_3 - 2
1985: *Cu* - 1; NH_3 - 2
1984: *pH* - 1

Packaging Corporation of America–Paperboard Division (PCA)

PCA produces paperboard (60%) and coated paperboard (40%) from recycled newsprint and cardboard. The facility has four permitted outfalls. Outfall 001 (RM 0.92) discharges approximately 2.5 MGD of treated wastewater from hydropulping screening operations. Secondary treatment of this wastewater includes dissolved air floatation (with partial wastewater recycling), primary settling, aerated stabilization lagoons (operated either in series or in parallel), settling (final clarifier installed in June 1992) and post aeration. Ammonia and phosphoric acid are added for nutritional supplement of the biologic processes. Sludge is gravity thickened, centrifuged, chlorinated and returned to the pulp making process. Previously, the sludge was incinerated and the incinerator ash disposed in lagoons on plant property. Boiler blowdown and coal pile run-off also is treated in the lagoon system. Outfall 002 (RM 0.74) discharges approximately 1.7 MGD of cooling water overflow from a separate cooling pond. Hypochlorite was used as a biocide additive to the cooling water until about 1991. No biocides are currently used in this waste stream. Make up

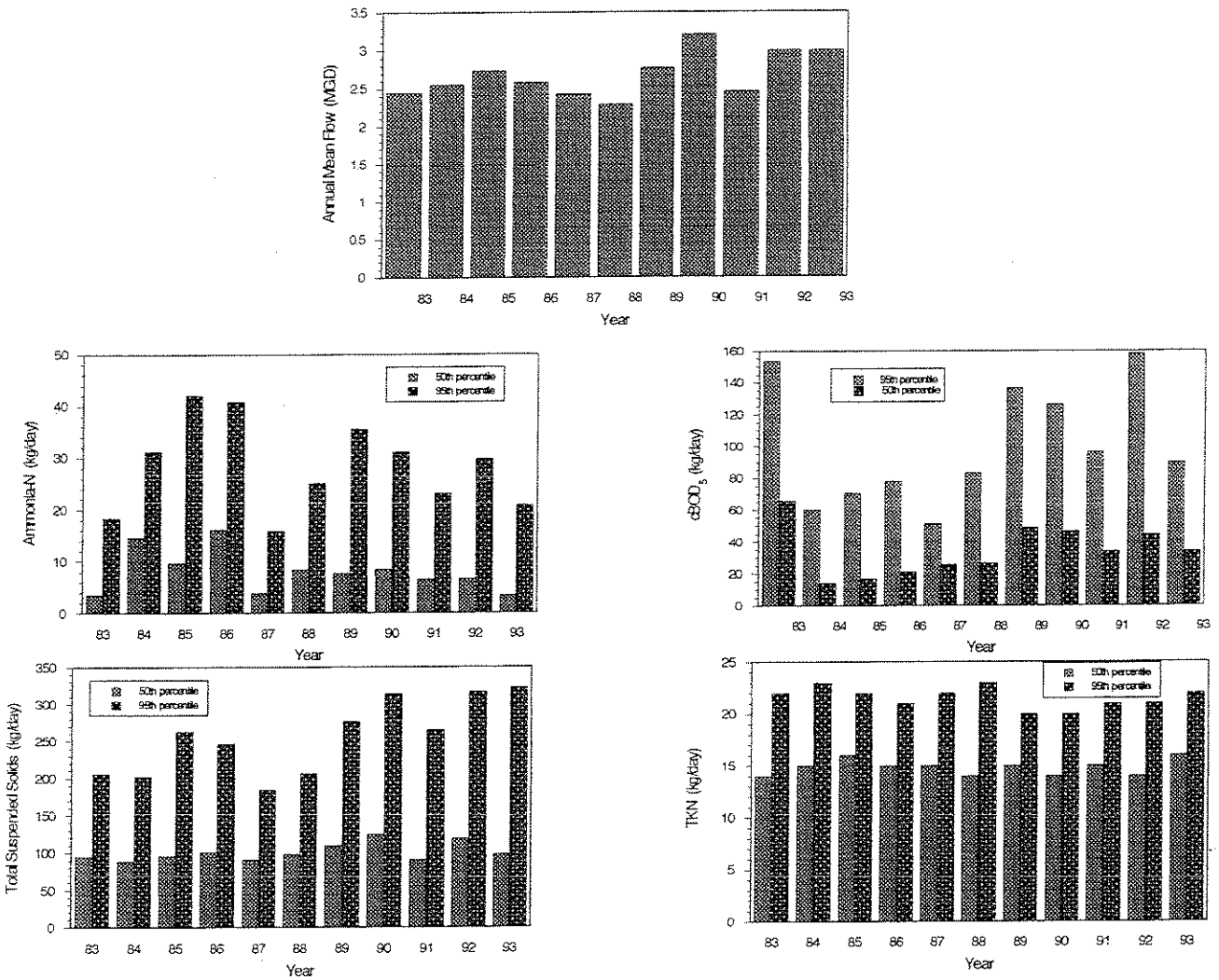


Figure 2. Annual loadings (kg/day) of ammonia–N, carbonaceous biochemical oxygen demand ($cBOD_5$), total suspended solids (TSS), total Kjeldahl nitrogen (TKN) and annual mean flows (MGD) for the Wadsworth WWTP discharge to the River Styx, 1983 through 1993. Loadings of $cBOD_5$ in 1983 are calculated from BOD_5.

water is from Chippewa Creek and on–site groundwater wells. Outfalls 004 and 003 (RM 0.8) are storm water run-off from abandoned coal storage area and parking lots, respectively.

Acute bioassays conducted in April and August 1988 indicated acute toxicity of both *daphnia* and fathead minnows at outfall 001. Two acute bioassay tests conducted in 1993 did not indicate toxicity at the same outfall. A treatment facility upset at 001 was noted during in-stream biological sampling on August 11, 1993 which turned the River Styx light brown with suspended solids. The PCA monthly operating reports for that date record no exceedences of their daily maximum permit limits. A suspended solids value of 118 mg/l was reported. The daily maximum permit limit is 150 mg/l.

The following NPDES violations have been recorded for the PCA outfalls from 1984 to 1993:
(Violations are for 001 unless noted otherwise)
1993: *Zn* - 3; *TSS* - 3; *Hg* - 3 (002); NH_3 - 1; *Ag* - 1; *Phenol* - 1; *pH* (004) - 2.
1992: *TSS* - 6; NH_3 - 1; *Hg* (002) - 2; *Zn* - 4; *pH* (004) - 2.
1991: *TSS* - 1
1990: *TSS* - 1; *pH* (002) - 1; *pH* (004) - 2
1989: BOD_5 - 2; *Bypass* - 1; *Overflow* (002) - 1.
1985-1988: *No violations*
1984 - BOD_5 - 2.

Figure 3 illustrates loadings trend of the PCA 001 outfall from 1983 to 1993. Total zinc loadings and temperature have remained fairly constant since 1983 while ammonia loadings have declined . TKN loadings appear to closely follow temperature. TKN loadings and temperature readings at 002 also seem to be inversely related to flow.

Rittman WWTP

The newly constructed Rittman WWTP (RM 0.74) is an extended aeration activated sludge plant with polymer addition, settling, chlorination and dechlorination. Construction of the new Rittman WWTP was essentially completed in February 1993. The discharge location for the Rittman WWTP changed from RM 0.6 (west bank) to RM 0.75 (east bank) after the new WWTP was constructed. The new discharge location is directly across the stream from the PCA 002 discharge. The average design flow of the new plant is 1.6 MGD with a peak flow of 3.8 MGD. Less than ten percent of the plant flow is derived from industrial sources.

Temperature, TKN and phosphorus loadings and temperature readings were essentially unchanged since 1983. Ammonia loadings decreased while TSS loadings seem to be slightly decreased since 1983. The WWTP had declining flows until 1992 when the flows sharply increased. This increased flow could be attributed to the elimination of SSOs that were not treated at the WWTP prior to 7/1/93. Figure 4 illustrates loading trends of the Rittman WWTP outfall from 1983 to 1993.

Chemical Water Quality

- Water quality sampling was conducted during the summer of 1993. There is no flow gaging station on the River Styx. The nearest USGS station in the same system is Chippewa Creek at Sterling. Minimum discharge observed at the Sterling station was 1.7 CFS in 1975. Q_7-10 for the period May to November is calculated by USGS as 0.8 CFS (0.0124 CFS/mi^2).

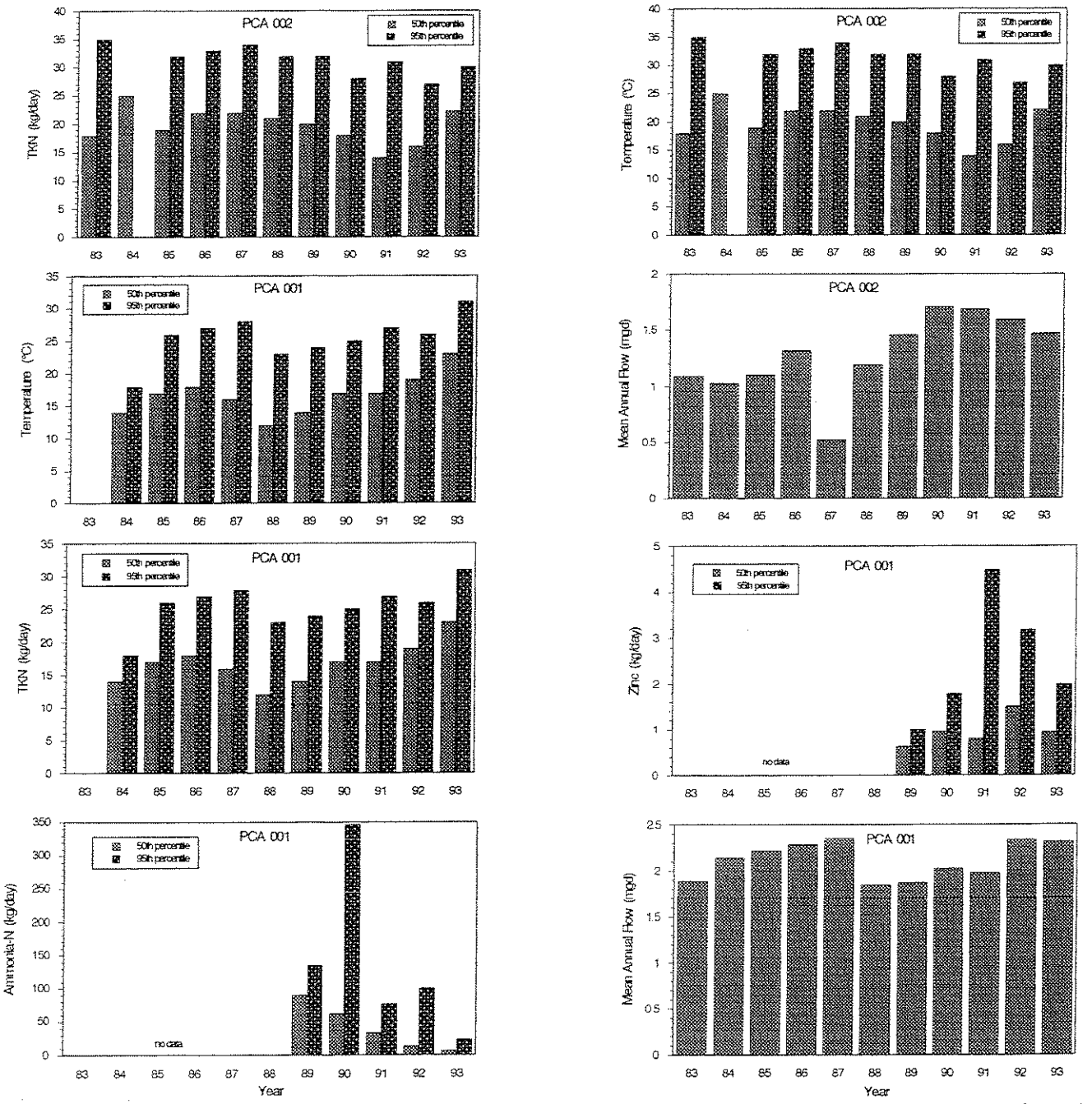


Figure 3. Mean annual flow (MGD), 50th and 95th percentile temperature measurements (°C) and annual loadings (kg/day) of ammonia–N, total zinc and total Kjeldahl nitrogen (TKN) for the PCA outfall 001. Mean annual flow (MGD), 50th and 95th percentile temperature measurements (°C) and annual loadings (kg/day) of TKN for PCA outfall 002 to the River Styx, 1983 through 1993.

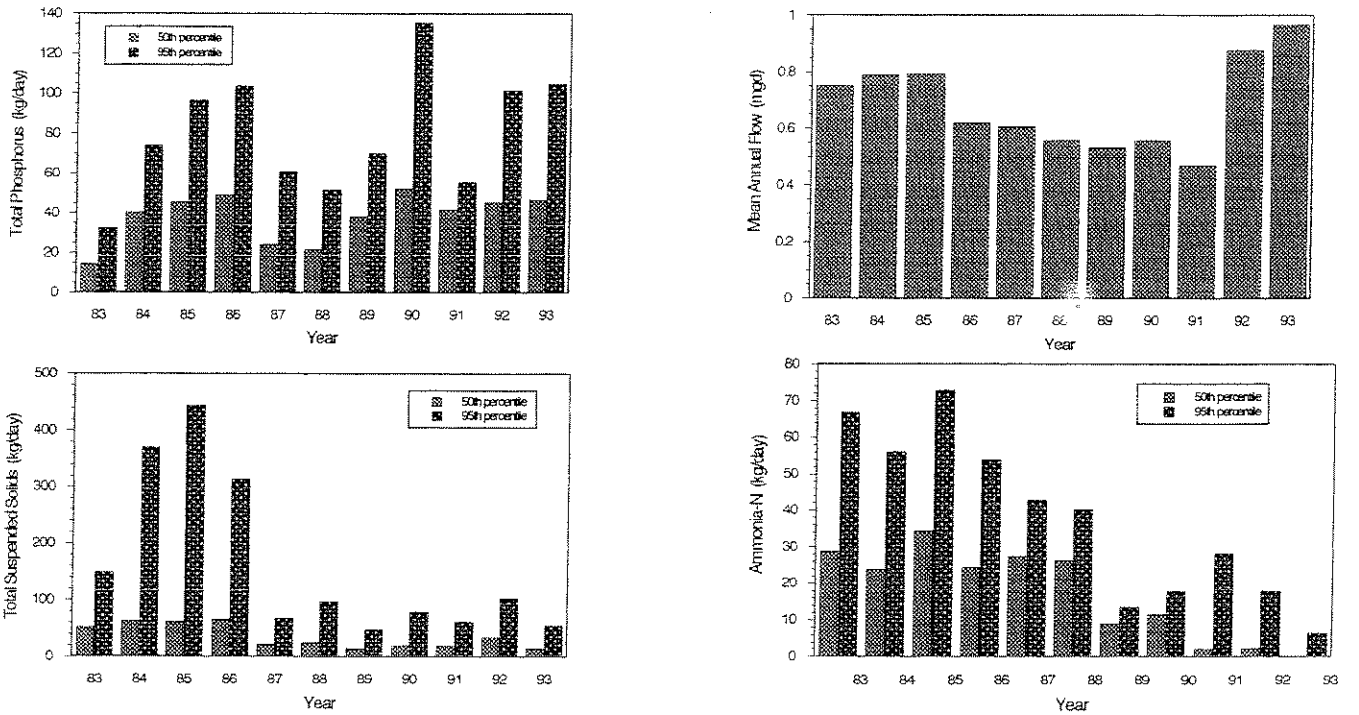


Figure 4. Annual loadings (kg/day) of ammonia–N, total suspended solids, total phosphorus and mean annual flow (MGD) for the Rittman WWTP to the River Styx, 1983 through 1993.

- Figure 5 shows the sampling results of the 1993 survey for Total phosphorus, TKN, ammonia–N and nitrate/nitrite.
- A single exceedence of the chronic MWH ammonia-N criteria was recorded at RM 2.8 (3.89 mg/l). One exceedence of the average daily water temperature criteria was recorded by an instantaneous measurement at RM 0.1. No other exceedences of either chronic or acute water quality criteria were documented.
- Elevated counts of bacteria were documented in 8 of 10 samples. *E. coli* (840 at RM 0.01; 1190 at RM 0.75; 3040 at RM 3.5) and fecal coliform bacteria (4900 at RM 0.01; 4200 at RM 0.75; 3300 at RM 3300) counts exceeded the primary contact recreation criteria. RM 2.8 counts (downstream from the Wadsworth WWTP) were significantly lower than both upstream and downstream counts. This indicates probable in–stream exceedences of the chlorine water quality criteria from the Wadsworth WWTP effluent.
- 7 of the 16 (44%) instream phosphorus values exceeded 1.0 mg/l. None of these high values were reported upstream from the WWTPs.
- Concentrations of chemical oxygen demand (COD), total zinc and total arsenic increased from upstream to downstream.
- Concentration of nitrate/nitrite decreased from upstream to downstream.
- Instream temperature increased downstream from the PCA discharges.

Table 5. Exceedences of Ohio EPA Warmwater Habitat criteria (OAC 3745-01) for chemical/physical parameters measured in the River Styx study area, 1993 (units are µg/l for metals, ° C for Temperature, #/100 ml for fecal coliform and *E. coli*, and mg/l for all other parameters).

Stream Name	River Mile	Violation: Parameter (value)
River Styx		
	3.5	***E. coli* (3040)◊◊; Fecal Coliform Bacteria (3300)◊◊**
	2.8	NH_3-N (3.89)*
	0.75	***E. coli* (1190)◊◊; Fecal Coliform Bacteria (4200)◊◊**
	0.1	***E. coli* (840)◊◊; Fecal Coliform Bacteria (4900)◊◊**
		Temperature (28° C)†

* indicates an exceedence of numerical criteria for prevention of chronic toxicity (CAC).
** indicates an exceedence of numerical criteria for prevention of acute toxicity (AAC).
◊ indicates an exceedence of the primary contact recreation criteria.
◊◊ indicates an exceedence of the secondary contact recreation criteria.
† indicates an exceedence of the average temperature criterion

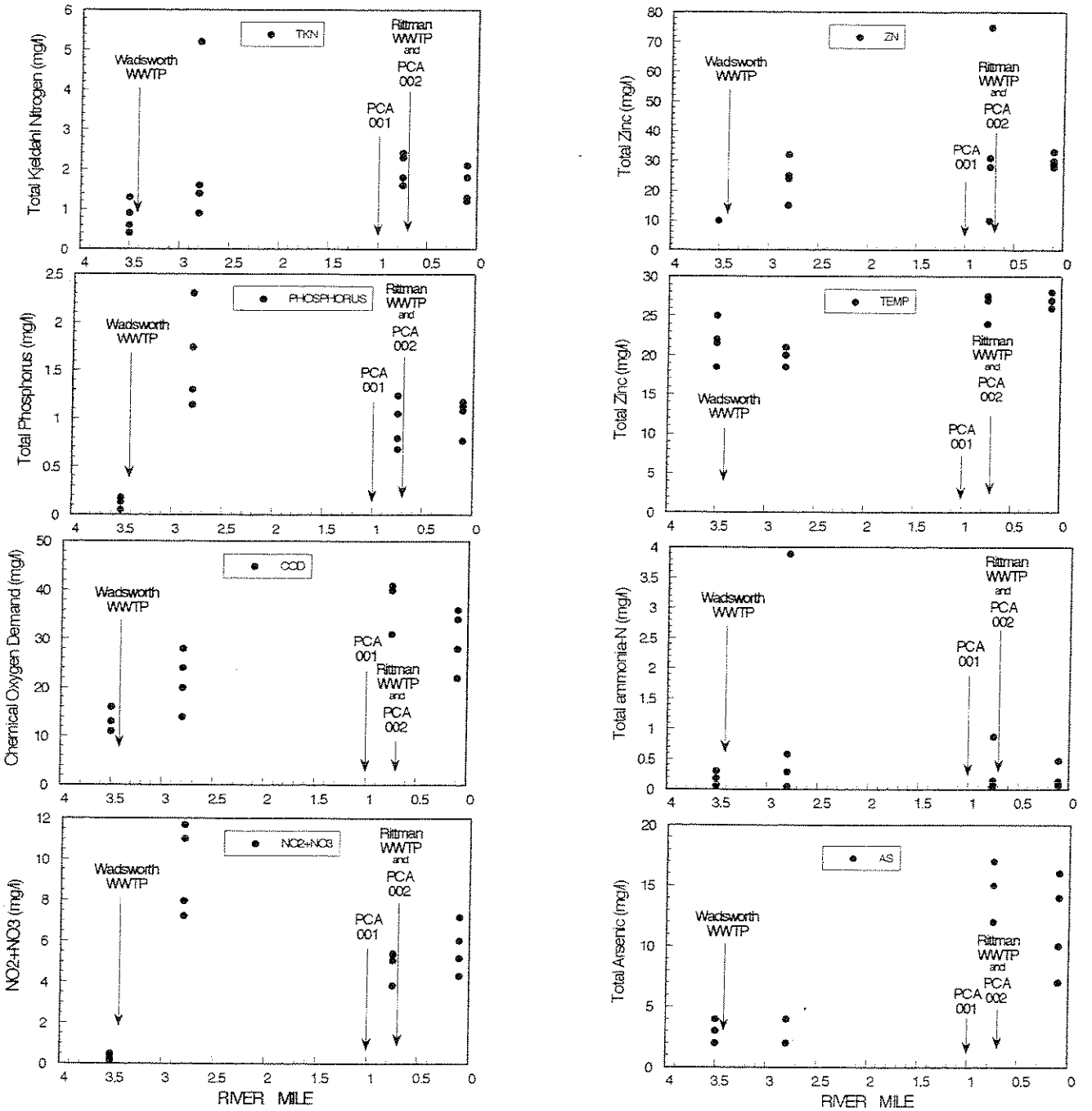


Figure 5. Longitudinal trends of total phosphorus, total Kjeldahl nitrogen (TKN), chemical oxygen demand (COD), total zinc, total arsenic, nitrate/nitrite, temperature and ammonia-N in the River Styx, 1993.

Physical Habitat for Aquatic Life

- Macrohabitats were evaluated at each of the four fish sampling locations on the River Styx. Qualitative Habitat Evaluation Index values ranged from 31.0 (RM 0.1) to 44.0 (RM 2.8) with a mean score of 36.3. A mean QHEI value less than 45.0 suggests that near and in–stream habitats of the River Styx are not of sufficient quality to support and maintain an aquatic community that can attain the WWH biological criteria.

- Habitat quality remained uniformly poor within the study area due to past modification of the stream channel. Portions of the stream near RM 2.8 are beginning to show signs of recovery from the 1975 and 1980 channelization efforts.

- Table 6 lists the key QHEI components which indicates that the River Styx macrohabitat is affected predominantly by MWH attributes (Moderate influence)

Biological Assessment: Macroinvertebrate Community

- Median Qualitative Community Tolerance Values (QCTVs) were determined from qualitative sampling in the River Styx. Quantitative macroinvertebrate sampling was not performed in the study area due to resource constraints. The median QCTVs indicate that the river is impacted from point sources within the study area. Median QCTV values ranged from 34.3 (fair) upstream from point source discharges to 23.2 (poor) downstream from Wadsworth, PCA and Rittman WWTP discharges. Median QCTV values greater than 35.7 reflect conditions where ICI values would be expected to meet or exceed biocriterion while median QCTV values less than 31.7 reflect conditions where ICI values would not be expected to meet biocriterion.
- Total macroinvertebrate taxa ranged from 41 upstream from point source discharges to 16-22 taxa downstream from Wadsworth, PCA and Rittman WWTPs. Total *Ephemeroptera*, *Plecoptera* and *Trichoptera* (EPT) taxa decreased from 6 to 1 downstream from the Wadsworth WWTP.
- Tolerant and common midge taxa were the predominant organisms found at all sites. Macroinvertebrate total organism density was low downstream from the point source dischargers in the study area indicating possible toxicity.
- In–stream toxicity of *ceriodaphnia dubia* was observed in two of three samples collected upstream of the Wadsworth WWTP for upstream dilution waters used in theWadsworth bioassay tests.

Biological Assessment: Fish Community

- A total of 3,906 fish comprised of 26 species and three hybrids were collected from the River Styx mainstem between July 27 and September 16, 1993. The sampling effort included a total of 1.6 km at four sampling stations between RM 3.5 (upstream Wadsworth WWTP) and RM 0.1 (near the mouth).
- The fish species that numerically predominated were: creek chub (34.5%), central stoneroller minnow (20.4%), white sucker 10.0%), bluntnose minnow (6.9%) and blacknose dace (5.5%). Species that predominated in terms of biomass were: common carp (53.7%), creek chub (17.2%), central stoneroller minnow (6.3%), yellow bullhead (3.0%) and green sunfish (2.1%).
- In terms of relative abundance the community consisted mainly of tolerant and moderately tolerant, insectivorous and omnivorous cyprinid species. In terms of relative weight the community was predominated by highly tolerant forms. Based on IBI and MIwb scores and the accompanying narrative evaluations, overall fish community performance can be characterized as fair to very poor.

Table 6. Key QHEI Components of the River Styx

River Mile	QHEI	Gradient (ft/mile)	WWH Attributes: *No Channelization or Recovered*	*Boulder/Cobble/Gravel Substrates*	*Silt Free Substrates*	*Good/Excellent Substrates*	*Moderate/High Sinuousity*	*Extensive/Moderate Cover*	*Fast Current/ Eddies*	*Low/Normal Embeddedness*	*Max Depth > 40 cm*	*Low/No Riffle Embeddedness*	**Total WWH Attributes**	MWH *High Influence*: *Channelized or No Recovery*	*Silt/Muck Substrates*	*Low Sinuousity*	*Sparse/No Cover*	*Max Depth < 40 cm (WD,HW)*	**Total H.I. MWH Attributes**	MWH *Moderate Influence*: *Recovering Channel*	*Heavy/Moderate Silt Cover*	*Sand Substrates (Boat)*	*Hardpan Substrate Origin*	*Fair/Poor Development*	*Low/No Sinuosity*	*Only 1-2 Cover Types*	*Intermittent & Poor Pools*	*No Fast Current*	*High/Moderate Embeddedness*	*Ext./Moderate Riffle Embed.*	*No Riffle*	**Total M.I. MWH Attributes**	**MWH H.I./WWH Ratio**	**MWH M.I./WWH Ratio**
(17-553) – River Styx																																	
Year: 93																																	
3.5	37.5	2.6									■		1			●	●		2	▲	▲		▲	▲			▲	▲	▲	▲	▲	8	1.50	5.50
2.8	44.0	2.6						■			■		2				●		1	▲	▲		▲	▲				▲	▲	▲		7	.67	3.00
.8	32.5	2.6	■								■		2			●	●		2	▲	▲		▲	▲				▲	▲		▲	7	1.00	3.33
.1	31.0	1.2											0			●	●	●	3	▲	▲		▲	▲				▲	▲		▲	7	4.00	*.**

Table 7. Qualitative evaluation of the macroinvertebrate community in the River Styx study area, 1993

Qualitative Evaluation

Stream River Mile	No. Taxa	Qual. QCTV[c]	Qual. EPT[b]	Relative Density	Predominant Organisms	Narrative Evaluation[a]
River Styx						
3.5	41	34.3	6	Medium	Midges/Odonates	Fair
2.8	16	23.2	1	Low	Midges	Poor
0.75	22	23.2	2	Low	Midges	Poor
0.1	16	23.2	3	Low	Midges	Poor

a A qualitative narrative evaluation is based on best professional judgement is used when quantitative data is not available to calculate the Invertebrate Community Index (ICI) scores.

b EPT= total Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies).

c Qualitative Community Tolerance Value (QCTV) calculated as the average of the weighted ICI for each taxa.

- Community indices and narrative evaluations ranged from fair (most upstream sampling station) to poor/very poor (near the mouth and downstream of all dischargers). Good or exceptional performance was not observed. Only the most upstream site on the River Styx met expectations consistent with the MWH biocriteria (Table 8).
- At RM 3.5 (upstream of Wadsworth WWTP) community performance was fair (IBI=27; MIwb=7.9). The fish assemblage at this station maintained a structural and functional organization reflective of modified instream habitats, fully achieving the MWH biological criteria.
- At RM 2.8 (downstream of Wadsworth WWTP at Wall Road) community performance was marginally fair to poor (IBI=26; MIwb=5.9). However, intermediate species such as the southern redbelly dace and barred fantail darter found at RM 3.5 were not found at this site, indicating impacts from the Wadsworth WWTP.
- At RM 0.75 (downstream of PCA) community performance was poor to very poor (IBI=23; MIwb=4.1). The fish assemblage at this station indicated degraded conditions from upstream sites possibly due to organic enrichment.
- Near the river's mouth (RM 0.1), diminished community performance was noted resulting in non-achievement of MWH biological criteria at RM 0.1. In comparison to the sampling station upstream overall species richness and number of individuals were significantly reduced, and the percent DELT anomalies and percent omnivorous species showed an increase. The observed shifts within the fish community were those typically associated with complex toxic pollution impacts.
- Erratic swimming of *fathead minnows* was observed in one of three bioassay samples collected upstream of the Wadsworth WWTP for upstream dilution waters used for Wadsworth bioassay tests.

Trend Assessment

River Styx

Chemical Water Quality Changes: 1983-1993.

- Improved chemical water quality for nearly all parameters was noted for the River Styx from 1983 to 1993. These improvements include ammonia–N, total Kjeldahl nitrogen, dissolved oxygen, conductivity, total copper, total lead and total zinc. Since no flow information is available for each survey, it is not known if these improvements in water quality can be attributed to improvements in wastewater discharges, or are related to differing flow conditions.
- Notable decreases of TKN, and to a lesser extent NH3–N and COD, were documented downstream from PCA, the City of Rittman and the Rittman WWTP.
- Increased phosphorus concentrations were noted downstream from the Wadsworth WWTP from 1983 to 1993.

Table 9. WWTP changes in the River Styx Basin since 1981.

Facility	Receiving stream	Change
Rittman WWTP	River Styx	Upgrade to advanced secondary
City of Rittman	River Styx	Elimination of SSOs
PCA River Styx	River Styx	Sludge recycle to process Installation of final clarifier

Changes in Biological Community Performance: 1983- 1993

- Habitat indices (QHEI) were similar from 1983 to 1993. The habitat within the study area is described as recovering from channelization.
- MIwb and IBI indices values between 1983 and 1993 have not changed significantly and the values at each sampling location are within the error ranges for the indices.
- The number of fish species declined from 1983 to 1993 (Figure 7). This decline in fish species may be attributed to collections of only one or two individuals of a species collected in 1983 that were not collected in 1993.
- The biota at the river mouth in 1993 continues to be severely degraded similar to that found in 1983.
- Area of Degradation Values (ADV) for the River Styx increased from 1983 to 1993 indicating decreased performance of the aquatic communities (Table 10).

Table 9. Fish community indices based on pulsed D.C. electrofishing samples at four locations sampled by Ohio EPA in the River Styx study area during July - September, 1993.

Stream River Mile	Mean Number of Species	Cumulative Species	Mean Rel. No. (No./Km)	Mean Rel. Wt. (Kg/Km)	QHEI	Mean Modified Index of Well-Being	Mean Index of Biotic Integrity	Narrative Evaluation
River Styx								
3.5	17	17	1824	26	41	7.9	**27**	Good/**Poor**
2.8	19	19	842	16	43.5	5.9	**26***	Fair/**Poor**
0.75	16	16	182	42	34.5	**4.1***	**23***	**V.Poor/Poor**
0.1	12	19	81	4	35	**4.3***	**17***	**V.Poor/V.Poor**

Ecoregion Biocriteria: Erie Ontario Lake Plain (EOLP)

INDEX - Site Type	WWH	EWH	MWH[d]
IBI - Headwaters/Wading	40	50	20
IBI - Wading	38	50	22
Mod. Iwb - Wading	7.9	9.4	5.6

[d] - Modified Warmwater Habitat for channel modified areas.

* - Significant departure from applicable biological criterion; underlined values are in the poor and very poor range.

a - Narrative evaluation is based on both MIwb and IBI scores.

NA - Headwater site; MIwb is not applicable.

ns - Nonsignificant departure from biocriterion (≤4 IBI units or < 0.5 MIwb units)

a - Narrative evaluation is based on both MIwb and IBI scores.

NA - Headwater site; MIwb is not applicable.

Table 10. Area of Degradation (ADV) statistics for the River Styx study area, 1983 and 1993

Stream Index	Biological Index Scores				ADV Statistics			Attainment Status (miles)[a]			
	Upper RM	Lower RM	Mini-mum	Maxi-mum	ADV	**ADV/ Mile**	**Poor/VP ADV**	FULL	PARTIAL	**NON**	**Poor/VP**
River Styx (1983)											
IBI[a]			19	38	14	3.7	26				
MIwb	3.9	0.1	4.2	8.6	30	7.9	5	1.6	1.7	1.2	1.2
ICI			10	18	227	60	9				
River Styx (1993)											
IBI[a]			17	27	42	12.4	78				
MIwb	3.5	0.1	4.1	7.9	25	7.4	4	0.6	0.6	2.9	2.9
ICI			P[b]	F	320	94	0				

[a] - ADV statistics based on local expectations (e.g. upstream).

[b] - Narrative evaluation used in lieu of ICI where quantitative sampling was not done (E=Exceptional; G=good; MG=Marginally good; F=Fair; P=Poor; VP=Very Poor).

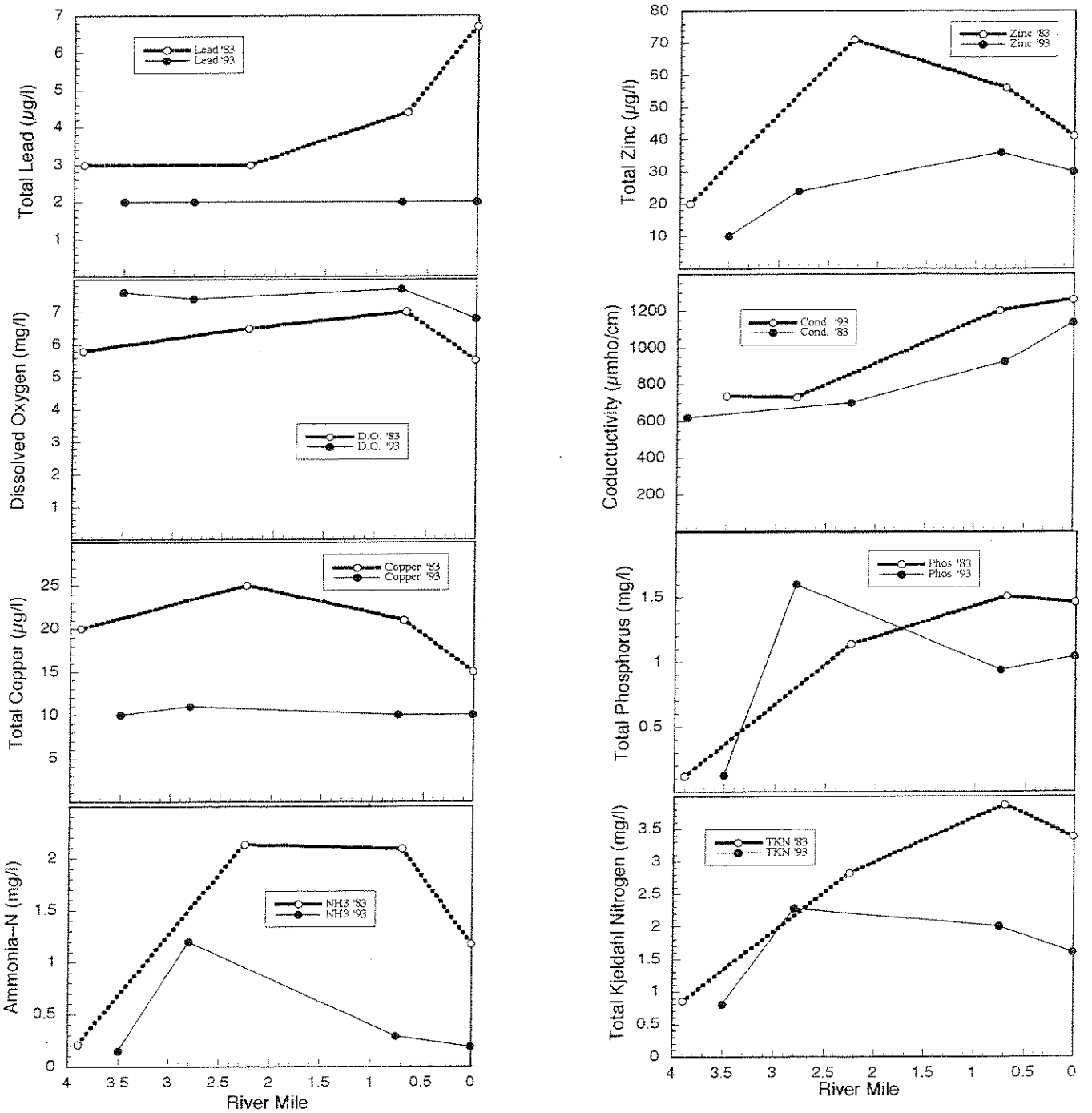


Figure 6. Historical trends of ammonia–N, total Kjeldahl nitrogen, dissolved oxygen, total copper, total lead, total zinc, total phosphorus and conductivity in the River Styx from 1983 to 1993.

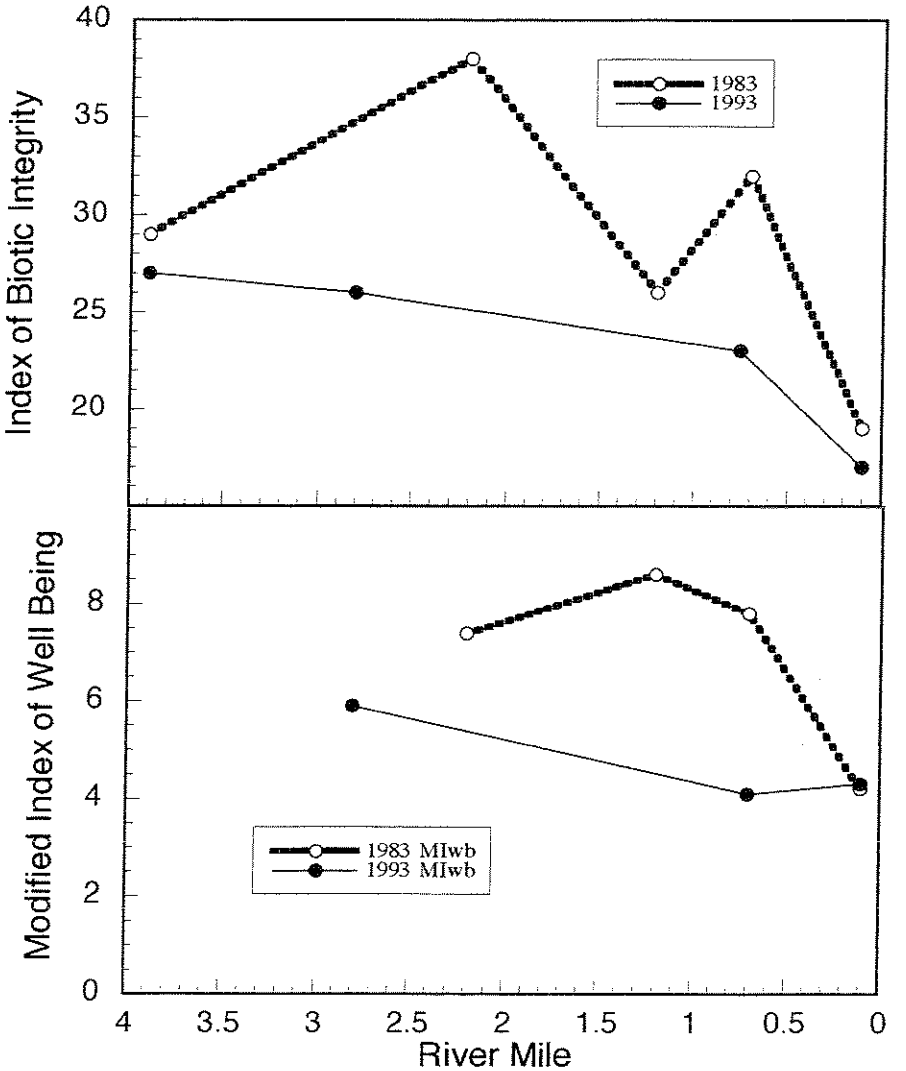


Figure 7. Historical trends of the Index of Biotic Integrity and the Modified Index of Well Being in the River Styx from 1983 to 1993.

References

Fausch, D.O., J.R. Karr and P.R. Yant. 1984. Regional application of an index of biotic integrity based on stream fish communities. Trans. Amer. Fish. Soc. 113:39-55.

Gammon, J.R. 1976. The fish populations of the middle 340 km of the Wabash River. Tech. Report No. 86. Purdue University. Water Resources Research Center, West Lafayette, Indiana. 73 pp.

Gammon, J.R., A. Spacie, J.L. Hamelink, and R.L. Kaesler. 1981. Role of electrofishing in assessing environmental quality of the Wabash River. pp. 307-324. In: Ecological assessments of effluent impacts on communities of indigenous aquatic organisms. ASTM STP 703, J.M. Bates and C.I. Weber (eds.). Philadelphia, PA.

Hughes, R. M., D. P. Larsen, and J. M. Omernik. 1986. Regional reference sites: a method for assessing stream pollution. Env. Mgmt. 10(5): 629-635.

Karr, J.R. 1981. Assessment of biotic integrity using fish communities. Fisheries 6 (6): 21-27.

Karr, J.R. and D.R. Dudley. 1981. Ecological perspective on water quality goals. Env. Mgmt. 5(1): 55-68.

Kelly, M. H., R. L. Hite. 1984. Evaluation of Illinois stream sediment data: 1974-1980. Illinois Environmental Protection Agency, Division of Water Pollution Control. Springfield, Illinois.

Ohio Dept. of Natural Resources 1954. Gazetteer of Ohio streams. Division of Water, Ohio Water Plan Inventory Report No. 12.

___ 1992. Species of animals that are considered to be endangered, threatened, of special interest, extirpated, or extinct in Ohio. Inservice note 659. Division of Wildlife, Columbus, Ohio.

Ohio Environmental Protection Agency. 1987a. Biological criteria for the protection of aquatic life: Volume I. The role of biological data in water quality assessment. Division of Water Quality Monitoring and Assessment, Surface Water Section, Columbus, Ohio.

___ 1987b. Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters. Division of Water Quality Monitoring and Assessment, Surface Water Section, Columbus, Ohio.

___ 1989a. Addendum to biological criteria for the protection of aquatic life: Users manual for biological field assessment of Ohio surface waters. Division of Water Quality Planning and Assessment, Surface Water Section, Columbus, Ohio.

___ 1989b. Biological criteria for the protection of aquatic life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities. Division of Water Quality Planning and Assessment, Columbus, Ohio.

___ 1989c. Ohio EPA manual of surveillance methods and quality assurance practices, updated edition. Division of Environmental Services, Columbus, Ohio.

___ 1990b. Ohio water resource inventory - 1992 305b report. Volume II. Edward T. Rankin, editor. Division of Water Quality Planning and Assessment, Surface Water Section, Columbus, Ohio.

___ 1983. Unpublished River Styx water quality data. Division of Surface Water, Water Quality Section, Twinsburg, Ohio.

Omernik, J. M. 1988. Ecoregions of the conterminous United States. Ann. Assoc. Amer. Geogr. 77(1): 118-125.

Rankin, E.T. 1989. The qualitative habitat evaluation index (QHEI): rationale, methods, and application. Division of Water Quality Planning and Assessment, Columbus, Ohio.

Rankin,E.T.and C.O. Yoder. 1991. Calculation and uses of the Area of Degradation Value (ADV). Division of Water Quality Planning and Assessment, Surface Water Section, Columbus, Ohio.

Trautman, M.B. 1981 The fishes of Ohio with illustrated keys. Ohio State Univ. Press, Columbus, Ohio. 782pp.

United States Department of Agriculture. 1977. Soil Survey of Medina County.

United States Department of Agriculture. 1984. Soil Survey of Wayne County.

United States Geological Survey. 1981. Low flow characteristics of Ohio Streams. Open-File Report 81-1195.

___ 1992. Water resources data for Ohio. Volume 2. Ohio River Basin. Water-Data Report OH-091-2.

U.S. Environmental Protection Agency. 1988. Ecoregions of the Upper Midwest States. EPA/600/3-88/037.

APPENDICES

Appendix 1. List of fish species collected during 1993 River Styx Survey.

OHIO EPA WATER QUALITY PLANNING & ASSESMENT
FISH INFORMATION SYSTEM (FINS)

RIVER CODE: 17-553
RIVER MILE: 0.10
MPLE DATE: 1993
MPLER TYPE: E

BASIN NAME: Muskingum River
STREAM NAME: River Styx
TIME FISHED: 5700 SEC
DIST FISHED: 0.40 PASSES: 2

DATA SOURCE: 03
PURPOSE:
DATE RANGE: 08/24/93
THRU: 09/16/93

SPECIES CODE	SPECIES NAME	NO FISH	REL NO	% BY NUMBER	REL WT	% BY WEIGHT	AVE(GM) WEIGHT
20-003	GIZZARD SHAD	2	1.50	1.85	.030	.85	20.00
43-001	COMMON CARP	37	27.75	34.26	2.826	79.91	101.85
43-013	CREEK CHUB	2	1.50	1.85	.012	.33	7.50
43-015	SUCKERMOUTH MINNOW	2	1.50	1.85	.019	.54	12.50
43-026	COMMON SHINER	10	7.50	9.26	.025	.71	3.30
43-034	SAND SHINER	2	1.50	1.85	.014	.38	9.00
43-043	BLUNTNOSE MINNOW	6	4.50	5.56	.016	.44	3.33
43-044	CENTRAL STONEROLLER	6	4.50	5.56	.036	1.02	8.00
47-004	YELLOW BULLHEAD	24	18.00	22.22	.465	13.15	25.83
77-008	GREEN SUNFISH	13	9.75	12.04	.081	2.28	8.23
77-009	BLUEGILL SUNFISH	2	1.50	1.85	.007	.20	4.50
80-014	JOHNNY DARTER	2	1.50	1.85	.008	.21	5.00
	MILE TOTAL	108	81.00		3.539		
	NUMBER OF SPECIES	12					

RIVER CODE: 17-553
RIVER MILE: 0.80
SAMPLE DATE: 1993
SAMPLER TYPE: E

BASIN NAME: Muskingum River
STREAM NAME: River Styx
TIME FISHED: 9000 SEC
DIST FISHED: 0.40 PASSES: 2

DATA SOURCE: 03
PURPOSE:
DATE RANGE: 08/11/93
THRU: 09/10/93

SPECIES CODE	SPECIES NAME	NO FISH	REL NO	% BY NUMBER	REL WT	% BY WEIGHT	AVE(GM) WEIGHT
20-003	GIZZARD SHAD	8	6.00	3.29	.031	.07	5.13
40-016	WHITE SUCKER	6	4.50	2.47	.106	.25	23.50
43-001	COMMON CARP	29	21.75	11.93	37.838	89.73	1,739.65
43-002	GOLDFISH	2	1.50	.82	.308	.73	205.00
43-026	COMMON SHINER	5	3.75	2.06	.034	.08	9.00
43-034	SAND SHINER	1	.75	.41	.008	.02	10.00
43-043	BLUNTNOSE MINNOW	6	4.50	2.47	.033	.08	7.17
43-044	CENTRAL STONEROLLER	2	1.50	.82	.027	.06	17.50
43-045	COM. CARP X GOLDFISH	1	.75	.41	.900	2.13	1,200.00
47-004	YELLOW BULLHEAD	16	12.00	6.58	.833	1.97	69.37
77-001	WHITE CRAPPIE	1	.75	.41	.027	.06	35.00
77-006	LARGEMOUTH BASS	7	5.25	2.88	.048	.11	9.15
77-008	GREEN SUNFISH	119	89.25	48.97	1.348	3.20	15.10
77-009	BLUEGILL SUNFISH	34	25.50	13.99	.551	1.31	21.59
77-013	PUMPKINSEED SUNFISH	1	.75	.41	.027	.06	35.00
77-014	B'GILL X PUMPKINSEED	1	.75	.41	.012	.03	15.00
80-014	JOHNNY DARTER	2	1.50	.82	.008	.02	5.00
85-001	FRESHWATER DRUM	2	1.50	.82	.034	.08	22.50
	MILE TOTAL	243	182.25		42.173		
	NUMBER OF SPECIES	16					
	NUMBER OF HYBRIDS	2					

OHIO EPA WATER QUALITY PLANNING & ASSESMENT
FISH INFORMATION SYSTEM (FINS)

RIVER CODE: 17-553
RIVER MILE: 2.80
'PLE DATE: 1993
.PLER TYPE: E

BASIN NAME: Muskingum River
STREAM NAME: River Styx
TIME FISHED: 9000 SEC
DIST FISHED: 0.40 PASSES: 2

DATA SOURCE: 03
PURPOSE:
DATE RANGE: 08/09/93
THRU: 09/10/93

SPECIES CODE	SPECIES NAME	NO FISH	REL NO	% BY NUMBER	REL WT	% BY WEIGHT	AVE(GM) WEIGHT
34-001	CENTRAL MUDMINNOW	2	1.50	.18	.017	.10	11.00
40-016	WHITE SUCKER	169	126.75	15.05	2.869	17.76	22.63
43-001	COMMON CARP	2	1.50	.18	4.950	30.64	3,300.00
43-011	BLACKNOSE DACE	30	22.50	2.67	.067	.41	2.97
43-013	CREEK CHUB	560	420.00	49.87	5.284	32.71	12.58
43-026	COMMON SHINER	26	19.50	2.32	.339	2.10	17.36
43-034	SAND SHINER	3	2.25	.27	.018	.11	7.67
43-039	SILVERJAW MINNOW	14	10.50	1.25	.082	.51	7.79
43-043	BLUNTNOSE MINNOW	116	87.00	10.33	.502	3.11	5.77
43-044	CENTRAL STONEROLLER	25	18.75	2.23	.180	1.11	9.56
47-004	YELLOW BULLHEAD	15	11.25	1.34	.653	4.04	58.00
77-001	WHITE CRAPPIE	4	3.00	.36	.060	.37	20.00
77-006	LARGEMOUTH BASS	6	4.50	.53	.045	.28	10.00
77-007	WARMOUTH SF	8	6.00	.71	.200	1.23	33.25
77-008	GREEN SUNFISH	65	48.75	5.79	.333	2.06	6.82
77-009	BLUEGILL SUNFISH	25	18.75	2.23	.393	2.43	20.92
77-013	PUMPKINSEED SUNFISH	4	3.00	.36	.062	.38	20.50
77-014	B'GILL X PUMPKINSEED	1	.75	.09	.015	.09	20.00
80-014	JOHNNY DARTER	47	35.25	4.19	.090	.56	2.55
95-001	BROOK STICKLEBACK	1	.75	.09	.002	.01	2.00
	MILE TOTAL	1,123	842.25		16.161		
	NUMBER OF SPECIES	19					
	NUMBER OF HYBRIDS	1					

RIVER CODE: 17-553 BASIN NAME: Muskingum River DATA SOURCE: 03
RIVER MILE: 3.50 STREAM NAME: River Styx PURPOSE:
SAMPLE DATE: 1993 TIME FISHED: 8100 SEC DATE RANGE: 07/27/93
SAMPLER TYPE: E DIST FISHED: 0.40 PASSES: 2 THRU: 08/24/93

SPECIES CODE	SPECIES NAME	NO FISH	REL NO	% BY NUMBER	REL WT	% BY WEIGHT	AVE(GM) WEIGHT
40-016	WHITE SUCKER	210	157.50	8.63	5.073	19.80	32.21
43-001	COMMON CARP	3	2.25	.12	1.395	5.45	620.00
43-011	BLACKNOSE DACE	184	138.00	7.57	1.032	4.03	7.47
43-013	CREEK CHUB	784	588.00	32.24	9.713	37.91	16.52
43-016	SOUTH. REDBELLY DACE	2	1.50	.08	.019	.07	12.50
43-026	COMMON SHINER	23	17.25	.95	.257	1.00	14.89
43-034	SAND SHINER	2	1.50	.08	.010	.04	6.50
43-039	SILVERJAW MINNOW	125	93.75	5.14	.634	2.47	6.76
43-043	BLUNTNOSE MINNOW	142	106.50	5.84	.862	3.36	8.10
43-044	CENTRAL STONEROLLER	763	572.25	31.37	5.233	20.42	9.14
47-004	YELLOW BULLHEAD	32	24.00	1.32	.631	2.46	26.27
77-003	ROCK BASS	1	.75	.04	.019	.07	25.00
77-008	GREEN SUNFISH	12	9.00	.49	.090	.35	9.92
77-009	BLUEGILL SUNFISH	6	4.50	.25	.081	.32	18.00
77-013	PUMPKINSEED SUNFISH	1	.75	.04	.019	.07	25.00
77-015	GREEN SF X BLUEGILL	1	.75	.04	.014	.05	18.00
80-014	JOHNNY DARTER	136	102.00	5.59	.496	1.93	4.86
80-024	FANTAIL DARTER	5	3.75	.21	.046	.18	12.00
	MILE TOTAL	2,432	1,824.00		25.624		
	NUMBER OF SPECIES	17					
	NUMBER OF HYBRIDS	1					

RIVER CODE: 17-553 BASIN NAME: Muskingum River
MILE RANGE: 0.10 STREAM NAME: River Styx
THRU: 3.50 TIME FISHED: 31800 SEC
SAMPLER TYPE: E DIST FISHED: 1.60 PASSES: 8

RIVER SEGMENT TOTALS
PER SELECTED RANGES
DATE RANGE: 07/27/93
THRU: 09/16/93

SPECIES CODE	SPECIES NAME	NO FISH	REL NO	% BY NUMBER	REL WT	% BY WEIGHT	AVE(GM) WEIGHT
20-003	GIZZARD SHAD	10	1.88	.26	.015	.07	8.10
34-001	CENTRAL MUDMINNOW	2	.38	.05	.004	.02	11.00
40-016	WHITE SUCKER	385	72.19	9.86	2.012	9.20	27.87
43-001	COMMON CARP	71	13.31	1.82	11.752	53.74	882.79
43-002	GOLDFISH	2	.38	.05	.077	.35	205.00
43-011	BLACKNOSE DACE	214	40.13	5.48	.275	1.26	6.84
43-013	CREEK CHUB	1,346	252.38	34.46	3.752	17.16	14.87
43-015	SUCKERMOUTH MINNOW	2	.38	.05	.005	.02	12.50
43-016	SOUTH. REDBELLY DACE	2	.38	.05	.005	.02	12.50
43-026	COMMON SHINER	64	12.00	1.64	.164	.75	13.62
43-034	SAND SHINER	8	1.50	.20	.012	.06	8.00
43-039	SILVERJAW MINNOW	139	26.06	3.56	.179	.82	6.86
43-043	BLUNTNOSE MINNOW	270	50.63	6.91	.353	1.61	6.97
43-044	CENTRAL STONEROLLER	796	149.25	20.38	1.369	6.26	9.17
43-045	COM. CARP X GOLDFISH	1	.19	.03	.225	1.03	1,200.00
47-004	YELLOW BULLHEAD	87	16.31	2.23	.645	2.95	39.55
77-001	WHITE CRAPPIE	5	.94	.13	.022	.10	23.00
77-003	ROCK BASS	1	.19	.03	.005	.02	25.00
77-006	LARGEMOUTH BASS	13	2.44	.33	.023	.11	9.54
77-007	WARMOUTH SF	8	1.50	.20	.050	.23	33.25
77-008	GREEN SUNFISH	209	39.19	5.35	.463	2.11	11.80
77-009	BLUEGILL SUNFISH	67	12.56	1.72	.258	1.18	20.51
77-013	PUMPKINSEED SUNFISH	6	1.13	.15	.027	.12	23.67
77-014	B'GILL X PUMPKINSEED	2	.38	.05	.007	.03	17.50
77-015	GREEN SF X BLUEGILL	1	.19	.03	.003	.02	18.00
80-014	JOHNNY DARTER	187	35.06	4.79	.150	.69	4.28
80-024	FANTAIL DARTER	5	.94	.13	.011	.05	12.00
85-001	FRESHWATER DRUM	2	.38	.05	.009	.04	22.50
95-001	BROOK STICKLEBACK	1	.19	.03	.000	.00	2.00
	CODE TOTAL	3,906	732.44		21.872		
	NUMBER OF SPECIES	26					
	NUMBER OF HYBRIDS	3					

Appendix 2. List of macroinvertebrates collected during 1993 River Styx Survey.

Ohio EPA Ecological Assessment Section
Macroinvertebrate Collection

Collection Date: 08/24/93 River Code: 17-553 River: River Styx RM: .10

Taxa Code	Taxa	Quan/Qual
11130	*Baetis intercalaris*	0 +
17200	*Caenis sp*	0 +
22001	*Coenagrionidae*	0 +
45400	*Trichocorixa sp*	0 +
52200	*Cheumatopsyche sp*	0 +
63900	*Laccophilus sp*	0 +
67800	*Tropisternus sp*	0 +
74100	*Simulium sp*	0 +
77355	*Clinotanypus pinguis*	0 +
77750	*Hayesomyia senata or Thienemannimyia norena*	0 +
79020	*Tanypus neopunctipennis*	0 +
80420	*Cricotopus (C.) bicinctus*	0 +
83300	*Glyptotendipes (Phytotendipes) sp*	0 +
84450	*Polypedilum (P.) convictum*	0 +
84470	*Polypedilum (P.) illinoense*	0 +
95100	*Physella sp*	0 +

Taxa Code	Taxa	Quan/Qual

No. Quantitative Taxa: 0 Total Taxa: 16

No. Qualitative Taxa: 16 ICI:

Ohio EPA Ecological Assessment Section
Macroinvertebrate Collection

Collection Date: 08/11/93 River Code: 17-553 River: River Styx RM: .80

Taxa Code	Taxa	Quan/Qual
01801	*Turbellaria*	0 +
03600	*Oligochaeta*	0 +
11130	*Baetis intercalaris*	0 +
11200	*Callibaetis sp*	0 +
22001	*Coenagrionidae*	0 +
45400	*Trichocorixa sp*	0 +
63900	*Laccophilus sp*	0 +
67800	*Tropisternus sp*	0 +
71300	*Limonia sp*	0 +
74100	*Simulium sp*	0 +
77500	*Conchapelopia sp*	0 +
80420	*Cricotopus (C.) bicinctus*	0 +
80430	*Cricotopus (C.) tremulus group*	0 +
80510	*Cricotopus (Isocladius) sylvestris group*	0 +
81201	*Nanocladius (N.) sp*	0 +
82711	*Chironomus (C.) sp I*	0 +
82730	*Chironomus (C.) decorus group*	0 +
82820	*Cryptochironomus sp*	0 +
83158	*Endochironomus nigricans*	0 +
83300	*Glyptotendipes (Phytotendipes) sp*	0 +
84470	*Polypedilum (P.) illinoense*	0 +
95100	*Physella sp*	0 +

Taxa Code	Taxa	Quan/Qual

No. Quantitative Taxa: 0 Total Taxa: 22
No. Qualitative Taxa: 22 ICI:

Ohio EPA Ecological Assessment Section
Macroinvertebrate Collection

Collection Date: 08/09/93 River Code: 17-553 River: River Styx RM: 2.80

Taxa Code	Taxa	Quan/Qual	Taxa Code	Taxa	Quan/Qual
03600	*Oligochaeta*	0 +			
08260	*Orconectes (Crokerinus) sanbornii sanbornii*	0 +			
17200	*Caenis sp*	0 +			
22001	*Coenagrionidae*	0 +			
45300	*Sigara sp*	0 +			
45400	*Trichocorixa sp*	0 +			
60820	*Haliplus fasciatus*	0 +			
65800	*Berosus sp*	0 +			
67800	*Tropisternus sp*	0 +			
72700	*Anopheles sp*	0 +			
77500	*Conchapelopia sp*	0 +			
82730	*Chironomus (C.) decorus group*	0 +			
84210	*Paratendipes albimanus or P. duplicatus*	0 +			
84470	*Polypedilum (P.) illinoense*	0 +			
95100	*Physella sp*	0 +			
96900	*Ferrissia sp*	0 +			

No. Quantitative Taxa: 0 Total Taxa: 16

No. Qualitative Taxa: 16 ICI:

Ohio EPA Ecological Assessment Section
Macroinvertebrate Collection

Collection Date: 07/27/93 River Code: 17-553 River: River Styx RM: 3.50

Taxa Code	Taxa	Quan/Qual
01801	*Turbellaria*	0 +
03600	*Oligochaeta*	0 +
08260	*Orconectes (Crokerinus) sanbornii sanbornii*	0 +
08601	*Hydracarina*	0 +
11120	*Baetis flavistriga*	0 +
11130	*Baetis intercalaris*	0 +
11250	*Centroptilum sp (w/o hindwing pads)*	0 +
17200	*Caenis sp*	0 +
21200	*Calopteryx sp*	0 +
22001	*Coenagrionidae*	0 +
23704	*Anax junius*	0 +
23909	*Boyeria vinosa*	0 +
45300	*Sigara sp*	0 +
52200	*Cheumatopsyche sp*	0 +
52530	*Hydropsyche (H.) depravata group*	0 +
63900	*Laccophilus sp*	0 +
65700	*Anacaena sp*	0 +
67700	*Paracymus sp*	0 +
68708	*Dubiraphia vittata group*	0 +
69400	*Stenelmis sp*	0 +
71900	*Tipula sp*	0 +
74100	*Simulium sp*	0 +
74501	*Ceratopogonidae*	0 +
77355	*Clinotanypus pinguis*	0 +
77500	*Conchapelopia sp*	0 +
77740	*Hayesomyia senata*	0 +
78401	*Natarsia species A (sensu Roback, 1978)*	0 +
82730	*Chironomus (C.) decorus group*	0 +
82770	*Chironomus (C.) riparius group*	0 +
82820	*Cryptochironomus sp*	0 +
84300	*Phaenopsectra obediens group*	0 +
84450	*Polypedilum (P.) convictum*	0 +
84470	*Polypedilum (P.) illinoense*	0 +
84540	*Polypedilum (Tripodura) scalaenum group*	0 +
84612	*Saetheria tylus*	0 +
84750	*Stictochironomus sp*	0 +
85500	*Paratanytarsus sp*	0 +
85800	*Tanytarsus sp*	0 +
85814	*Tanytarsus glabrescens group*	0 +
85840	*Tanytarsus guerlus group*	0 +

Taxa Code	Taxa	Quan/Qual
95100	*Physella sp*	0 +

No. Quantitative Taxa: 0 Total Taxa: 41

No. Qualitative Taxa: 41 ICI:

Appendix 3. Water quality data collected during 1993 River Styx Survey.

Station	RM 1	Date	Time	Cond fld	D.O.	pH fld.	Temp C	COD	NO2+NO3	Nitrite	Ammonia	TKN	Phos.	Flt. Res	Nflt.Res	Sulfate
R06P40	0.01	930713	910	1144	6.15	7.8	27	34	4.3	0.05	0.13	1.3	0.77	664	36	118
R06P40	0.01	930719	1015	1250	6.9	8.08	28	22	7.17	0.06	0.07	1.2	1.13	740	15	134
R06P40	0.01	930802	1010	1400	6.7	8.12	27	36	6.04	0.08	0.1	1.8	1.08	840	26	169
R06P40	0.01	930907	1128	1248	7.5	8.1	26	28	5.19	0.12	0.47	2.1	1.17	732	24	
R06S13	0.75	930713	1015	988	7.4	7.9	27.5	31	3.84	0.04	0.08	1.8	0.8	584	15	116
R06S13	0.75	930719	1000	1150	7.3	8	27	40	5.36	0.07	0.15	1.6	1.05	684	14	144
R06S13	0.75	930802	950	1200	7.8	8.06	27	40	5.43	0.08	<0.05	2.4	0.68	750	20	180
R06S13	0.75	930907	1110	1470	8.3	8.1	24	41	5.09	0.13	0.87	2.3	1.24	654	14	
R06W39	2.8	930713	1050	696	7.76	6.8	20	14	7.96	0.04	0.05	0.9	1.14	462	<5	92
R06W39	2.8	930719	915	775	6.9	7.45	21	20	11	0.13	0.29	1.4	1.74	602	7	107
R06W39	2.8	930802	940	740	7.2	7.5	21	28	11.7	0.22	0.58	1.6	1.3	513	6	128
R06W39	2.8	930907	1104	707	7.8	7.6	18.5	24	7.23	0.15	3.89	5.2	2.3	462	6	
R06W38	3.5	930713	1140	738.4	8.4	7.4	25	11	0.25	0.02	0.07	0.4	0.17	430	79	
R06W38	3.5	930719	930	700	5.3	7.45	22	13	0.4	0.03	0.18	1.3	0.18	490	47	90
R06W38	3.5	930802	915	800	7.2	7.86	21.5	16	0.14	0.02	0.06	0.6	0.05	530	<5	108
R06W38	3.5	930907	1030	707	7.9	7.8	18.5	13	0.48	0.02	0.36	0.9	0.13	484	5	

Station	RM	Date	Time	Arsenic	Cadmium	Cr, Tot	Copper	Lead	Zinc	Hardness	E.–coli Bacteria
R06P40	0.01	930713	910	16	<0.2	<30	<10	<2	28	307	
R06P40	0.01	930719	1015	7	<0.2	<30	<10	<2	30	312	
R06P40	0.01	930802	1010	10	<0.2	<30	<10	<2	33	46	
R06P40	0.01	930907	1128	14	<0.2	<30	<10	<2	29	305	840
R06S13	0.75	930713	1015	17	<0.2	<30	<10	<2	<10	296	
R06S13	0.75	930719	1000	17	<0.2	<30	<10	<2	75	323	
R06S13	0.75	930802	950	12	<0.2	<30	<10	<2	28	345	
R06S13	0.75	930907	1110	15	<0.2	<30	<10	<2	31	311	1190
R06W39	2.8	930713	1050	<2	<0.2	<30	<10	<2	15	204	
R06W39	2.8	930719	915	<2	<0.2	<30	<10	<2	24	218	
R06W39	2.8	930802	940	<2	0.3	<30	<10	<2	32	206	
R06W39	2.8	930907	1104	4	<0.2	<30	13	<2	25	187	120
R06W38	3.5	930713	1140	<2	<0.2	<30	<10	<2	<10	238	
R06W38	3.5	930719	930	3	<0.2	<30	<10	<2	<10	321	
R06W38	3.5	930802	915	<2	<0.2	<30	<10	<2	<10	286	
R06W38	3.5	930907	1030	4	<0.2	<30	<10	<2	10	245	3040

Station	RM 1	Date	Time	Fecal coliform Bacteria
R06P40	0.01	930916	1000	4900
R06S13	0.75	930916	1010	4200
R06W39	2.8	930916	1020	81
R06W38	3.5	930916	1035	3300