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Gorman O. T. & J. R. Karr. (1978) Habitat structure and stream fish communities. *Ecology* 59:
507-515.

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July 1978

SOME EFFECTS OF STREAM CHANNELIZATION ON FISH POPULATIONS, MACROINVERTEBRATES, AND FISHING IN OHIO AND INDIANA

by

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National Stream Alteration Team
Office of Biological Services
Fish and Wildlife Service
U.S. Department of the Interior

DISCLAIMER

The opinions, findings, conclusions, or recommendations expressed in this report are those of the authors and do not necessarily reflect the views of the Office of Biological Services, Fish and Wildlife Service, U.S. Department of the Interior, nor does mention of trade names or commercial products constitute endorsement or recommendation for use by the federal government.

PREFACE

This study was conducted to help define the mechanisms which cause changes in fish populations in channelized streams and to document the impact of these changes on recreational use of fishery resources. An understanding of these mechanisms is essential to making sound recommendations toward mitigation of changes or losses of fishery resources in stream channelization projects. It must be recognized that each stream system is inherently different ecologically and that each may react to channelization in a different way or to a different degree. This inconsistency was evident in the five streams studied in this project; therefore, data are of limited value for use in highly specialized predictive models. The data do provide general information on response of aquatic macroinvertebrates, fishes, and sport fisheries in warmwater streams affected to varying degrees by channelization, and the results were associated with changes in quality of habitat.

Three graduate theses were completed during the course of this study:

Edwards, Clayton J. 1977. The effects of channelization and mitigation on the fish community and population structure in the Olentangy River, Ohio. Ph.D. Dissertation. The Ohio State University. 161 p.

Weber, Earl C. 1977. Angler use and success in two channelized warm water Ohio streams. M.S. Thesis. The Ohio State University. 81 p.

Woods, Lewis C. 1977. The effect of stream channelization and mitigation on warm water macroinvertebrate communities. M.S. Thesis. The Ohio State University. 80 p.

The theses are available through interlibrary loan from The Ohio State University Library, Columbus, Ohio 43210, or from Fish and Wildlife Reference Service, 2100 West Mississippi Avenue, Denver, Colorado 80223.

Any suggestions or questions regarding this report should be referred to:

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EXECUTIVE SUMMARY

The effect of stream channelization on macroinvertebrates and fish was studied in four rivers in Ohio (the Olentangy, Sandusky, Hocking, and Little Auglaize) and Rock Creek in Indiana. Sampling areas were located in natural unchannelized areas and nearby channelized areas in all streams. A channelized area mitigated with artificial riffles and deep pools was also sampled in the Olentangy River.

Macroinvertebrate abundance, diversity, and/or biomass was significantly lower in channelized areas of the Olentangy River, Hocking River, and Rock Creek. Drift rates tended to be highest in unchannelized sections of the study streams. Dominant macroinvertebrates in the unchannelized areas were "riffle species", those which are found on substrate surfaces in areas of moving water, whereas dominant species in the channelized areas were burrowing forms adapted for living in soft substrates in standing water.

Gamefishes were more abundant in unchannelized areas, whereas some nongame species achieved extremely high abundance in some channelized areas. Diversity and relative abundance of the total fish community were significantly lower in channelized areas of the Olentangy River, but the fish population in the mitigated area approximated that in the natural area.

Creel censuses were run in the study areas of the Olentangy, Sandusky, and Hocking Rivers. Comparative results are confounded by the inaccessibility of the natural area of the Hocking River to fishermen and the extensive spring spawning runs of gamefish into all areas of the Sandusky River. A mid- to late-summer sport fishery in the Sandusky River was limited to the unchannelized area. Fishing activity and catch composition in the Olentangy River reflected the fish population in each area. Activity was highest in the mitigated and natural areas, and gamefish were much more abundant in the catch from these areas. Catch rate for gamefish was highest in the natural area.

Rock Creek was channelized in 1974, the first year of the study. Macroinvertebrate abundance in the channelized area two years after channelization approximated that in the natural area; however, macroinvertebrate biomass and gamefishes had not recovered to prechannelization levels as indicated by samples from the unchannelized area.

In 1974, an extremely dry year, the Little Auglaize River was completely dewatered for nearly two months along the entire 35 km channelized section. Scattered pools remained in the unchannelized area, although the biota was also adversely affected there. Repopulation of the channelized area from the

Maumee River below occurred within a year, but complete recovery in the unchannelized area, which was isolated from the Maumee by two low-head dams, did not occur in 1975. Still, the presence of some fishes and macroinvertebrates early in 1975 demonstrates some animals found refuge in the unchannelized area and survived.

Recommendations of the study are: 1) to include natural or artificial riffles and deep pools in stream alteration projects to provide substrate and habitat for desirable macroinvertebrates and fishes, 2) to minimize alteration of bottom contours and substrates in stream alteration projects, 3) to furnish public access to mitigated areas so use of the fish resource provided may be optimized, and 4) to provide unaltered areas within sizeable channelization projects to serve as biological refuges during periods of drought.

This report was submitted in fulfillment of contract number 14-16-0008-738 by the Ohio Cooperative Fishery Research Unit under the sponsorship of the Office of Biological Services, U.S. Fish and Wildlife Service. Work was completed as of May 19, 1978.

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ACKNOWLEDGMENTS

The authors wish to extend their gratitude to all who helped in the course of this study. Dr. Richard A. Tubb initiated the Project. Greg Young, Faber Bland, John Kurtz, Curtis Laird and Allen Bingham tirelessly served as technicians.

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Dr. N. Wilson Britt and Dr. Beth Hair, Ohio State University, gave considerable time toward invertebrate identification.

Dr. Hair and Dr. Norman G. Benson, National Stream Alteration Team Project Officer, provided guidance and critically reviewed the manuscript. Other reviewers were Fred June, Richard Anderson, James Reynolds, Thomas Yorke, and Robert Little.

INTRODUCTION

The drainage basins of the Great Lakes and Ohio River incorporate millions of acres of highly productive agricultural land and high population density. These two features have combined to result in extensive stream alteration or "channelization" in order to provide increased stream flow capacity for road construction, flood control, increased arable land, and navigation.

Economic benefits of stream alteration often appear to be achieved at the expense of environmental considerations. Channelization can be devastating to fish and wildlife habitat and aesthetic quality (Anonymous 1972). Indirect effects include increased development of potentially hazardous floodplain areas, increased downstream flooding, promotion of wetland drainage and woodland destruction, reduction of groundwater levels, and increased erosion (Barstow 1971, Henegar and Harmon 1971, Hansen 1971, and Emerson 1971). Direct effects on fish and invertebrate populations have been documented by a number of authors. Morris, Langemeier, Russell, and Witt (1968), and Etnier (1972) found reduced benthic drift and changes in invertebrate communities in channelized stream sections. Channelization may also reduce both cold and warm water fish abundance (Congden 1971; Trautman and Gartman 1974; Tarplee, Louder, and Weber 1971; Elser 1968; Irizarry 1969; Bayless and Smith 1964; and Lund 1976) and growth (Hansen 1971; Purkett 1957; and Arner, Robinette, Frasier, and Gray 1975).

OBJECTIVES

The major objectives of this study were: (1) to compare warm water macroinvertebrate and fish populations in proximate natural, unchannelized (control) and channelized sections of two small rural streams and three larger streams flowing through urban areas; (2) to determine the effectiveness of artificial stream improvement devices in mitigating biological losses; (3) to measure biological recovery in small, well-maintained, channelized streams draining intensively farmed land; and (4) to evaluate recreational use of fishery resources in adjacent unchannelized (control) and channelized sections of the three larger urban rivers.

DESCRIPTION OF STUDY AREAS

The five rivers are widely distributed in Ohio and northeastern Indiana (Figure 1). The larger rivers channelized through urban areas were the Olentangy, Sandusky, and Hocking. The Little Auglaize River and Rock Creek are small rural streams channelized to promote agricultural drainage. Major physical characteristics of each study site are given in Table 1.

OLENTANGY RIVER

The Olentangy River (Figure 1) originates in Crawford County in north central Ohio, and flows southerly into the Scioto River in downtown Columbus. Row crop agriculture predominates in the watershed with mixed hardwood woodlands confined to moderate sized woodlots in the floodplains. Water quality is considered good (Olive and Smith 1975) with some degradation attributable to agricultural runoff and effluent from scattered sewage leaching fields.

Three types of stream habitats were studied in the Olentangy: a natural control site (N), a mitigated altered site (M), and an unmitigated channelized site (O).

Area N

Located 22.4 km (14 mi) above the mouth of the Olentangy, this natural control site ran downstream from the Powell Road bridge and contained one complete riffle-pool-run sequence (Figure 2). The bottom consisted of sand, gravel, cobble, boulders, and limestone bedrock. Bank stability in the area was good due to the heavy riparian vegetation on the slight to moderately steep banks. No alteration has occurred in the area, and the river is relatively undisturbed up to the Delaware Dam, 29 km (17 mi) upstream. The area is immediately accessible to fishermen from State Route 315.

Area M

This area was at the intersection of Interstate Route 270, 17.6 km (11 mi) upstream from the mouth of the Olentangy. The area was channelized in 1970 due to river relocation necessitated by construction of I-270. A series of artificial riffle-pools was constructed in the area (Figure 3). Five equally-spaced riffles, each 6.2 m (20 ft) long, were constructed of boulders over earthen fill. The pools below each riffle were 250 m (820 ft) long with a maximum depth of 2.5 m (8.2 ft) at mean discharge. The west half of the river bed slopes upward toward a 15-m (50-ft) wide grass-covered

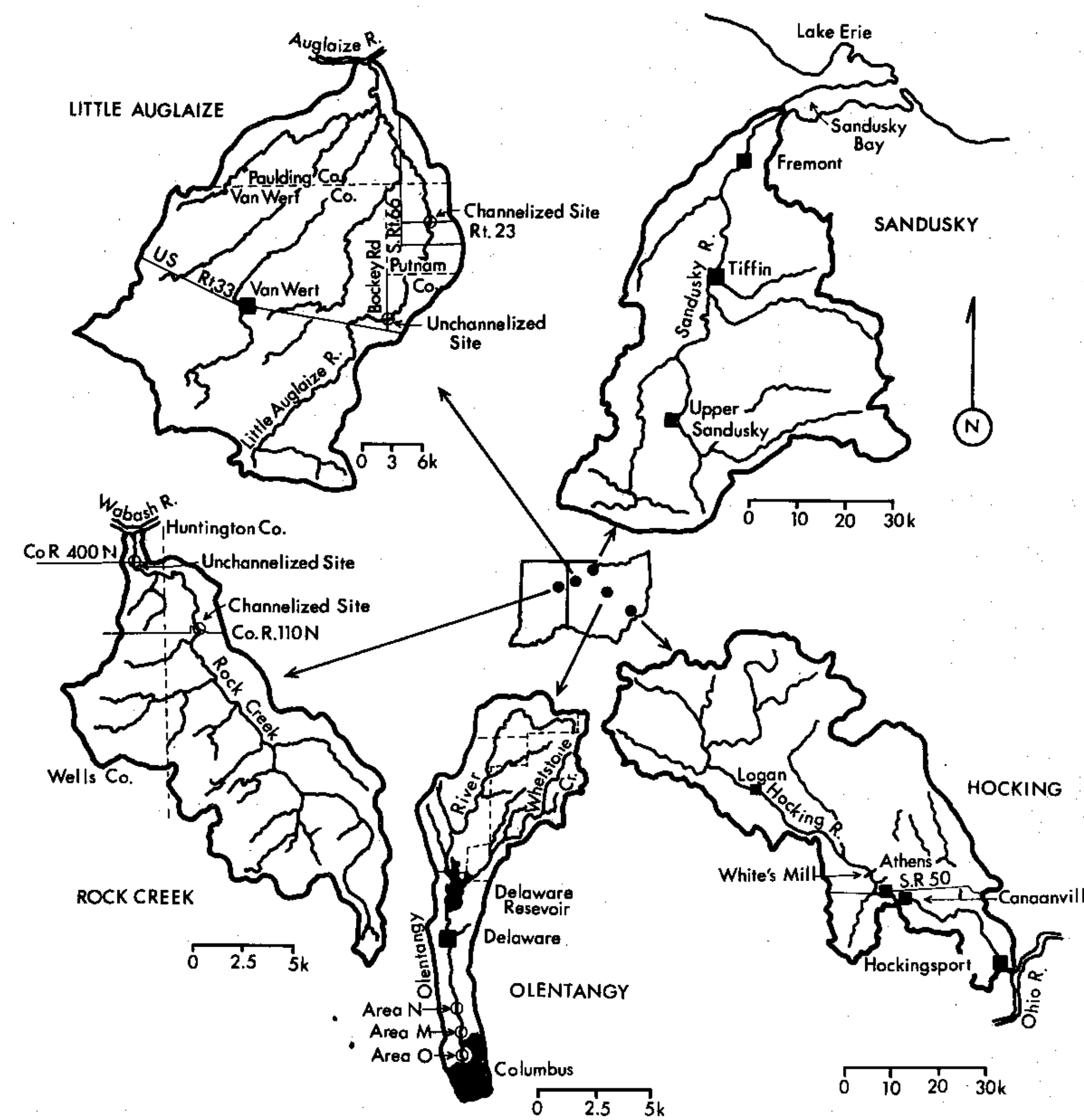

Figure 1. The drainage basins of the Olentangy River, Sandusky River, Hocking River, Little Auglaize River, and Rock Creek.

Table 1. Physical Characteristics of Five Channelized Rivers in Ohio and Indiana, and Study Sites Within These Rivers

River/ Study Site	Drainage area (km^2)	Length (km)	Minimum flow (m^3/s)	Maximum flow (m^3/s)	Average flow (m^3/s)	Average gradient (m/km)	Average width (m)	Length of reach (m)	Mean depth[a] (m)	Maximum depth[a] (m)
Olentangy	1390	142	0.1	120.0	12.9	1.1				
Natural							25	895	0.8	1.8
Mitigated							36	1350	1.7	2.5
Channelized							50	805	0.2	0.8
Sandusky	2590	186	0.1	238.0	25.0	1.5				
Natural							60	2000	0.8	2.0
Channelized							80	2000	1.5	2.0
Hocking	3100	153	0.8	114.0	29.0	0.9				
Natural							20	3500	0.8	4.0
Channelized							60	10000	0.5	0.8
Little Auglaize	1057	73	-	-	-	0.1				
Natural							4	150	0.5	1.2
Channelized							10	150	0.3	0.5
Rock Creek	247	40	-	-	-	0.2				
Natural							10	150	0.6	1.5
Channelized							12	150	0.3	0.4

[a]During mean flow conditions.

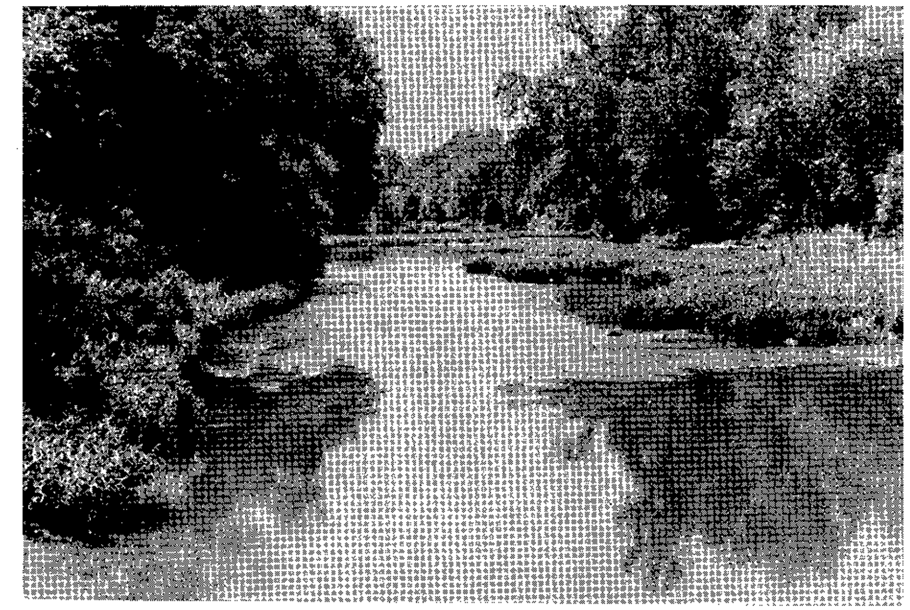

Figure 2. Study area N, the natural control area of the Olentangy River, Ohio.

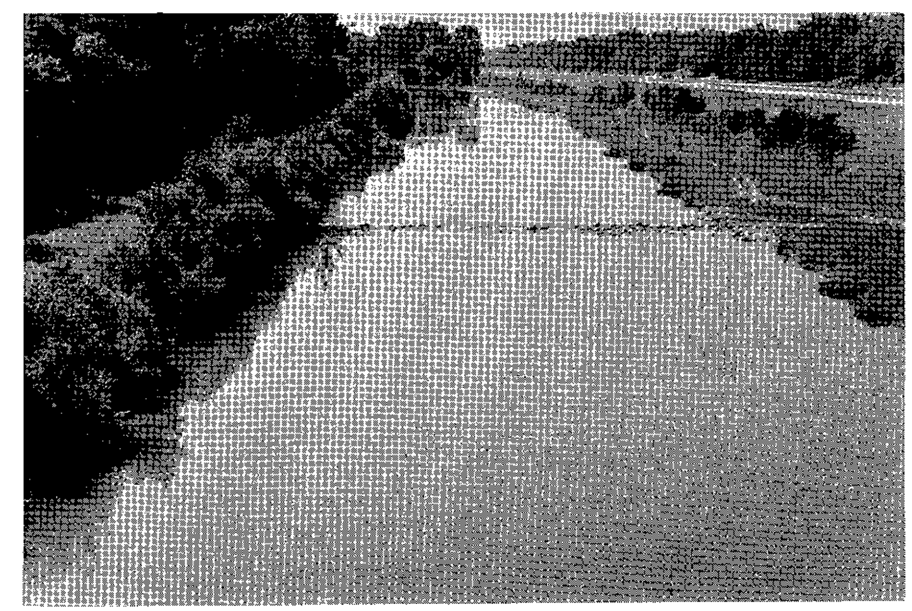

Figure 3. Study area M, the mitigated channelized area in the Olentangy River, Ohio, showing one of the series of artificial riffle-pools.

floodplain whereas, the deep areas of the pools have been dug adjacent to the heavily riprapped eastern bank. An access for fishermen, including parking for 20-30 cars, is located at the upstream end of the reach.

Area O

This site was 10 km (6 mi) above the mouth of the Olentangy, and extended downstream from the Henderson Road bridge, its upstream boundary. The area was channelized in 1950 in connection with a highway construction project (State Route 315) and contained no stream improvement structures. The entire area was a long, wide, shallow pool (Figure 4). The unstable banks were uniformly steep to a height of 2-3 m (6-10 ft) with vegetation limited to second growth water willow (Justica americana). The substrate was silt, often deeper than 1 m, and contained sunken branches along the shore. The area was accessible to fishermen from State Route 315 along the west bank, and there were five small parking areas within a few meters of the river. During 1975, access was limited, though still possible, by additional construction along Route 315.

SANDUSKY RIVER

The Sandusky River (Figure 1) originates in Marion County in north central Ohio and flows northerly. It empties into Sandusky Bay on the southwest shore of Lake Erie. The intensively farmed drainage area consists of glacial and lacustrine deposits with finely textured, poorly drained soils. The profile of the Sandusky River is extremely variable, but in most places gradient is less than 2 m/km. Agriculture runoff contributes to heavy silt loads. Municipal sewage effluents, agricultural chemicals, and silo liquors have resulted in periodic localized fish kills (Ohio DNR 1974). The river is heavily utilized by spring spawning runs of several fishes resident in Lake Erie.

A channelized section and a natural (control) section of the river were studied in Fremont, Ohio.

Unchannelized Section

This section was located immediately upstream from Fremont, Ohio. It contained typical run-riffle-pool sequences with sand to coarse rubble bottom. The banks were stabilized with a heavy growth of mature mixed hardwoods (Figure 5). Access to the section was through an adjacent golf course or by wading from the extreme downstream end.

Channelized Section

This section began in downtown Fremont and extended upstream to within 100 m of the lower end of the natural section (Figure 6). A high, concrete retaining wall was constructed on the west bank of the river as it flows past

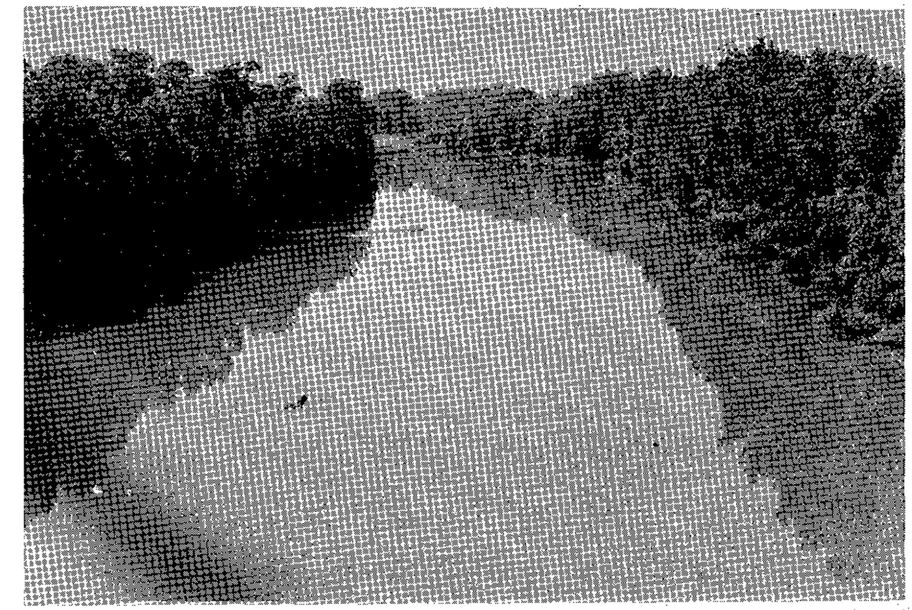

Figure 4. Study area O, the 25-year old channelized area of the Olentangy River, Ohio.

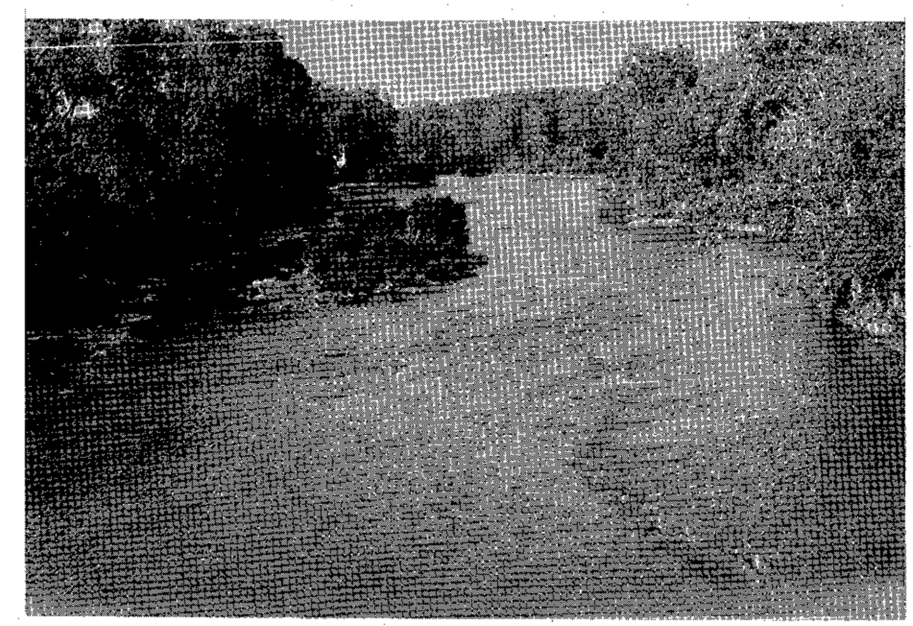

Figure 5. The unchannelized sampling area of the Sandusky River in Fremont, Ohio.

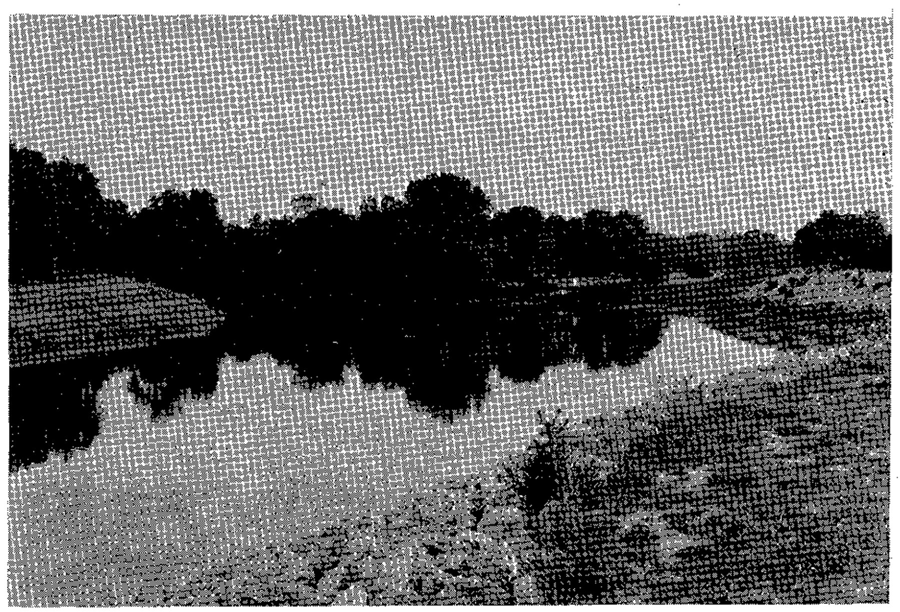

Figure 6. The border between unchannelized and channelized sections of the Sandusky River in Fremont, Ohio.

the commercial section of the city (Figure 7). The stream was dredged to limestone bedrock, and high levees for flood control were constructed on each bank in 1971. Levees were riprapped with large (.50 - .75 m) limestone boulders. Depth was less than 1 m over a bedrock bottom in the upper half of the section. Below a sharp low limestone outcropping midway in the section (Figure 8), depth increased to 2 m. Sedimentation in the downstream half of the section resulted in silt up to 1 m deep over the limestone bedrock. The channelized section was accessible to fishermen, who could park their cars immediately outside most sections of the levees.

HOCKING RIVER

The Hocking arises in Fairfield County in south central Ohio and flows southeasterly to the Ohio River at Hockingsport (Figure 1). The upper 24 km (13.4 mi) of the river flows through silty loam soils and rolling glaciated farm land. The remainder flows through the unglaciated region characterized by steep sandstone and shale slopes. Besides agriculture, some light manufacturing and strip mining occurs within the watershed. Fish kills have historically occurred following localized storms due to inflows of low pH water.

Eight km (13 mi) of the Hocking River were channelized in 1970-71 by the U.S. Corps of Engineers as flood protection for Athens. A new channel was created, and stream width was increased from 20 m (65 ft) to 65 m (211 ft). The project was extended downstream an additional 2 km (1.25 mi) in 1974-75 in conjunction with construction of a new bridge at SR 50. Channelized and natural (control) areas were sampled in Athens in 1974 and 1975.

<u>Unchannelized Section</u>

This section began 1 km below the SR 50 bridge and extended eastward to Canaanville. The banks were lined with mixed hardwoods, and the normal riffle, run, pool sequence predominated (Figure 9). Construction at the Route 50 bridge resulted in heavy sediment loads and high turbidity throughout the study. Land adjacent to the entire section was privately owned and fisherman access was limited.

<u>Channelized Section</u>

This section consisted of the entire 10 km channelized area, from the low-head dam at White's Mill on the west side of Athens downstream to the State Route 50 bridge. The modified river was uniformly less than one meter deep with an unstable silty sand bottom. Shoreline vegetation had been removed, and levees were planted in grasses or riprapped (Figure 10). Access to the section was relatively unrestricted.

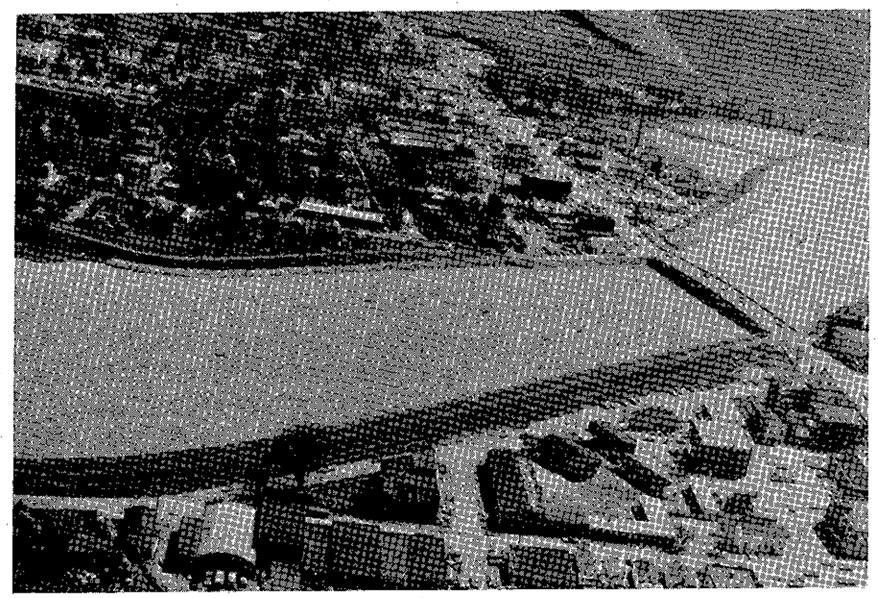

Figure 7. Aerial view of channelized sampling area of Sandusky River, including retaining wall and riprapped levees, in downtown Fremont, Ohio.

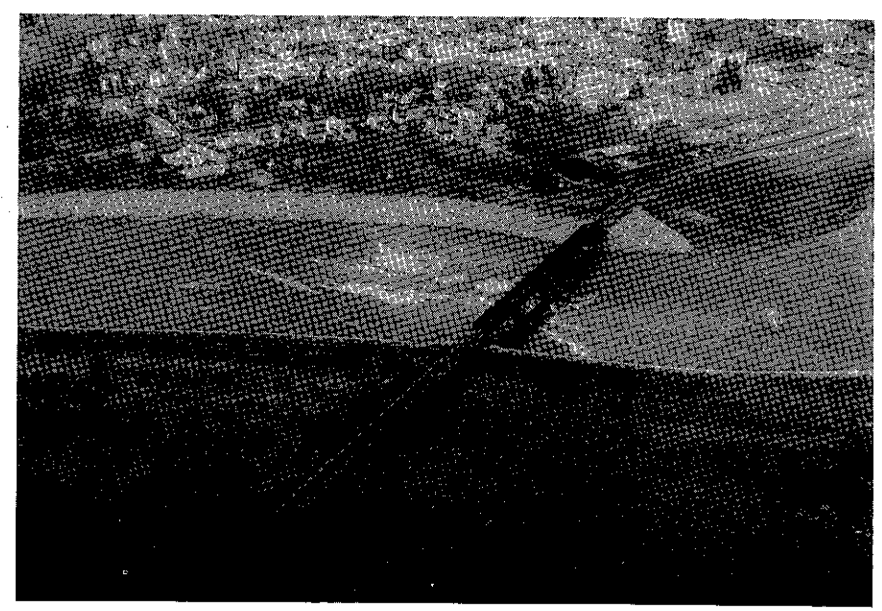

Figure 8. Riprapped levees and limestone outcropping crossing the channelized sampling area of the Sandusky River, Ohio.

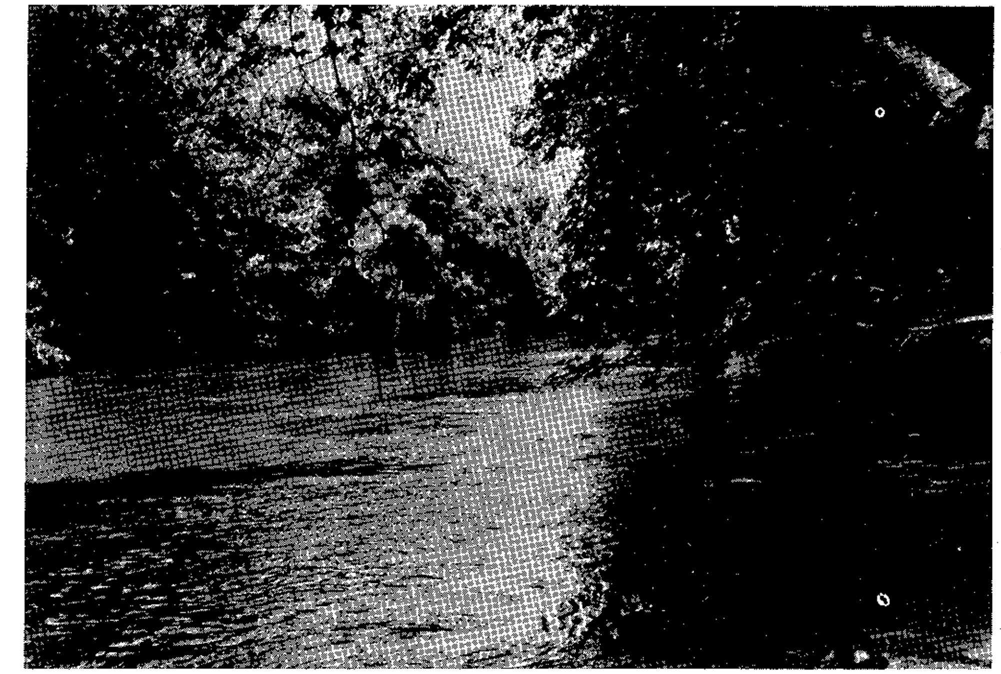

Figure 9. The unchannelized study area in the Hocking River near Athens, Ohio.

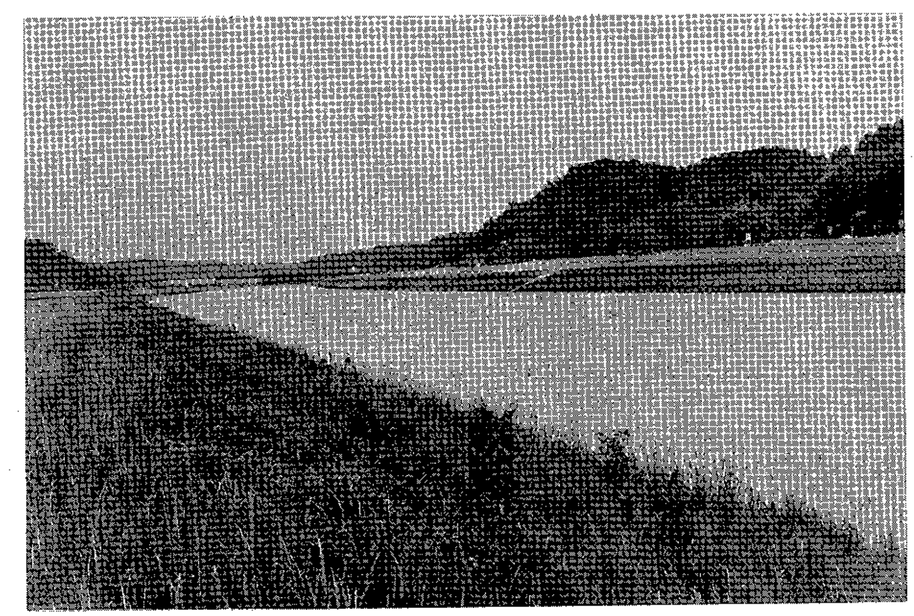

Figure 10. The channelized study area in the Hocking River in Athens, Ohio.

LITTLE AUGLAIZE RIVER

The source of the Little Auglaize River is in southern Van Wert County in northwest Ohio. The river flows northerly through Putnam County and empties into the Auglaize River, a tributary of the Maumee, in eastern Paulding County (Figure 1). The watershed is intensely farmed, and the soils are highly fertile lacustrine deposits of Glacial Lake Maumee. The remaining timber in the watershed is confined to stream banks and small isolated woodlots. Water quality is good, but suspended solids and turbidity are sometimes high.

In 1970-71, the U.S. Soil Conservation Service channelized 35 km (63 mi) immediately downstream from the Van Wert-Putnam County Line to increase drainage. Historical records indicated that the entire stream had been modified at one time, but there had been no modification upstream from the county line for at least 40 years. An experimental control site was selected about 6 km (9.7 mi) upstream and a channelized site about 1 km (1.6 mi) downstream from the county line. Two low-head mill dams were located between the areas.

Unchannelized Section

This section extended downstream from the Bockey Road bridge crossing in Van Wert County. No definitive riffles were present (Figure 11). The substrate was cobbles embedded in compacted clay. Canopy from overhanging deciduous trees was moderate to heavy, and the rooted aquatic plant, *Saururus cernuus* (lizard tail), was common throughout.

Channelized Section

This section extended immediately downstream from the R-23 bridge crossing in Putnam County. All woody vegetation had been removed, and the banks had been planted in grasses (Figure 12). The stream bottom was compacted silty clay over limestone bedrock. Substrate in areas of more rapid flow was exposed bedrock.

ROCK CREEK

The Rock Creek watershed is located in two northeastern Indiana counties, Wells and Huntington. Water flows northwest to the Wabash River (Figure 1). The region is a glacial moraine plain with extensive flat areas. The area is intensively farmed and contains only small, intermittent remnants of original woodlands.

Rock Creek averages less than 4 m wide and 1 m deep during the summer months. Discharge data were unavailable. Water quality was good with the exception of high silt loads after heavy rainfall. In 1973-74 the upper 35 km (57 mi) of stream were channeled by the U.S. Soil Conservation Service

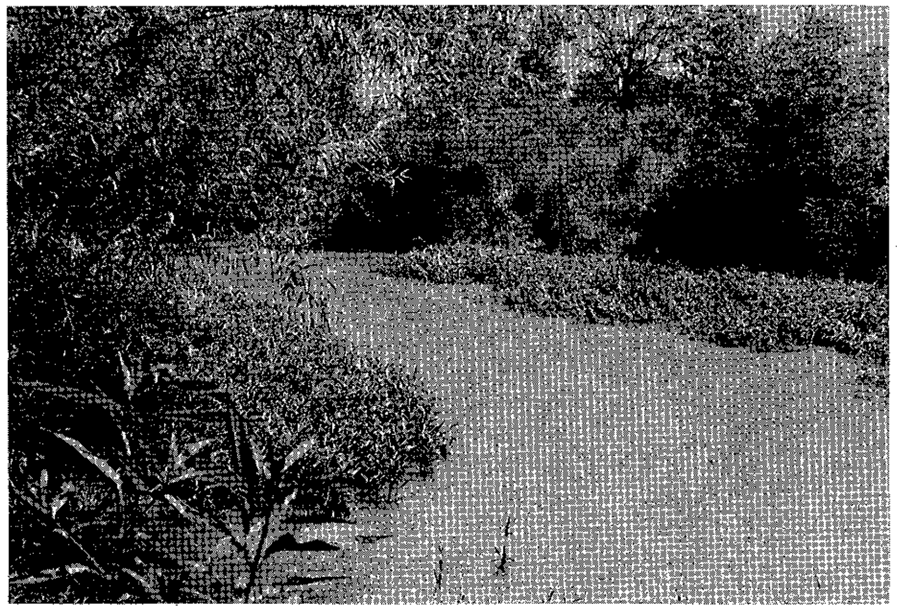

Figure 11. The unchannelized sampling area in the Little Auglaize River, Ohio, at Bockey Road.

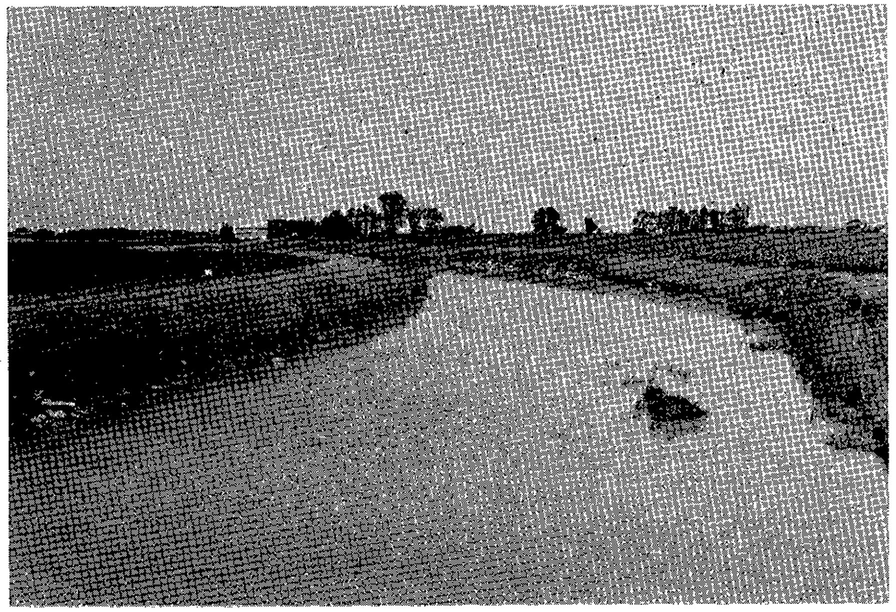

Figure 12. The channelized sampling area in the Little Auglaize River, Ohio, at State Route 23.

to prevent flooding and enhance drainage for agriculture. Two sampling areas were established after construction in 1974 --one in the channelized section and the other in the unchannelized section.

Unchannelized Section

The natural station was at the intersection of Huntington County Road 400N, 4.5 km (7.3 mi) above the mouth, and contained a complete run, riffle, pool sequence (Figure 13). Deciduous woody vegetation covered the banks and overhanging trees and branches were numerous. The substrate was mixed cobble and small boulders with wilt deposits in the pools. Patches of water willow were found in shallow areas.

Channelized Section

This station was at the intersection of Wells County Road 110N, 6.5 km (10.5 mi) above the control station. The banks were barren of woody vegetation and planted in mixed grasses (Figure 14). The habitat was a homogeneous riffly run without definitive pools or riffles. The substrate was limestone bedrock overlain by a thin silt layer which was periodically removed by freshets.

Figure 13. The unchannelized sampling area in Rock Creek, Indiana, at the intersection of Huntington County Road 400N.

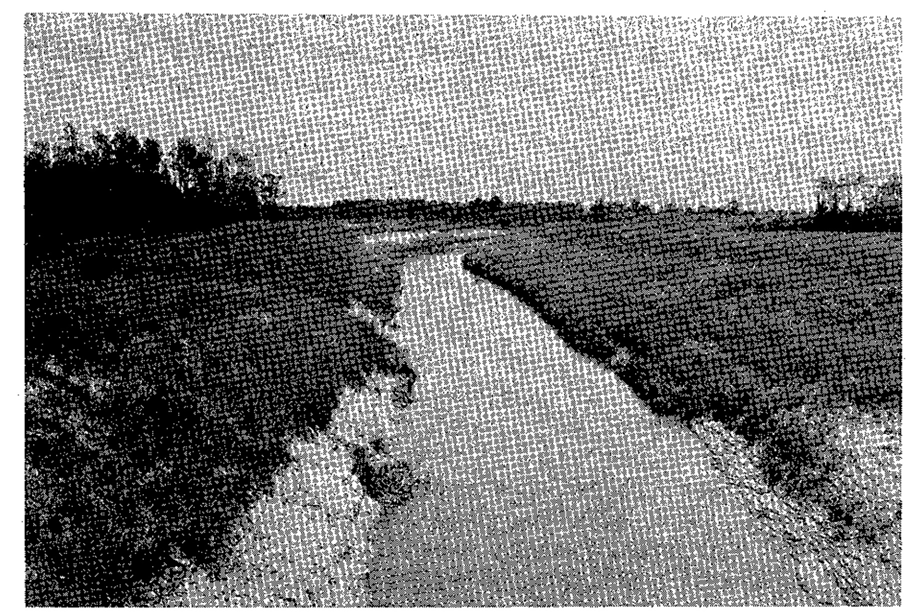

Figure 14. The channelized sampling area in Rock Creek, Indiana, at the intersection of Wells County Road 110N.

MATERIALS AND METHODS

AQUATIC INVERTEBRATES

Field collections of macrobenthos and aquatic drift were made monthly during the summer in 1974 and 1975 at all stations in the five streams (Table 2). Four additional sampling periods were accomplished for the Olentangy River in 1976. Samples were collected using Surber square foot samplers and drift nets with openings of 0.305 m^2 and 253-micron mesh on riffles within the sampling areas. If there were no riffles in the area, samples were taken at the point of maximum current. Four replicate Surber samples were taken at each station during each period to allow for analysis at the 80% confidence level (Needham and Usinger 1956). Two drift samples were collected at six-hour intervals for 24 hours each monthly sampling period.

Organisms were fixed in 10% formalin with rose bengal, sorted, identified to family, and counted. Dry weights of sorted material were obtained to the nearest 0.001 gm for each sample. Identification to the familial level was justified by Kaesler and Herricks (1976) who showed a negligible component for "diversity added" at the species level and strong correlation between diversity indices calculated for specific, generic and familial levels.

Replicates within each area on each sampling date were pooled to form a sample. Since effort for all areas within a river was equal, data are expressed in terms of total numbers and total biomass.

FISHES

The fish population of each section was sampled using a 3500-w, 110-v A.C. generator with a 0 to 350-v pulsed D.C. rectifier which allowed consistent voltage/amperage output regardless of water conductivity. The electrofishing gear was operated from a 5.5-m (18-ft) flat-bottom boat in the three large rivers, but hand-held electrodes were used while wading the Little Auglaize River and Rock Creek. Each sampling area in the three larger rivers was electrofished on an approximate monthly basis during the field season in 1974 and 1975, with additional sampling in the Olentangy in 1976 (Table 1). The two small rivers, Rock Creek and the Little Auglaize, were sampled once every two months. Each area was fished exhaustively throughout, and fish were identified to species, measured, weighed and released. Electrofishing time was recorded and catch per minute calculated.

Table 2. Dates of Fish (F) and Macroinvertebrate (M) Collections on Five Channelized Warm Water Streams in Ohio and Indiana (Mo/Day/Yr)

Olentangy River		Sandusky River		Hocking River		Little Auglaize River		Rock Creek	
F	M	F	M	F	M	F	M	F	M
5/4-6/74	6/9/74	5/8-9/74	7/6/74	6/4-5/74	7/15/74	6/3/74	6/19/74	5/24-25/74	7/10/74
6/10-12/74	7/24/74	7/2-6/74	8/6/74	7/16-17/74	8/21/74	5/31/75	5/16/75	8/11/74	8/10/74
7/23-25/74	9/2/74	8/5-6/74	9/13/74	8/21-22/74	6/12/75	7/29-30/75	7/4/75	9/18/74	9/18/74
8/26-30/74	4/11/75	9/13/74	4/16/75	6/12/75	7/23/75	11/1/75	8/6/75	7/3-4/75	7/1/75
11/1-4/74	5/12/75	10/17/74	5/12/75	7/23-24/75	8/20/75		9/8/75	8/19/75	8/7/75
4/2,6,9/75	6/18/75	4/17/75	6/5/75	8/27-28/75	9/3/75		10/11/75	10/27/75	9/4/75
5/23-25/75	7/18/75	5/5-6/75	7/12/75						10/10/75
6/16-18/75	8/19/75	6/26-27/75	8/18/75						
7/15-17/75	9/29/75	8/12-13/75	9/15/75						
10/7-11/75	5/10/76[a]								
5/7-9/76	6/8/76[a]								
7/7-9/76	7/17/76[a]								
10/13-14/76	10/3/76[a]								

[a]Surber samples only.

Common and scientific names of all species collected are given in Appendix A-1. Esocids, bullheads, catfish, centrarchids, white bass, and walleyes were considered gamefish, and all others were considered non-gamefish.

FISHERMAN SURVEYS

Fisherman counts and interviews were made from 3 June to 24 September, 1974, and 13 April to 13 September, 1975, in the Olentangy, Sandusky, and Hocking Rivers. Additional complete creel surveys were run by the Ohio Division of Wildlife in the Sandusky River from 15 March to 15 June, 1975, and their data are incorporated into this report. Creel surveys were conducted throughout each sampling area. The angler day was divided into three 4-hr periods --0800 to 1200, 1200 to 1600, and 1600 to 2000. Three periods were sampled on each river each week on a stratified random basis: two weekday periods and one weekend or holiday period. All fishermen were interviewed, preferably after fishing trips were completed, to determine catch rates, species composition, and fishing methods.

ANALYTICAL METHODS

Parameters derived from macroinvertebrate data included number of families, total number and biomass of individuals per family, and diversity. Analysis of data on the basis of total numbers and biomass rather than a square meter basis was justified as sampling intensity was equal for all sample sites at all times. Parameters derived for fish included number of species, relative abundance of each species expressed as number and grams of fish caught per minute of electrofishing, and diversity. Creel survey data were expressed as number of fish caught per man-hour. These parameters were analyzed with various statistical tests to determine if there were significant differences between parameters for the various sample sites. Nonparametric procedures were employed when data displayed non-normality.

Recorded field data were transferred to carbon scan forms designed for direct Hollerith card production. Completed data cards were verified against the original data sheets.

All subsequent mathematical analyses were performed on an IBM 370/168 computer or on a Canon paper tape desk calculator. The program Statistical Analysis System of Service, Barr and Goodnight (1972), was used for Student's t and X^2 tests as well as least squares regression and covariance analysis.

Shannon-Weaver diversity indices were modified for familial diversity ($\bar{H}$) by Pielou (1966) and computed as follows:

$$\bar{H} = \sum_{1}^{Si} (N_i/N) \log (N_i/N)$$

where N is the number of individuals in S families and N_i is the number of individuals in the i^{th} family.

Species diversity indices using biomass rather than abundance, as suggested by Wilhm (1968), were calculated using the same program. Page's L-statistic (Page 1963) was calculated to compare treatment effect on relative abundance and biomass, and the non-parametric Friedman rank sums test (Hollander and Wolfe 1973) was used to make multiple comparisons. Additional analytical procedures are described in appropriate sections of the text.

RESULTS

OLENTANGY RIVER

Benthos

The total number of families and individuals collected at each area is given in Table 3. The totals for each site were ranked relative to those from the other sites for each sampling period and tested using Page's L-statistic. The Friedman rank sums test, a multiple comparison test, was used to determine where significant treatment differences, as defined by the L-statistic, occurred.

There was a significant difference in number of families and number of individual organisms collected at the three areas ($P < 0.001$). Multiple comparisons indicated that both the number of benthic families and individuals in both the natural and mitigated channelized areas were significantly greater than those in the channelized area with no mitigation ($P < 0.01$) (Table 3). In addition, there was an obvious shift from what Neilson (1950) refers to as "torrential fauna", such as Hydropsychidae, Psephenidae, and Heptageniidae, in the natural area to slower water forms such as Ephemeridae, Oligochaeta (primarily Tubificidae), and many of the Chironomidae in the channelized area with no mitigation (Table 4).

Diversity indices (Table 3) indicated the natural area had consistently higher benthic diversity than did the mitigated area, which in turn had greater diversity than did the channelized area with no mitigation.

The biomass of benthic invertebrates collected in each area (Table 3) was ranked relative to that from the other sites for each sampling period, and tested using Page's L-statistic. A significant difference in biomass collected at each station per each sampling period was found ($P < 0.001$). Multiple comparisons showed that the total biomass collected during each period at the natural and mitigated areas was significantly greater than that collected in the channelized, unmitigated area ($P < 0.01$).

Drift

There was a significant difference between the total number of families collected in the drift from each of the three areas according to Page's L-statistic ($P < 0.001$) (Table 5). Multiple comparisons indicated that the

Table 3. The Number of Benthic Families and Organisms, Indices of Familial Diversity, and Biomass (g/M^2) Taken in Four Replicate Surber Samples from Three Study Areas of the Olentangy River, Ohio

	Area N				Area M				Area O			
Date	Number Families	Number Organisms	Diversity	Biomass	Number Families	Number Organisms	Diversity	Biomass	Number Families	Number Organisms	Diversity	Biomass
9 June 1974	17	1637	2.22	5.654	11	1232	1.82	13.912	10	214	1.90	0.091
27 July 1974	13	845	2.32	4.772	13	660	2.31	2.203	11	59	2.69	0.067
2 September 1974	16	1259	2.45	6.278	13	960	2.93	1.275	14	78	2.96	0.088
11 April 1975	20	745	3.00	3.819	17	1738	2.85	3.303	14	74	2.84	0.118
12 May 1975	17	628	2.61	1.942	12	2390	1.67	0.909	10	423	1.18	0.734
18 June 1975	22	643	3.00	5.304	15	699	2.80	1.452	6	112	1.40	0.026
18 July 1975	22	2565	1.77	22.407	17	2437	1.98	11.443	13	220	2.57	0.449
19 August 1975	14	385	2.75	1.164	19	1303	2.61	5.498	11	141	2.46	0.131
29 September 1975	18	355	3.00	10.714	18	537	2.97	10.811	10	112	2.55	0.139
10 May 1976	15	565	2.77	6.515	15	812	2.93	4.556	11	326	2.54	0.597
8 June 1976	20	1030	2.55	30.138	13	807	2.28	83.626	10	172	2.56	0.484
17 July 1976	18	650	3.19	13.307	17	1190	1.94	59.987	11	114	2.49	0.075
3 October 1976	18	785	3.11	86.478	17	515	2.98	44.003	12	211	2.64	0.220
Mean	17.7	934	2.67	15.269	15.1	1180	2.46	18.691	11.0	174	2.36	0.201

Table 4. The Five Most Abundant Families Collected in 52 Surber Samples Taken from Each of the Three Areas of the Olentangy River, Ohio, Expressed as the Average Number/Year

Area	Family	Average number of individuals/year
Area N	Hydropsychidae	1396
	Elmidae	550
	Heptageniidae	430
	Psephenidae	388
	Chironomidae	337
Area M	Hydropsychidae	1891
	Chironomidae	866
	Baetidae	548
	Oligochaeta[a]	509
	Elmidae	448
Area O	Oligochaeta[a]	233
	Chironomidae	202
	Heptageniidae	91
	Baetidae	68
	Ephemeridae	26

[a]Primarily Tubificidae.

natural area had significantly more families represented in the drift than did the channelized, unmitigated area ($P < 0.025$).

There was also a significant difference between the number of individual drifters in the three areas according to Page's L-statistic ($P < 0.001$) (Table 5). Statistically significant multiple comparisons at the 0.025 level showed that the number of drifters collected in the natural and mitigated areas were greater than those collected at the channelized, unmitigated area.

The three areas were also significantly different with respect to total drift biomass collected per sampling period ($P < 0.005$) (Table 5). Both the natural area and the mitigated area had significantly greater biomass than did the old conventionally channelized area ($P < 0.025$).

The major portion of the drift was composed of Chironomidae, Tubificidae, and Baetidae in all areas.

Table 5. The Total Number of Families, Individual Organisms, and Biomass (g dry weight) Collected in Drift Nets from Three Study Areas of the Olentangy River, Ohio. Each Entry Represents Two 10-Minute Replicate Samples Taken Every Six Hours for 24 Hours

Date	Area N			Area M			Area O		
	Families (No.)	Individuals (No.)	Biomass (g)	Families (No.)	Individuals (No.)	Biomass (g)	Families (No.)	Individuals (No.)	Biomass (g)
9 June 1974	26	2479	a	17	1159	a	7	343	a
27 July 1974	21	712	0.209	13	771	0.411	12	504	0.083
2 September 1974	29	1918	0.360	26	1610	0.282	25	877	0.322
11 April 1975	19	1677	0.193	10	309	0.072	11	128	0.013
12 May 1975	17	1705	0.468	16	3446	0.554	10	1336	0.180
18 June 1975	18	800	0.102	13	875	0.134	18	478	0.107
18 July 1975	16	648	0.274	18	309	0.075	7	130	0.024
19 August 1975	10	103	0.008	11	187	0.048	7	81	0.005
29 September 1975	17	147	0.078	12	100	0.032	10	49	0.021
Mean	19	1132	0.211	15	974	0.201	11	436	0.094

[a]The 9 June sample was discarded due to loss of sample in broken dessicator.

Fish

Species composition. The total numbers of species collected from the natural control (N), mitigated channelized (M), and conventionally channelized (O) area was 30, 26, 25 in 1974; 36, 31, 29 in 1975; and 31, 24, 23 in 1976, respectively (Appendix A-2, A-3 and A-4). It can be implied from the indices of relative abundance for the natural area that rock bass, bluegill, longear sunfish, smallmouth bass, white crappie and black crappie were the major game-fish available in undisturbed portions of the Olentangy River. Chi-square tests indicated highly significant differences in percent species composition among natural, mitigated, and channelized sections ($P < 0.001$).

Relative abundance of the total fish stock, expressed as total fish caught per minute of electrofishing per year (Figure 15), was analyzed using Page's test of the hypothesis $N > M > 0$. This was significant at the 0.01 level, and multiple comparisons indicated the differences were $N > 0$ and $M > 0$. Longear and green sunfish were particularly abundant in Area M in 1976, a fact which caused the catch per effort to be especially high.

Analyses of the hypothesis that $N > M > 0$, using Page's test on combined species diversity indices for numbers of individuals per species and biomass per species (Table 6), were significant at the 0.05 and 0.01 levels, respectively. Friedman's multiple comparisons indicated $N > M$ for relative abundance ($P < 0.01$), and $N > 0$ for relative biomass ($P < 0.05$). Within individual sampling periods, Area N had the highest diversity ten times and Area 0 three times for relative numbers. Area N had the highest biomass diversity seven times, Area M four times, and Area 0 twice.

Population dynamics. Page's L-statistic was calculated to compare relative abundance and relative biomass of individual species in the three areas. When significant differences were found, multiple comparisons determined which between-site differences were significant (Table 7). With the exception of white crappie, mitigation did not seem to harm abundance and standing stock of centrarchids, and even proved beneficial to some. Many non-game species which were abundant in the natural area, were not as common in the mitigated area. Unmitigated channelization had an adverse effect on abundance and standing stock of important centrarchids and the yellow bullhead. The black bullhead was more abundant in the unmitigated channelized area.

In addition, covariance analysis was used to test the difference between slopes of length-weight regression lines of abundant species caught from each of the three areas. The regression lines for each species were drawn from a common intercept calculated by pooling the data. This seemed justified because very small fish were not numerous in the collections. Also, fish from the entire reach of stream were assumed to be genetically linked, an assumption that seems proper considering the open-ended system and rather close proximity of the areas. These covariance analyses test hypotheses relating to growth in weight per increases in unit length in the three areas, a relationship we call "relative weight".

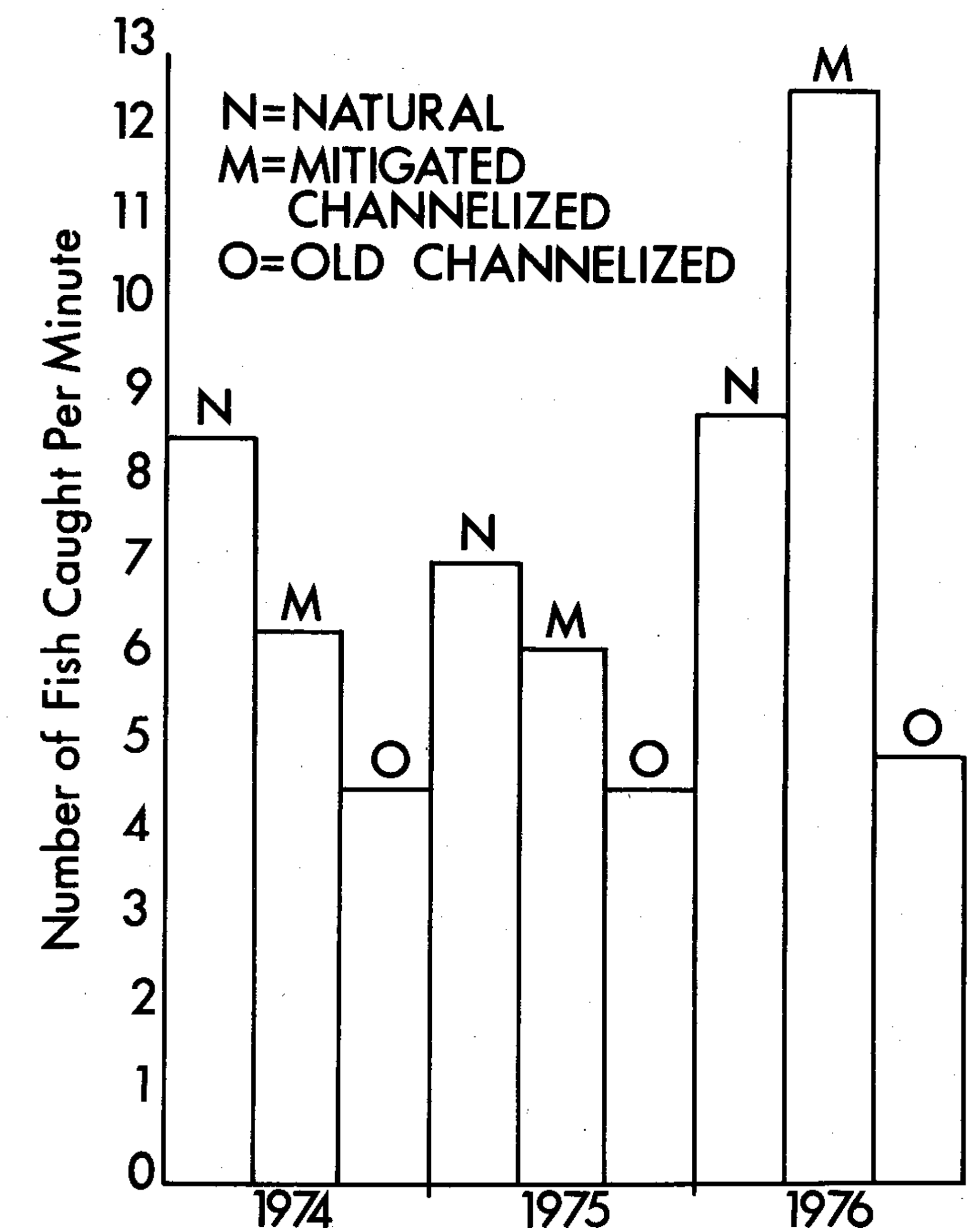

Figure 15. Number of fish of all species caught per minute of electrofishing from three areas of the Olentangy River, Ohio.

Table 6. Species Diversity Indices for Fish Collected from Three Study Areas in the Olentangy River Calculated for Relative Abundance and Relative Biomass

Date		Area M		Area N		Area O	
		Relative abundance	Relative biomass	Relative abundance	Relative biomass	Relative abundance	Relative biomass
4-6	May 1974	2.940	2.391	2.989	1.815	3.246	1.144
10-12	June 1974	3.266	2.613	2.992	2.494	2.836	1.302
23-25	July 1974	3.492	2.312	3.362	2.942	3.482	2.071
26-30	August 1974	3.483	2.105	3.380	2.803	3.250	2.088
1-4	November 1974	3.990	3.025	3.210	3.096	2.730	2.535
2,6,9	April 1975	3.960	1.817	3.838	1.667	3.327	1.288
23-25	May 1975	3.520	2.508	3.047	1.781	3.395	1.501
16-18	June 1975	4.062	2.499	3.112	2.228	3.330	1.702
15-17	July 1975	3.458	1.020	2.699	2.095	3.481	1.631
7-11	October 1975	3.558	2.041	2.917	1.883	3.288	2.984
7-9	May 1976	3.735	2.329	2.748	1.968	2.894	1.775
7-9	July 1976	3.575	2.451	2.808	2.389	3.567	3.000
13-14	October 1976	3.461	3.384	2.548	2.877	3.653	2.737
All collections combined		3.577	2.346	3.050	2.311	3.268	1.997

Table 7. Species of Fish from the Olentangy River which Showed Significant Between-Area Differences ($P < 0.05$) in Relative Abundance (A) and/or Biomass (B) when Analyzed by Page's L-Statistic and Friedman Rank Sums Multiple Comparison

Multiple Comparison					
N > M	N > O	M > N	M > O	O > N	O > M
Goldfish[AB]	Hog sucker[AB]	Green sunfish[A]	Yellow bullhead[B]	Golden redhorse[AB]	Goldfish[AB]
Quillback[AB]	Black redhorse[AB]	Smallmouth bass[B]	Rock bass[AB]	Black bullhead[AB]	Golden redhorse[AB]
Hog sucker[AB]	Yellow bullhead[AB]	Largemouth bass[A]	Green sunfish[A]	Orangespotted sunfish[B]	Black bullhead[AB]
Silver redhorse[A]	Longear sunfish[AB]		Bluegill[AB]	Largemouth bass[AB]	White crappie[AB]
Black redhorse[AB]	Rock bass[AB]		Longear sunfish[AB]		
White crappie[A]	Smallmouth bass[A]		Smallmouth bass[AB]		
	Logperch[AB]		Logperch[B]		

Species which exhibited significantly greater growth in weight per unit length ($P < 0.05$) in the natural area compared to the unmitigated old channelized area included carp, yellow bullhead, green sunfish, bluegill, and longear sunfish. Comparison of fish in the natural area with those in the mitigated channelized area showed the following species with greater relative weight in the natural area: carp, yellow bullhead, rock bass, bluegill, longear sunfish, and smallmouth bass. Yellow bullhead, bluegill, and smallmouth bass had significantly better growth in weight per unit length in Area M compared to Area O. The relative weight of the golden redhorse was significantly better in the old channelized area than in the other areas. The length range and number of fish used in the relative weight calculations for these species are given in Table 8.

Those species clearly showing benefit from channelization in the Olentangy included golden redhorse, black bullhead, orangespotted sunfish and the uncommon largemouth bass. The only species that benefitted from mitigation was the green sunfish. Although smallmouth bass were most abundant in the mitigated area, their relative weight was lower than in the control area. Those species adversely affected by channelization in the Olentangy included hog sucker, black redhorse, yellow bullhead, longear sunfish, rock bass, bluegill, smallmouth bass, and logperch. Goldfish, quillback, hog sucker, silver redhorse, and white crappie showed harm from mitigation.

Fisherman Survey

Point and 95% confidence interval estimates of the number of anglers at each station were calculated via a method described by Cochran (1963) for randomly stratified samples. The mitigated area (M) supported the largest number of angler trips among the three sample areas in both 1974 and 1975 (Table 9). The natural area (N) supported a relatively large number of anglers when considered on a number of anglers/kilometer of stream length/year basis. The 95% confidence intervals for comparisons of the number of anglers visiting Area N vs. Area O (unmitigated channelized area) and Area M vs. Area O in 1974 and Area M vs. Area N and Area M vs. Area O in 1975 did not overlap. Therefore, the estimated number of anglers using these areas was considered significantly different for these comparisons. The total estimated number of fish caught (calculated from the method by Dixon and Massey, 1969) in the three areas, exhibited identical trends and levels of significance as reported above for angler use (Table 10).

The overall catch rates were highest in Area N followed, in order, by Area M and Area O for both years combined (Table 11). With few exceptions, the catch rates for major individual species or groups of species followed in the same order. Area O exhibited the highest catch rates for only one group, the bullheads.

Significant differences in mean total length of fish of various species taken in the three areas could not be detected by t-test. This implies that significantly more biomass is supplied to the sport fishery by Areas N and M than is supplied by Area O since both Areas N and M supply significantly greater numbers of gamefish except for bullheads.

Table 8. The Number and Length Range (mm) of Fish Used in Calculating Relative Weight of Selected Species in Unchannelized (N), Mitigated Channelized (M), and Unmitigated Channelized (O) Areas of the Olentangy River, Ohio

Species	Area N		Area M		Area O	
	No. fish	Length range	No. fish	Length range	No. fish	Length range
Carp	295	121-741	276	125-773	281	111-760
Golden redhorse	174	95-461	164	91-503	189	84-477
Yellow bullhead	26	146-310	38	113-307	6	207-292
Rock bass	418	74-218	147	53-208	21	94-197
Green sunfish	92	49-192	1029	51-166	142	44-157
Bluegill	99	75-184	117	57-198	39	44-200
Longear sunfish	405	54-148	809	52-155	318	44-148
Smallmouth bass	375	52-361	632	43-409	88	52-431

Table 9. The Number of Anglers Observed (No.), Estimated (Est.) Number of Anglers and 95% Confidence Intervals for the Number of Anglers in the Control (N), Mitigated Channelized (M) and Unmitigated Channelized (O) Sections of the Olentangy River between 3 June and 24 September 1974 and between 13 April and 13 September 1975 inclusive (the Number of Anglers per Kilometer of Stream Length Appears in Parenthesis)

Year	Area N			Area M			Area O		
	Anglers		Confidence interval	Anglers		Confidence interval	Anglers		Confidence interval
	No.	Est.		No.	Est.		No.	Est.	
1974	81	489(537)	247-731	150	806(443)	497-1114	24	137(113)	36-238
1975	87	594(653)	408-780	442	2985(1640)	2447-3523	45	311(257)	164-458

Table 10. The Number of Fish Observed (No.) in Control (N), Mitigated Channelized (M) and Unmitigated Channelized (O) Sections of the Olentangy River during Creel Surveys Beginning on 3 June and Ending 24 September 1974 and on 13 April and 13 September 1975, the Estimated Total Catch (Est.) and the 95% Confidence Interval Estimates for the Total Catch (the Estimated Catch-per-Kilometer is Given in Parenthesis)

Year	Area N			Area M			Area O		
	Catch		Confidence interval	Catch		Confidence interval	Catch		Confidence interval
	No.	Est.		No.	Est.		No.	Est.	
1974	121	838(910)	477-1180	131	903(496)	479-1324	18	123(102)	42-204
1975	47	365(401)	173-558	289	2152(1182)	1465-2841	18	134(111)	18-298

Table 11. The Percent Species Composition, Catch-per-Hour, Mean Length, Length Range, and Total Number of Fish Observed in Areas N, M, and O of the Olentangy River, Ohio during 1974 and 1975 Creel Surveys

	Area N					Area M					Area O				
	%	C/H	Mean length (mm)	Length range (mm)	Total counted	%	C/H	Mean length (mm)	Length range (mm)	Total counted	%	C/H	Mean length (mm)	Length range (mm)	Total counted
Smallmouth bass	25.6	0.177	207	170-342	43	23.4	0.114	209	123-340	98	8.3	0.024	221	140-339	3
Rock bass	44.6	0.310	154	100-215	75	26.7	0.130	152	118-198	112	11.1	0.032	137	103-182	4
Sunfish[a]	20.8	0.144	139	100-182	35	33.1	0.161	128	90-195	139	27.8	0.080	126	100-195	10
Crappies[b]	3.6	0.025	165	134-190	6	3.6	0.017	155	140-182	15	0.0	0.000	0	0	0
Channel catfish	2.4	0.016	309	302-358	4	7.8	0.038	294	207-380	33	8.4	0.024	285	257-340	3
Bullheads[c]	1.8	0.012	184	160-240	3	2.6	0.013	242	197-256	11	38.9	0.111	210	190-224	14
Carp	0.0	0.000	-	-	0	1.4	0.007	250	180-520	6	0.0	0.000	-	-	0
Other	1.2	0.008	-	-	2	1.4	0.007	-	-	6	5.5	0.015	-	-	2
Combined	100.0	0.694			168	100.0	0.487			420	100.0	0.285			36

[a]Green sunfish, pumpkinseed, bluegill, and longear sunfish.
[b]Black crappie and white crappie.
[c]Yellow bullhead and black bullhead.

SANDUSKY RIVER

Macroinvertebrates

There were no statistical differences in the number of benthic taxa or in the number of benthic organisms collected in channelized and unchannelized areas of the Sandusky River; however, the number of drift organisms and the number of taxa represented in each drift collection were significantly higher in the unchannelized area at the 95% level (Tables 12 and 13). According to multiple comparison analysis, the baetids, hydropsychids and culicids were the major taxa contributing to the difference in relative drift abundance. The additional taxa in the unchannelized drift were of minor consequence in terms of number of individuals or biomass. Total biomass of benthos and drift reflected these results. A total of 23.20 and 25.70 gms of material was taken in 18 Surber samplers from unchannelized and channelized areas respectively. This undoubtedly is a reflection of the bedrock substrate in both areas. However, 0.95 gm of drift was sampled in the unchannelized area compared to 0.26 gm in the channelized area.

Table 12. Total Number of Families[a] Taken in Benthos and Drift Samples from Unchannelized and Channelized Areas of the Sandusky River, Ohio

Date	Unchannelized		Channelized	
	Benthos	Drift	Benthos	Drift
6 July 1974	10	12	7	9
6 August 1974	7	9	9	7
13 September 1974	9	9	10	8
16 April 1975	6	9	6	6
12 May 1975	9	8	7	8
5 June 1975	5	10	8	4
12 July 1975	9	11	8	10
18 August 1975	13	12	12	7
15 September 1975	8	11	8	7
Total families	17	19	16	15

[a]Oligochaeta and Bivalvia identified to Class.

Table 13. Total Number of Benthic and Drift Organisms Collected in Unchannelized and Channelized Areas of the Sandusky River, Ohio Identified to Family[a]

Taxa	1974[b] Unchannelized Benthos	1974[b] Unchannelized Drift	1974[b] Channelized Benthos	1974[b] Channelized Drift	1975[c] Unchannelized Benthos	1975[c] Unchannelized Drift	1975[c] Channelized Benthos	1975[c] Channelized Drift
Elmidae	199	12	365	5	73	18	346	15
Culicidae	4	128	0	29	0	39	0	13
Astacidae	1	1	5	0	3	0	3	0
Chironomidae	531	1212	1072	1287	647	2068	914	1730
Empididae	10	0	1	3	2	2	3	0
Simuliidae	0	6	33	19	158	41	90	78
Baetidae	476	355	196	78	193	143	353	113
Ephemeridae	7	0	9	0	0	0	1	0
Heptageniidae	357	57	389	83	343	8	741	110
Pyralidae	204	24	15	1	113	8	40	2
Coenagrionidae	0	1	38	0	13	0	1	0
Hydropsychidae	4420	416	2736	194	1665	108	3339	90
Hydroptilidae	0	1	1	0	14	1	2	2
Gerridae	0	28	0	3	0	2	0	0
Psephenidae	0	1	0	0	2	0	1	0
Perlidae	0	0	0	0	1	0	0	0
Philopotamidae	0	0	0	0	0	0	5	0
Psychomyiidae	0	0	0	0	4	0	0	0
Oligochaeta	53	31	5	25	317	41	20	81
Bivalvia	24	2	0	0	1	0	1	0
Gastropoda	0	0	0	0	83	1	0	0
Other	0	8	0	8	0	9	0	7
Total	6286	2284	4865	1732	3632	2497	5860	2242

[a]Oligochaeta and Bivalvia identified to Class.

[b]Represents total from 12 Surber samples and 24 drift samples from each area.

[c]Represents total from 24 Surber samples and 48 drift samples from each area.

Monthly individual diversity indices for benthos were nearly the same in each area. Individual diversity indices were 1.88 and 1.62 in 1974 and 1.94 and 2.50 in 1975 for the channelized and unchannelized areas, respectively.

Fish

A total of 1226 minutes of electrofishing yielded 4432 fish of 31 species from the two Sandusky River stations (Appendix A-5). The April, 1975, sample was not included because it was overwhelmingly biased toward spawning walleyes in both areas. Although white bass undergo considerable annual fluctuation in the river due to spawning activity, they were present in the river throughout much of the spring and summer and, therefore, were considered residents in this study. Walleyes, on the other hand, moved in and out of the river within the month of April and were therefore considered non-residents.

Catch per effort of all resident species combined was highest both years in the unchannelized area, but it was statistically significant only in 1975 ($P < .05$). There were 27 species collected in the unchannelized area and 28 in the channelized area. Individual species diversity was 2.92 in the unchannelized area and 3.21 in the channelized area.

Only two gamefishes, white crappie and white bass, were among the six most abundant species in each area (Table 14), and these were considerably more abundant in the unchannelized area. Other gamefishes (bullheads, catfish, and the larger centrarchids) were uncommon in both areas.

Table 14. The Six Most Abundant Resident Species of Fishes as Measured by Number of Fish Caught per Minute Electrofishing in Unchannelized and Channelized Areas of the Sandusky River, Ohio, in 1974 and 1975

Unchannelized Species	Unchannelized No./minute	Channelized Species	Channelized No./minute
Carp	1.044	Gizzard shad	0.832
Gizzard shad	0.557	Carp	0.534
White bass	0.518	Green sunfish	0.503
White crappie	0.478	Goldfish	0.497
Golden redhorse	0.244	White crappie	0.196
Goldfish	0.161	White bass	0.098

Catch rates of fish near the large limestone riprap in the channelized area seemed high compared to other locations within the area.

Fisherman Survey

The estimated number of anglers fishing for non-migratory fishes during the summer months was considerably greater in the unchannelized control area (Table 15). In fact, no anglers were observed in the channelized area in 1975. Aside from 18 white bass taken in 1974, the catch from the channelized area was inconsequential. The catch from the unchannelized area was also small, but tended to be more diverse (Table 16). An estimated 2667 (±2000) resident fishes were caught during the two summers in the control area, compared to 766 (±745) in the channelized area.

In 1975, over 80% (5664) of the anglers fished in the river during spring spawning runs, and 85% of these (4846) fished in the channelized section. Over 90% of the total catch was walleye and white bass, and 89% of these fishes were taken in the channelized area (Table 17). Fish were more available in this section during spawning runs as they congregated below the sharp limestone outcropping which crossed the stream in the middle of the channelized area (Figure 8).

HOCKING RIVER

Results from the Hocking River appeared to be highly confounded by highway construction adjacent to the channelized area which influenced large portions of both areas. At the outset of this project, the investigators were unaware that construction, which commenced immediately after the project began, was even planned for the area.

Macroinvertebrates

The only significant difference between the unchannelized and channelized areas in Hocking River macroinvertebrate data involved the number of benthic organisms collected. The number of organisms in the unchannelized area was significantly higher ($P < 0.05$) than in the channelized area (Table 18). Chironomidae, Baetidae, and Hydropsychidae were more numerous in unchannelized areas ($P < 0.05$). Numbers of taxa and biomass of benthos and drift, and numbers of drift organisms in the two areas were not different. In general, macrobenthic populations in the unchannelized area were unchanged in 1974 and 1975, but an increase was indicated in the channelized area in 1975.

Individual benthic diversity indices were higher in the unchannelized area. In 1974, diversity indices were 1.72 and 1.60, and in 1975 they were 1.82 and 1.61 in the unchannelized and channelized areas, respectively. Overall macrobenthic diversity and abundance in the Hocking River were the lowest of the five rivers studied, which was probably the result of high silt loads from highway construction.

Table 15. The Number and Percentage of Anglers Observed, the Estimated Total Number of Anglers, and the 95% Confidence Intervals for Estimates of Total Anglers Fishing in the Unchannelized and Channelized Sections of the Sandusky River between 8 June and 19 August 1974 and between 18 July and 21 September 1975

Year	Unchannelized				Channelized			
	Number observed	Percent	Estimated anglers	Confidence interval	Number observed	Percent	Estimated anglers	Confidence interval
1974	22	52.4	696	22 - 1669	20	47.6	633	200 - 1153
1975	57	100.0	969	57 - 1919	0	0.0	0	- - -

Table 16. The Percent Species Composition, Catch-per-Hour and Total Catch in Unchannelized and Channelized Sections of the Sandusky River, Ohio, During 12 Four-Hour Creel Surveys Beginning 8 June and Ending 19 August 1974 and 12 Four-Hour Surveys Beginning 18 July and Ending 21 September 1975

	Unchannelized						Channelized					
	Percent		Catch/Hour		Catch		Percent		Catch/Hour		Catch	
Species	1974	1975	1974	1975	1974	1975	1974	1975	1974	1975	1974	1975
Smallmouth bass	0.0	3.0	0.000	0.032	0	3	0.0	0.0	0.000	0.000	0	0
Largemouth bass	0.0	1.0	0.000	0.011	0	1	0.0	0.0	0.000	0.000	0	0
Crappie	0.0	14.0	0.000	0.151	0	14	0.0	0.0	0.000	0.000	0	0
Sunfish	0.0	6.0	0.000	0.065	0	6	0.0	0.0	0.000	0.000	0	0
White bass	0.0	13.1	0.000	0.140	0	13	85.7	0.0	0.537	0.000	18	0
Drum	34.5	7.0	0.285	0.075	10	7	0.0	0.0	0.000	0.000	0	0
Carp	27.6	2.0	0.299	0.022	8	2	9.5	0.0	0.060	0.000	2	0
Channel catfish	37.9	53.5	0.314	0.571	11	53	4.8	0.0	0.030	0.000	1	0
Total	100.0	100.0	0.829	1.067	29	99	100.0	0.0	0.627	0.000	21	0

Table 17. Estimates of the Percent Species Composition, Catch-per-Hour, Total Number and Weight (kg) of Fish Caught During Creel Surveys in Unchannelized and Channelized Sections of the Sandusky River, Ohio, from 15 March to 15 June, 1975 (Unpublished Data from Ohio Division of Wildlife, Sandusky)

	Unchannelized				Channelized			
Species	%	No./hr	Total no./ km of stream	Total wt./ km of stream	%	No./hr	Total no./ km of stream	Total wt./ km of stream
Walleye	17.2	0.129	2,838	3799.5	3.5	0.036	4,889	6,519.5
White bass	72.2	0.544	11,943	2794.7	94.4	0.970	130,593	30,558.8
Smallmouth bass	0.2	0.001	24	8.7	0	0.001	7	2.4
Channel catfish	5.1	0.038	839	292.8	0	0	0	0
Other	5.4	0.041	892	0	2.1	0.022	2,908	0
Total	100.0	0.753	16,536	6895.7	100.0	1.029	138,336	37,080.7

Table 18. Total Number of Benthic and Drift Organisms Collected in Unchannelized and Channelized Areas of the Hocking River, Ohio, Identified to Family[a]

Taxa	1974 Unchannelized Benthos	1974 Unchannelized Drift	1974 Channelized Benthos	1974 Channelized Drift	1975 Unchannelized Benthos	1975 Unchannelized Drift	1975 Channelized Benthos	1975 Channelized Drift
Ptilliidae	1		0		0		0	
Chironomidae	267	1384	64	1068	351	1080	263	1572
Simuliidae	5	51	0	19	1	0	0	2
Baetidae	27	79	4	3	108	139	20	163
Heptageniidae	100	8	7	0	24	7	67	10
Hydropsychidae	249	36	1	3	41	31	14	13
Elmidae	0	36	0	0	1	1	2	0
Culicidae	0	75	0	23	0	23	1	71
Heleidae	0	1	0	1	3	0	1	13
Entobryidae	0		0		0	0	0	12
Psychomyiidae	0		0		5	16	8	26
Oligochaeta	8	2	13	2	7	32	7	26
Other	1	9	6	3	10	11	4	28
Total	658	1681	95	1121	551	1340	387	1937
Total biomass (gm)	.11	.13	.20	.07	.07	.10	.42	.11
Total taxa	8	12	7	9	17	13	13	25

[a]Oligochaeta identified to Class.

Fish

The relative abundance of fishes in the Hocking River was also low compared to the other study rivers (Appendix A-6). Catch per minute was significantly greater in the channelized section ($P < 0.05$), and chi-square tests indicated a significant difference in species composition between areas at the 0.01 level. Multiple comparisons indicated that carp, quillback, spotted sucker, black redhorse, and white crappie were significantly more abundant in the channelized area ($P < 0.05$). Longear sunfish and golden redhorse were significantly more numerous in the unchannelized area ($P < 0.05$). Although 38 largemouth bass were collected in the channelized area, 29 of these were taken during the first sampling trip on 4-5 June, 1974. Thereafter, highway construction caused increased turbidity, and gamefish were rarely collected at either station. The five most common fishes in the channelized area, in order of relative abundance, were: gizzard shad, carp, quillback, bluegill, and spotted sucker. Gizzard shad, carp, black bullhead, bluegill, and longear sunfish were most common in the control area.

Individual diversity indices for 1974 and 1975 combined were 3.03 in the channelized area and 1.20 in the unchannelized area. The relatively high diversity in the channelized area was due to greater numbers of several non-game species.

Fisherman Survey

Fishing activity was highest in the channelized area. In 1974, 81 anglers were interviewed in this area, and in 1975, 79 were interviewed. An estimated 918 (95% confidence interval = ±606) anglers used the channelized area in 1974 and 813 (±426) in 1975. The total catch per hour in 1974 was 0.599 in 1974, but it dropped to 0.317 in 1975. Common fishes in the catch, in order of their contribution to the creel, were: sunfish, largemouth bass, smallmouth bass, carp, and channel catfish.

Only one fisherman was interviewed in the control section during both years, and he caught one channel catfish.

The sport fishery in the river was negligible. Although the catch composition contained a good percentage of gamefishes, the catch per unit of effort was low, and fish were small. Over 85% of the anglers interviewed were local youngsters. Access appeared to be a major limiting factor in the control area. Fisherman success paralleled electrofishing success in that most gamefishes were counted in early summer, 1974, prior to commencement of the highway construction project.

LITTLE AUGLAIZE RIVER

In midsummer 1974, the entire channelized portion of the Little Auglaize River was completely dry for nearly two months as the result of an extended drought (Figure 16). Standing water in the control section was limited to

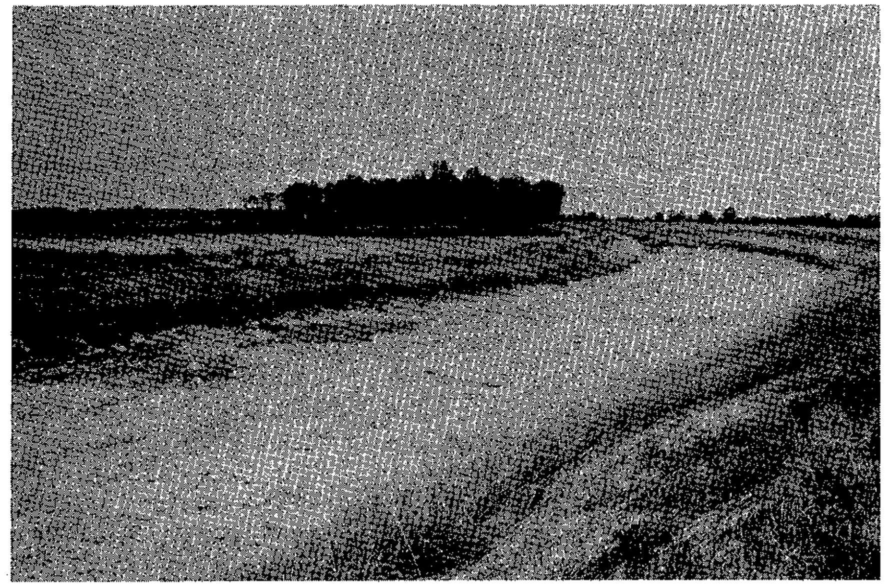

Figure 16. The channelized area of the Little Auglaize River during drought in summer, 1974.

Figure 17. The unchannelized area of the Little Auglaize River during 1974 drought taken same day as picture in Figure 16.

the deeper pools (Figure 17). The impacts of the drought were evident throughout the period of study.

Macroinvertebrates

In 1974, benthic sampling was limited to four replicate Surber samples per station in June. No statistical inferences could be made; however, eight families of macroinvertebrates were identified and 171 individuals counted in samples from the channelized section. A total of 115 individuals from six families were found in the samples from the unchannelized area.

In 1975, 14 taxa were identified from each area, but significantly ($P < 0.05$) more individuals were taken in the channelized area (Table 19). Multiple comparisons indicated that oligochaetes, simulids, baetids, and hydropsychids contributed significantly more individuals ($P < 0.05$) in this area. Total biomass collected with Surber samplers was nearly equal in both areas --9.75 gm in the control area and 9.25 gm in the channelized area.

Individual benthic species diversity was 2.33 in the unchannelized area and 3.02 in the channelized area in 1975.

Drift sampling in 1974 was also limited by the drought, and quantitative analysis was precluded. A total of 17 taxa and 619 individual drifters were collected from the unchannelized area, and 205 individuals from 9 taxa were collected from the channelized area in the single 24-hr drift sample attempted.

In 1975, drift, expressed in numbers of taxa and numbers of organisms, was heavier in the unchannelized area than in the channelized area at the 99% confidence level (Table 19). Chironomids were significantly more abundant in the unchannelized area ($P < 0.01$) and largely accounted for the difference. Except for Oligochaeta, all other major taxa were also equally or more abundant in the unchannelized area. Total biomass in the drift from the unchannelized area (4.50 gm) was nearly five times greater than that collected in the channelized area (0.95 gm).

Fish

No quantitative data on fish populations were collected in 1974. By mid-June, fishes in the channelized portion had collected in the few remaining pools and were limited to species that are especially tolerant of low dissolved oxygen and high temperature (water temperatures ranged to 28.3°C). In contrast, maximum water temperature at the Bockey Road control area at the same time was 17.2°C, and other stream conditions appeared normal. By early July, the entire 35 km (56.6 mi) of the channelized stream bed was completely dewatered and devoid of fish life. The unchannelized area upstream contained relatively cool discontinuous pools in which fishes had congregated. The maximum temperature (24.7°C) was recorded on 26 July 1974. These conditions prevailed until late August. Although considerable mortality probably occurred in the pools in the unchannelized area, live individuals of several tolerant species were seen throughout the drought period.

Table 19. Total Number of Benthic and Drift Organisms Collected in Unchannelized and Channelized Areas of the Little Auglaize River, Ohio, in 1975

Taxa	Unchannelized area		Channelized area	
	Benthos	Drift	Benthos	Drift
Elmidae	11	134	77	30
Astacidae	7	0	8	0
Chironomidae	553	3969	430	602
Simulidae	0	29	304	24
Baetidae	35	192	162	146
Heptageniidae	292	69	91	37
Asellidae	100	36	32	0
Hydropsychidae	39	119	170	8
Ptilidae	0	0	247	0
Culicidae	0	30	0	30
Heleidae	0	0	0	17
Corixidae	2	64	14	13
Perlidae	11	3	27	0
Oligochaeta	87	154	415	573
Bivalvia	10	4	0	0
Gastropoda	42	8	4	0
Other	3	38	5	6
Total individuals	1192	4858	1986	1486
Total taxa	14	29	14	16

Fish populations in the channelized area had made a recovery by the summer of 1975 (Appendix A-7). Thirty species were represented in the samples, and the catch per minute of a number of species was high. The catch primarily consisted of cyprinids, catostomids, and shad. Gamefish were uncommon. Indices of relative abundance in the unchannelized area were comparatively low, and species collected there were generally limited to some of the more abundant species occurring in the channelized area downstream. Stream survey records obtained from the Ohio Division of Wildlife indicated that a number of additional species were common to abundant in the general area of the unchannelized site as recently as 1973. These were generally less tolerant species that apparently perished during the drought and had not repopulated the area. Repopulation rates of the unchannelized area from below were probably limited by the two low-head dams.

ROCK CREEK

Macroinvertebrates

There were no significant differences in the number of organisms in benthos or drift collections from channelized and unchannelized areas during 1974 and 1975, although results were inconsistent (Table 20). In 1974, benthic fauna seemed more numerous in the unchannelized area, and drift was higher in the channelized area. The reverse seemed true in 1975. It was impossible to tell if this change was real or the result of sampling error.

The six most abundant taxa in the samples were identical in both benthos and drift in the two areas (Table 21). Chironomids were most abundant in the samples from the channelized area. The remaining five taxa were more abundant in the drift samples from the unchannelized area, but this was not true for benthos samples. Diversity indices calculated from Surber samples were also inconsistent. Indices were 2.88 in the unchannelized area and 2.49 in the channelized area in 1974 and 1.96 and 2.02 in these respective areas in 1975. Total biomass collected in the two years was significantly higher in the unchannelized area for both benthos ($P < 0.05$) and drift ($P < 0.01$). Forty-three grams of material were taken in Surber samples from the unchannelized area and 12.25 gm from the channelized area. Biomass in the unchannelized drift samples exceeded that in the channelized samples by 800% (1.33 gm to 0.16 gm).

Fish

Fish abundance was significantly ($P < 0.01$) greater in the channelized area than in the unchannelized area of Rock Creek (Appendix A-8). Multiple comparisons indicated that stonerollers, bluntnose minnows, creek chubs, and hog suckers had significantly ($P < 0.01$) higher relative abundance in the channelized area, while gizzard shad, carp, bluegill, and longear sunfish were significantly more numerous in samples from the unchannelized area ($P < 0.01$). Yellow bullheads and rock bass were also significantly more abundant in the unchannelized area samples ($P < 0.05$).

Table 20. Total Number of Benthic and Drift Organisms of Various Taxa Collected in Unchannelized and Channelized Areas of Rock Creek, Indiana

Taxa	1974				1975			
	Unchannelized		Channelized		Unchannelized		Channelized	
	Benthos	Drift	Benthos	Drift	Benthos	Drift	Benthos	Drift
Elmidae	237	74	35	22	46	81	52	39
Astacidae	7	0	2	0	1	0	3	0
Chironomidae	288	503	157	1303	104	1457	445	1144
Empididae	8	2	1	4	3	3	1	5
Heleidae	1	1	0	1	0	0	0	2
Simulidae	2	35	0	49	9	76	36	25
Baetidae	97	131	35	69	57	214	227	71
Heptageniidae	55	2	97	15	80	74	148	20
Pyralidae	37	0	0	0	1	1	0	0
Hydropsychidae	1320	50	374	28	78	109	535	78
Hydroptilidae	5	2	0	2	13	6	108	9
Ptilidae	0	0	0	4	0	0	0	3
Isotomidae	0	0	0	3	0	9	0	11
Corixidae	0	2	0	0	0	8	0	0
Gerridae	0	8	0	1	0	44	0	0
Oligochaeta	22	128	15	9	182	213	25	22
Gastropoda	13	1	1	0	17	0	0	0
Other	3	6	4	11	6	10	12	12
Total individuals	2120	951	724	1521	668	2305	1592	1435
Total taxa	16	19	12	20	17	18	13	15

Table 21. Numbers of Organisms in the Six Most Abundant Taxa Collected in Benthos and Drift Samples from Unchannelized and Channelized Areas of Rock Creek, Indiana, in 1974 and 1975

Taxa	Benthos		Drift	
	Unchannelized	Channelized	Unchannelized	Channelized
Chironomidae	452	602	1960	2447
Oligochaeta	204	40	341	31
Baetidae	154	262	345	140
Heptageniidae	135	245	76	35
Hydropsychidae	1378	909	159	106
Elmidae	283	87	283	61

Twenty-three species were collected in the channelized area and 33 in the unchannelized area. Diversity indices calculated from pooled 1974 and 1975 data were 3.29 and 3.23 in the unchannelized and channelized areas, respectively. Although fishes were less numerous in the unchannelized area, the diversity indices reflected a more even spread of numbers of individuals over more species.

Interpretation of abundance data is clouded by the extremely high abundance of a few species in one area or the other. A chi-square test showed a significant ($P < 0.01$) difference in percent species biomass in the two areas. The most numerous species in the channelized area were typically small non-gamefishes; whereas, the unchannelized area supported a larger biomass of game species (Table 22). Ictalurids and centrarchids, which generally include important gamefish groups, accounted for 25% of the total biomass collected in the unchannelized area in 1975. In comparison, these two families contributed only 4% of the biomass collected from the channelized area. Obviously, channelization in Rock Creek created habitat for large numbers of small non-game forage fishes.

Table 22. The Total Catch[a] of Fish in Unchannelized and Channelized Areas of Rock Creek, Indiana, Expressed as gm/min, Electrofishing in 1974 and 1975

Species	Unchannelized area	Channelized area
Stoneroller	1.71	83.25
Carp	345.23	25.07
Silverjaw minnow	0	0.36
Common shiner	1.22	17.43
Spotfin shiner	0.53	1.46
Sand shiner	0.03	0
Suckermouth minnow	0.15	0.83
Bluntnose minnow	1.56	7.66
Creek chub	0.49	194.30
White sucker	110.66	83.83
Hog sucker	23.46	169.67
Spotted sucker	19.32	0
Golden redhorse	8.53	0
Black bullhead	3.81	0
Yellow bullhead	27.38	12.63
Channel catfish	15.70	0
Stonecat madtom	0.34	1.88
Blackstripe topminnow	0.01	0.01
Rock bass	17.10	3.18
Green sunfish	9.60	1.51
Bluegill	3.80	0
Longear sunfish	22.50	3.42
Smallmouth bass	52.18	5.27
Largemouth bass	1.20	0
White crappie	0.73	0
Greenside darter	0.07	0.92
Rainbow darter	0	0.03
Fantail darter	0.05	0.12
Logperch	1.17	8.21
Blackside darter	0.07	0
Total gm/min	668.61	621.15

[a]Gizzard shad were not weighed.

DISCUSSION

Variability in physical parameters and in the fish and macroinvertebrate populations of the five study streams was too great to permit development of hypotheses that could withstand rigorous analysis. However, a number of generalizations can be made concerning the effects of channelization on macroinvertebrates and warm water fish populations in the study streams.

One of the inevitable effects of stream channelization involves widening of the stream bed. The resultant loss of water velocity enhances deposition and instability of bottom material, especially in silt-laden warm water streams draining agricultural lands. The result is frequently a loss of abundance, diversity, and/or biomass of macrobenthic invertebrates. These parameters were all adversely affected by channelization in the Olentangy River. Macroinvertebrate abundance in the channelized area of the Hocking River was significantly lower than in the unchannelized area, and macroinvertebrate biomass was adversely affected by channelization in Rock Creek. No effects were noted in the benthos of the Sandusky River, a fact which may be explained by the prevalence of bedrock bottom in both sampling areas. The Little Auglaize, in 1975, was the only stream sampled where macroinvertebrates were significantly more abundant and diverse in the channelized area, a phenomenon which might be related to dewatering the stream in 1974. In addition, dominant riffle species, such as hydropsychids, heptageniids, elmids, and psephenids were replaced by slow water forms such as oligochaetes and chironomids in channelized areas of the Olentangy and Hocking Rivers. The latter groups generally build tubes or burrow in the silt-mud bottoms where they are less available as food for fish unless they drift.

Drift rates tended to be highest in unchannelized sections of the study streams. Waters (1969) stated that drift rates are highest where production rates are highest and re-attachment to a suitable unoccupied site is most difficult. Since drift distance is generally quite short (Waters 1965, 1969, and Elliot 1967), drifting invertebrates collected in this study presumably originated in the general area of the sampling sites. The obvious implication is that production of macrobenthic invertebrates was generally greater in unchannelized areas. It follows that macroinvertebrates thus constituted a greater food supply for fishes in unchannelized areas through increased production, increased drift rates, and mode of living on the surface of the substrate.

The common groups of fishes found in the study streams included important game species; these were the sunfishes, crappies, basses, and, to some extent, the catfishes. As juveniles and adults, these fishes generally inhabit deeper pools and sight feed on macroinvertebrates and/or small fishes (Trautman 1957 and Flieger 1975). In general, these fishes were much more abundant in unchannelized areas, whereas non-game random bottom and detritus feeders (e.g., catostomids and cyprinids) dominated channelized areas. This result was especially true in the Olentangy River, Hocking River, and Rock Creek. Diversity and/or relative abundance of fish was greater in unchannelized areas of the Olentangy and Hocking Rivers, but there were cases where no differences occurred. Significant differences favoring channelized areas for any of these parameters were rare and generally occurred when one or two species adapted to the specific habitat provided by channelization achieved extremely high relative abundance and/or biomass (e.g. gizzard shad in the Olentangy, quillback in the Hocking, and stoneroller and other minnows in Rock Creek and the Little Auglaize). The mitigation structures in the Olentangy River served to reduce the stress induced by channelization on aquatic biota. The deep pools and artificial riffles allowed macroinvertebrate production and relative abundance, standing crop, and fitness of high value fishes to approximate that of the control area. Diversity of both macroinvertebrates and fishes in the artificial riffle-pools was intermediate to the control and old channelized site; therefore, some loss of stability and niche availability may be indicated. Certainly the long-term recovery of the biota in the unmitigated channelized area, constructed over 25 years earlier, has been slow and may never again approximate that of the other areas.

Fisherman use in the study areas was dictated by a combination of accessibility and availability of desirable fishes in the area. Catch composition closely reflected relative abundance of the different species inhabiting an area. If desirable species were relatively scarce, fisherman use tended to be negligible, even if good access was available. Alternatively, if access was poor, use was low. The combination of good access and relatively large numbers of desirable fishes in the mitigated area of the Olentangy was particularly appealing to fishermen. Use of this area was highest of any area studied, and catch rates of desirable species were relatively good, although they did not exceed those of the Olentangy unchannelized area. Fisherman use of the channelized area in the Sandusky River during the spring walleye run was exceptionally high because of the combination of easy access and walleye aggregations below the shallow bedrock shelves; however, sport fishing in the channelized area slowed significantly when walleyes returned to Lake Erie.

Data relating to short-term biological recovery from channelization of Rock Creek are inconclusive. Macroinvertebrate abundance in the channelized area approximated that in the unchannelized area 1 to 2 years post-channelization, but macroinvertebrate biomass was significantly lower in the channelized area. Centrarchids, which comprise the gamefishes, were not as well represented in the channelized samples as in the unchannelized samples two years after channelization; however, most non-game fishes were abundant in the channelized area. If the hypothesis that physical changes in the habitat induced by channelization limit gamefish populations in warm water streams is correct, it is reasonably safe to assume that centrarchid populations in the channelized area will not approach those in the unchannelized area over a longer period of time.

Of the five rivers studied, the Sandusky River showed the greatest similarity of animal populations in both channelized and unchannelized sections. The channelized area in this river probably provided more suitable habitat and allowed for more diverse and abundant animal populations than channelized areas in any of the other study streams. The bedrock bottom and large riprap in the channelized area provided deep pools, some riffles, and large interstitial spaces which provide cover.

Special reference should be made to the results of the Little Auglaize River study. Drought conditions led to intolerable thermal stress prior to complete dewatering of the entire channelized section. Since there were no good riffle areas in which to sample macroinvertebrates in the unchannelized area, and sampling of fishes in early 1974 was limited, pre-drought conditions there are hard to document. Comparison of post-drought data with historical Ohio fishery survey records indicate that the drought also induced severe, although incomplete, mortality in the unchannelized area. In 1975, fish populations were considerably larger and more diverse in the channelized area than in the unchannelized area. Fish populations in the latter area did not approximate those indicated by Ohio survey records in the early 1970's. Therefore, recovery of the channelized area, which is open to the Maumee River, seemed rapid. The control area, which is separated from the Maumee by two dams, had no refuges from which repopulation might originate, and recovery was comparatively slow. Channelization may drain small- to moderately-sized watersheds so efficiently as to dewater associated stream channels under drought conditions. The provision of refuges for aquatic biota is recommended. These may be in the form of direct access to unchannelized receiving streams, unchannelized tributary streams of equal stream order, or unmodified stream sections within sizeable channelization projects.

CONCLUSIONS

Riffle species (heptageniids, hydropsychids, elmids) in macroinvertebrate communities are replaced by slow water forms (chironomids and tubificids) after channelization of warm water streams.

Populations of macroinvertebrates are generally lower in channelized than in unchannelized areas of warm water streams.

Fish communities show increasing dominance by warm water non-game fishes and reduced relative abundance of gamefishes in channelized sections.

Abundance, biomass, and/or diversity of both macroinvertebrates and fishes are frequently reduced by channelization.

Macroinvertebrate and fish communities in unmitigated channelized sections of the Olentangy River have not recovered in the 27 years since alteration.

Artificial riffle-pool areas in an altered section of the Olentangy River have been effective in providing standing crops of desirable fishes approximating those in an unaltered section.

Recreational use of channelized warm water streams depends upon availability of desirable species and ease of access.

Fish and macroinvertebrate recolonization of recently altered unmitigated sections of small warm water streams can occur naturally within a year after channel construction, but community structure may be changed.

In small, well-drained agricultural watersheds, channel alterations can lead to complete dewatering of long sections of the stream bed during drought conditions.

Fish recolonization of dewatered sections of altered streams can occur within a year after the drought if adjacent waters are available as fish refuges.

RECOMMENDATIONS

Natural or artificial riffles and large rock riprap should be included in all stream alteration projects to provide substrate and habitat for production of desirable macroinvertebrates and fishes.

Deep pools should be available downstream from the riffles to provide habitat for warm water gamefish, principally centrarchids. To minimize sediment deposition in the pools, increases in stream width should be minimized in riffle-pool areas.

Public access should be provided to mitigated areas to insure use of the resource provided by mitigation.

Unaltered refuges such as unaltered receiving streams or tributaries should be provided for fish adjacent to altered stream sections in case of drought. If alteration is extensive in terms of stream length (e.g. more than 5-8 kilometers), an unaltered section(s) should be left midway within the construction area.

Alteration of the bottom in natural streams should be minimized where possible. Levees may provide an alternative to stream widening and deepening in order to minimize changes in flow characteristics, yet furnish protection from flooding.

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Appendix A-1. The Common and Scientific Names of Fishes Used in this Study as Identified by the American Fisheries Society (1970)

Common Name	Scientific Name
Longnose gar	Lepisosteus osseus (Winchell)
Gizzard shad	Dorosoma cepedianum (Lesueur)
Muskellunge	Esox masquinongy Mitchill
Grass pickerel	Esox lucius Linnaeus
Stoneroller	Campostoma anomalum (Rafinesque)
Goldfish	Carassius auratus (Linnaeus)
Carp	Cyprinus carpio Linnaeus
Silverjaw minnow	Ericymba buccata Cope
Suckermouth minnow	Phenacobius mirabilis (Girard)
Bluntnose minnow	Pimephales notatus (Rafinesque)
Fathead minnow	Pimephales promelas Rafinesque
Golden shiner	Notemigonus crysoleucas (Mitchill)
Emerald shiner	Notropis atherinoides Rafinesque
Striped shiner	Notropis chrysocephalus (Rafinesque)
Common shiner	Notropis cornutus (Mitchill)
Silver shiner	Notropis photogenis (Cope)
Spotfin shiner	Notropis spilopterus (Cope)
Sand shiner	Notropis stramineus (Cope)
Redfin shiner	Notropis umbratilis (Girard)
Steelcolor shiner	Notropis whipplei (Girard)
Creek chub	Sematilus atromaculatus (Mitchill)
Quillback	Carpiodes cyprinus (Lesueur)
White sucker	Catostomus commersoni (Lacépède)
Creek chubsucker	Erimyzon oblongus (Mitchill)
Northern hogsucker	Hypentelium nigricans (Lesueur)
Smallmouth buffalo	Ictiobus bubalus (Rafinesque)
Largemouth buffalo	Ictiobus cyprinellus (Valenciennes)
Spotted sucker	Minytrema melanops (Rafinesque)
Silver redhorse	Moxostoma anisurum (Rafinesque)
Black redhorse	Moxostoma duquesne (Lesueur)
Golden redhorse	Moxostoma erythurum (Rafinesque)
Shorthead redhorse	Moxostoma macrolepidetum (Lesueur)
Black bullhead	Ictalurus melas (Rafinesque)
Yellow bullhead	Ictalurus natalis (Lesueur)
Brown bullhead	Ictalurus nebulosus (Lesueur)
Channel catfish	Ictalurus punctatus (Rafinesque)
Stonecat	Noturus flavus Rafinesque
Tadpole madtom	Noturus gyrinus (Mitchill)
Brindled madtom	Noturus miurus Jordan
Flathead catfish	Pylodictis olivaris (Rafinesque)
Troutperch	Percopsis omiscomaycus (Walbaum)
Blackstripe topminnow	Fundulus notatus (Rafinesque)
Brook silverside	Labidesthes sicculus (Cope)
White bass	Morone chrysops (Rafinesque)
Rock bass	Ambloplites rupestris (Rafinesque)
Green sunfish	Lepomis cyannelus (Rafinesque)
Pumpkinseed	Lepomis gibbosus (Linnaeus)
Warmouth	Lepomis gulosus (Cuvier)
Orangespotted sunfish	Lepomis humilis (Girard)
Bluegill	Lepomis macrochirus Rafinesque
Longear sunfish	Lepomis megalotis (Rafinesque)
Smallmouth bass	Micropterus dolomieui Lacépède
Spotted bass	Micropterus punctulatus (Rafinesque)
Largemouth bass	Micropterus salmoides (Lacépède)
White crappie	Pomoxis annularis Rafinesque
Black crappie	Pomoxis nigromaculatus (Leseuer)
Greenside darter	Ethestoma blennioides Rafinesque
Rainbow darter	Etheostoma caeruleum Storer
Fantail darter	Etheostoma flabellare Rafinesque
Johnny darter	Etheostoma nigrum Rafinesque
Banded darter	Etheostoma zonale (Cope)
Logperch	Percina caprodes (Rafinesque)
Blackside darter	Percina maculata (Girard)
Dusky darter	Percina sciera (Swain)
Walleye	Stizostedion vitreum vitreum (Mitchill)
Freshwater drum	Aplodinatus grunniens Rafinesque

Appendix A-2. Cumulative Catch by Electrofishing from Three Areas of the Olentangy River, 1974, Expressed as Total Number of Fish Caught, Numbers per Minute, and Grams per Minute

Species	Area N			Area M			Area O		
	Total Number	Number/ Minute	gm/ Minute	Total Number	Number/ Minute	gm/ Minute	Total Number	Number/ Minute	gm/ Minute
Gizzard shad	24	0.096	-	109	0.224	-	418	1.366	-
Muskellunge	-	-	-	1	0.002	17.75	-	-	
Stoneroller	40	0.161	4.82	1	0.002	0.08	-	-	-
Goldfish	10	0.040	9.73	-	-	-	5	0.016	3.82
Carp	196	0.787	1169.1	153	0.315	527.76	248	0.810	1152.0
Silver shiner	31	0.124	1.24	5	0.010	0.10	-	-	-
Spotfin shiner	29	0.116	1.16	-	-	-	-	-	-
Bluntnose minnow	17	0.068	0.45	11	0.023	0.15	4	0.013	0.08
Quillback	47	0.189	109.13	7	0.014	8.05	28	0.092	35.63
White sucker	33	0.133	40.14	92	0.189	82.53	23	0.075	21.76
Hog sucker	47	0.189	60.38	13	0.027	11.80	4	0.013	4.89
Silver redhorse	42	0.169	193.59	18	0.037	47.86	19	0.062	81.07
Black redhorse	65	0.261	125.56	45	0.093	30.61	6	0.020	8.34
Golden redhorse	141	0.566	304.80	193	0.397	221.14	165	0.539	326.25
Shorthead redhorse	-	-	-	3	0.006	6.17	1	0.003	3.27
Black bullhead	-	-	-	-	-	-	26	0.085	13.67
Yellow bullhead	17	0.068	13.95	38	0.078	14.36	8	0.026	4.45
Channel catfish	3	0.012	2.92	10	0.021	3.92	4	0.013	3.20
Stonecat	7	0.028	1.27	-	-	-	-	-	-
Tadpole madtom	1	0.004	0.03	-	-	-	-	-	-
Brindled madtom	-	-	-	-	-	-	1	0.003	0.02
White bass	-	-	-	2	0.004	0.021	-	-	-
Rock bass	351	1.410	93.72	287	0.591	44.54	19	0.062	5.04
Green sunfish	23	0.092	2.62	611	1.257	46.19	83	0.271	9.88
Orangespotted sunfish	1	0.004	0.03	2	0.004	0.08	22	0.072	1.24
Bluegill	93	0.373	16.74	136	0.280	14.02	36	0.118	6.21
Longear sunfish	323	1.297	53.55	612	1.259	55.43	124	0.405	13.75
Smallmouth bass	207	0.831	65.14	621	1.278	124.39	46	0.150	29.83
Largemouth bass	5	0.020	0.89	34	0.070	1.26	11	0.036	1.78
White crappie	39	0.157	12.53	27	0.056	5.38	60	0.196	16.95
Black crappie	43	0.173	16.89	56	0.115	10.52	22	0.072	4.25
Greenside darter	2	0.008	0.06	-	-	-	-	-	-
Rainbow darter	3	0.012	0.05	-	-	-	-	-	-
Logperch	46	0.185	4.71	13	0.027	0.77	-	-	-
Walleye	1	0.004	3.37	-	-	-	1	0.003	0.82
Total	1187	7.578	2308.6	3100	6.379	1275.1	1384	4.523	1748.2
Total Fishing Time (min)		249			486			306	

Appendix A-3. Cumulative Catch by Electrofishing from Three Areas of the Olentangy River, 1975, Expressed as Total Number of Fish Caught, Numbers per Minute and Grams per Minute

Species	Area N			Area M			Area O		
	Total Number	Number/ Minute	gm/ Minute	Total Number	Number/ Minute	gm/ Minute	Total Number	Number/ Minute	gm/ Minute
Gizzard shad	13	0.055	-	152	0.520	-	182	0.746	-
Stoneroller	24	0.012	1.40	4	0.014	0.40	-	-	-
Goldfish	13	0.055	14.96	1	0.003	0.82	8	0.033	9.06
Carp	204	0.871	1303.2	164	0.561	1088.7	226	0.926	1310.9
Golden shiner	-	-	-	1	0.003	0.13	-	-	-
Silver shiner	50	0.213	2.13	12	0.041	0.60	1	0.004	0.07
Spotfin shiner	27	0.115	0.88	1	0.003	0.01	5	0.020	0.12
Sand shiner	1	0.004	0.01	1	0.003	0.01	-	-	-
Bluntnose minnow	198	0.845	2.87	34	0.116	0.41	9	0.037	0.09
Creek chub	1	0.004	0.64	1	0.003	0.05	-	-	-
Quillback	19	0.081	35.39	6	0.021	14.38	40	0.164	80.04
White sucker	13	0.055	10.73	17	0.058	20.59	19	0.078	21.85
Hog sucker	52	0.222	57.23	2	0.007	1.53	4	0.016	4.67
Silver redhorse	43	0.184	112.83	12	0.041	63.65	19	0.078	103.26
Black redhorse	45	0.192	78.48	18	0.062	20.86	2	0.008	2.91
Golden redhorse	55	0.235	83.41	124	0.424	249.83	86	0.352	222.04
Shorthead redhorse	2	0.009	13.76	-	-	-	1	0.004	1.91
Black bullhead	-	-	-	-	-	-	29	0.119	21.82
Yellow bullhead	18	0.077	17.48	21	0.072	12.69	4	0.016	2.71
Channel catfish	2	0.009	2.20	1	0.003	1.03	-	-	-
Stonecat	14	0.060	2.92	-	-	-	-	-	-
Brindled madtom	2	0.009	0.06	-	-	-	-	-	-
Trout perch	-	-	-	-	-	-	1	0.004	0.11
Brook silversides	3	0.013	0.06	1	0.003	0.02	1	0.004	0.02
White bass	-	-	-	-	-	-	1	0.004	0.23
Rock bass	240	0.124	77.43	51	0.174	11.87	13	0.053	4.94
Green sunfish	45	0.192	6.15	475	1.624	52.89	82	0.336	12.57
Pumpkinseed	1	0.004	0.21	1	0.003	0.05	1	0.004	0.10
Orangespotted sunfish	4	0.017	0.09	7	0.024	0.24	19	0.078	0.75
Bluegill	87	0.371	17.44	83	0.284	12.41	29	0.119	8.32
Longear sunfish	189	0.807	39.04	219	0.749	28.41	137	0.561	16.10
Smallmouth bass	205	0.875	53.62	282	0.964	92.83	56	0.230	46.98
Largemouth bass	10	0.043	1.28	56	0.192	4.90	32	0.131	8.77
White crappie	21	0.090	7.57	6	0.021	1.56	37	0.152	18.60
Black crappie	36	0.154	16.40	19	0.065	6.16	50	0.205	18.76
Greenside darter	8	0.034	0.21	1	0.003	0.03	-	-	-
Rainbow darter	2	0.009	0.02	-	-	-	-	-	-
Fantail darter	1	0.004	0.03	-	-	-	-	-	-
Logperch	25	0.107	2.18	6	0.021	0.54	-	-	-
Walleye	1	0.004	0.58	-	-	-	1	0.004	1.14
Total	1674	7.145	1963.0	1779	6.084	1687.6	1095	4.488	1918.0
Total Fishing Time (min)		234.3			292.4			244.0	

Appendix A-4. Cumulative Catch by Electrofishing from Three Areas of the Olentangy River, 1976, Expressed as Total Number of Fish Caught, Numbers per Minute and Grams per Minute

Species	Area N			Area M			Area O		
	Total Number	Number/ Minute	gm/ Minute	Total Number	Number/ Minute	gm/ Minute	Total Number	Number/ Minute	gm/ Minute
Gizzard Shad	-	-	-	-	-	-	7	0.051	-
Stoneroller	65	0.466	10.85	3	0.019	0.79	-	-	-
Goldfish	5	0.036	8.12	2	0.013	2.49	8	0.058	22.51
Carp	91	0.652	987.65	92	0.595	661.53	55	0.398	431.79
Silver shiner	23	0.165	1.60	2	0.013	0.10	1	0.007	0.06
Spotfin shiner	17	0.122	1.22	3	0.019	0.16	15	0.108	0.55
Bluntnose minnow	26	0.186	1.20	44	0.285	1.14	22	0.159	0.59
Creek chub	1	0.007	0.46	-	-	-	-	-	-
Quillback	27	0.193	125.06	13	0.084	11.09	17	0.123	19.33
White sucker	13	0.093	12.75	14	0.091	31.38	32	0.231	41.02
Hog sucker	94	0.673	127.14	9	0.058	18.30	3	0.022	6.60
Silver redhorse	12	0.086	39.49	2	0.013	1.67	11	0.080	42.09
Black redhorse	24	0.172	76.92	-	-	-	-	-	-
Golden redhorse	119	0.852	164.33	40	0.259	70.36	103	0.745	208.29
Black bullhead	-	-	-	-	-	-	14	0.101	21.52
Yellow bullhead	8	0.057	15.09	17	0.110	30.79	2	0.014	3.80
Channel catfish	2	0.014	4.00	5	0.032	10.85	-	-	-
Stonecat	3	0.021	0.67	-	-	-	-	-	-
Brindled madtom	1	0.007	0.08	-	-	-	-	-	-
White bass	1	0.007	0.36	-	-	-	-	-	-
Rock bass	178	1.275	98.95	96	0.621	33.50	8	0.058	6.02
Green sunfish	47	0.337	9.35	554	3.586	112.41	60	0.434	12.44
Pumpkinseed	-	-	-	2	0.013	0.84	5	0.036	1.99
Orangespotted sunfish	1	0.007	0.07	18	0.116	1.66	17	0.123	1.26
Bluegill	12	0.086	2.45	34	0.220	6.93	10	0.072	3.05
Longear sunfish	216	1.547	39.30	590	3.819	83.28	181	1.309	31.95
Smallmouth bass	170	1.218	64.84	350	2.265	138.41	32	0.231	32.91
Largemouth bass	4	0.029	1.40	17	0.110	5.25	41	0.296	23.74
White crappie	4	0.029	3.07	3	0.019	1.78	12	0.087	7.69
Black crappie	14	0.100	13.45	10	0.064	7.25	16	0.116	15.33
Greenside darter	5	0.036	0.26	-	-	-	-	-	-
Rainbow darter	1	0.007	0.01	-	-	-	-	-	-
Banded darter	1	0.007	0.01	-	-	-	-	-	-
Logperch	26	0.186	4.19	17	0.110	2.04	-	-	-
Total	1211	8.675	1814.4	1937	12.537	1234.0	672	4.859	934.52
Total Fishing Time (min)		139.6			154.5			146.6	

Appendix A-5. Cumulative Catch of Fish by Electrofishing Channelized and Unchannelized Areas of the Sandusky River, Ohio, in 1974 and 1975

Species	1974				1975[a]			
	Unchannelized		Channelized		Unchannelized		Channelized	
	Total Number	Number/ Minute	Total Number	Number/ Minute	Total Number	Number/ Minute	Total Number	Number/ Minute
Longnose gar	9	0.015	6	0.019	18	0.098	5	0.033
Gizzard shad	352	0.604	322	1.042	76	0.412	60	0.401
Stoneroller	2	0.003	-	-	-	-	-	-
Goldfish	74	0.127	186	0.602	50	0.271	42	0.280
Carp	545	0.935	123	0.398	257	1.392	122	0.815
Spotfin shiner	-	-	-	-	1	0.005	2	0.013
Quillback	56	0.096	23	0.074	32	0.173	2	0.013
White sucker	9	0.015	1	0.003	34	0.184	5	0.033
Hog sucker	4	0.007	-	-	1	0.005	-	-
Spotted sucker	4	0.007	1	0.003	1	0.005	3	0.020
Silver redhorse	20	0.034	15	0.048	10	0.054	2	0.013
Black redhorse	21	0.036	8	0.026	6	0.032	-	-
Golden redhorse	144	0.247	24	0.078	44	0.238	11	0.073
Shorthead redhorse	14	0.024	1	0.003	25	0.135	19	0.127
Black bullhead	1	0.002	-	-	16	0.087	3	0.020
Brown bullhead	-	-	-	-	-	-	5	0.033
Yellow bullhead	-	-	2	0.006	-	-	1	0.007
Channel catfish	8	0.014	-	-	-	-	1	0.007
White bass	186	0.319	18	0.058	212	1.148	27	0.180
Rock bass	4	0.007	-	-	-	-	-	-
Green sunfish	16	0.027	26	0.084	1	0.005	205	1.369
Orangespotted sunfish	9	0.015	1	0.003	5	0.027	16	0.107
Bluegill	23	0.039	3	0.010	-	-	5	0.033
Longear sunfish	-	-	2	0.006	-	-	3	0.020
Smallmouth bass	6	0.010	2	0.006	7	0.038	9	0.060
Largemouth bass	9	0.015	3	0.010	-	-	-	-
White crappie	82	0.141	22	0.071	185	1.022	68	0.454
Black crappie	18	0.031	4	0.013	2	0.011	-	-
Logperch	3	0.005	1	0.003	2	0.011	-	-
Walleye	11	0.019	1	0.003	3	0.016	2[a]	1.757
Freshwater drum	49	0.084	12	0.039	7	0.038	6	0.040
Total	1679	2.880	812	2.628	1056	5.389	885	4.168
Total Fishing Time (min)	583.0		309.0		184.6		149.7	

[a]April sample omitted due to high incidence of non-resident species

Appendix A-6. Cumulative Catch of Fish by Electrofishing Channelized and Unchannelized Areas of the Hocking River, Ohio, in 1974 and 1975

Species	1974				1975			
	Unchannelized		Channelized		Unchannelized		Channelized	
	Total Number	Number/ Minute	Total Number	Number/ Minute	Total Number	Number/ Minute	Total Number	Number/ Minute
Gizzard shad	146	0.387	186	0.473	113	0.714	114	0.822
Goldfish	-	-	1	0.002	-	-	-	-
Carp	37	0.085	93	0.237	24	0.152	73	0.526
Spotfin shiner	-	-	1	0.002	2	0.013	-	-
Steelcolor shiner	-	-	-	-	1	0.006	-	-
Striped shiner	-	-	-	-	1	0.006	-	-
Bluntnose minnow	1	0.002	-	-	-	-	-	-
Quillback	7	0.016	47	0.120	6	0.038	59	0.425
White sucker	3	0.007	2	0.005	-	-	2	0.014
Hog sucker	2	0.005	3	0.008	-	-	-	-
Smallmouth buffalo	-	-	1	0.002	-	-	-	-
Largemouth buffalo	-	-	1	0.002	-	-	-	-
Spotted sucker	-	-	32	0.081	3	0.019	14	0.101
Silver redhorse	1	0.002	-	-	-	-	-	-
Black redhorse	2	0.005	6	0.015	-	-	11	0.079
Golden redhorse	55	0.127	39	0.099	6	0.038	-	-
Black bullhead	1	0.002	5	0.013	-	-	4	0.029
Yellow bullhead	4	0.009	4	0.010	1	0.006	2	0.014
Channel catfish	7	0.016	4	0.010	4	0.025	5	0.036
Flathead catfish	-	-	-	-	1	0.006	-	-
Rock bass	1	0.002	1	0.002	-	-	1	0.007
Green sunfish	2	0.005	-	-	-	-	1	0.007
Warmouth	-	-	-	-	1	0.006	1	0.007
Bluegill	16	0.040	38	0.097	38	0.240	18	0.130
Longear sunfish	24	0.055	4	0.010	4	0.025	1	0.007
Smallmouth bass	4	0.009	-	-	-	-	-	-
Largemouth bass	8	0.018	34	0.086	1	0.006	4	0.029
Spotted bass	2	0.005	-	-	5	0.032	1	0.007
White crappie	5	0.012	40	0.102	2	0.013	17	0.122
Black crappie	-	-	4	0.010	-	-	1	0.007
Dusky darter	-	-	-	-	2	0.013	-	-
Total	327	0.755	546	1.389	215	1.359	329	2.372
Total Fishing Time (min)	433.0		393.0		158.2		138.7	

Appendix A-7. Cumulative Catch of Fish by Electrofishing Channelized and Unchannelized Areas of the Little Auglaize River, Ohio, in 1975

Species	Unchannelized		Channelized	
	Total Number	Number/ Minute	Total Number	Number/ Minute
Gizzard shad	-	-	445	3.371
Grass pickerel	26	0.220	1	0.008
Stoneroller	-	-	15	0.114
Carp	102	0.863	289	2.189
Silverjaw minnow	-	-	270	2.045
Emerald shiner	-	-	1	0.008
Spotfin shiner	-	-	37	0.280
Sand shiner	-	-	1305	9.886
Redfin shiner	85	0.719	234	1.777
Suckermouth minnow	-	-	24	0.182
Bluntnose minnow	68	0.575	2973	22.523
Fathead minnow	5	0.042	208	1.576
Creek chub	23	0.194	352	2.667
Quillback	-	-	62	0.470
White sucker	83	0.702	128	0.970
Black bullhead	2	0.017	24	0.182
yellow bullhead	10	0.085	11	0.083
Channel catfish	-	-	1	0.008
Tadpole madtom	-	-	3	0.023
Blackstripe topminnow	-	-	3	0.023
Green sunfish	175	1.480	310	2.348
Orangespotted sunfish	-	-	227	1.720
Bluegill	-	-	1	0.008
Largemouth bass	-	-	7	0.053
Black crappie	-	-	1	0.008
White crappie	-	-	3	0.023
Greenside darter	-	-	1	0.008
Johnny darter	7	0.059	90	0.682
Logperch	-	-	10	0.076
Blackside darter	4	0.034	19	0.144
Total	590	4.992	7055	53.447
Total Fishing Time (min)	118.2		132.0	

Appendix A-8. Cumulative Catch of Fish by Electrofishing Channelized and Unchannelized Areas of Rock Creek, Indiana, in 1974 and 1975

Species	1974				1975			
	Unchannelized		Channelized		Unchannelized		Channelized	
	Total Number	Number/ Minute	Total Number	Number/ Minute	Total Number	Number/ Minute	Total Number	Number/ Minute
Gizzard shad	729	6.339	78	0.896	122	1.085	17	0.251
Stoneroller	4	0.034	477	5.483	21	0.187	453	6.701
Carp	52	0.425	7	0.080	57	0.507	4	0.059
Silverjaw minnow	-	-	5	0.057	-	-	11	0.163
Common shiner	3	0.026	14	0.161	13	0.116	41	0.606
Spotfin shiner	5	0.043	1	0.011	9	0.080	14	0.207
Sand shiner	-	-	-	-	1	0.009	-	-
Suckermouth minnow	3	0.026	46	0.529	4	0.036	13	0.192
Bluntnose minnow	13	0.113	43	0.494	16	0.142	169	2.500
Creek chub	7	0.061	184	2.115	5	0.044	267	3.950
White sucker	61	0.530	58	0.667	93	0.738	53	0.784
Creek chubsucker	4	0.034	-	-	-	-	-	-
Hog sucker	10	0.087	37	0.425	15	0.133	114	1.686
Spotted sucker	5	0.043	-	-	19	0.169	-	-
Golden redhorse	1	0.009	-	-	2	0.078	-	-
Black bullhead	2	0.104	-	-	3	0.027	-	-
Yellow bullhead	17	0.148	9	0.103	34	0.302	10	0.148
Channel catfish	-	-	-	-	6	0.053	-	-
Stonecat	1	0.009	1	0.011	1	0.009	6	0.089
Blackstripe topminnow	-	-	1	0.011	1	0.009	1	0.015
Brook silversides	3	0.026	-	-	-	-	-	-
White bass	3	0.026	-	-	-	-	-	-
Rock bass	17	0.148	2	0.023	30	0.267	4	0.059
Green sunfish	21	0.183	19	0.218	28	0.249	8	0.118
Orangespotted sunfish	4	0.034	-	-	-	-	-	-
Bluegill	18	0.156	-	-	20	0.178	-	-
Longear sunfish	34	0.296	6	0.069	96	0.854	8	0.118
Smallmouth bass	4	0.034	5	0.057	18	0.160	12	0.178
Largemouth bass	3	0.026	-	-	10	0.089	-	-
White crappie	2	0.017	-	-	12	0.107	-	-
Greenside darter	-	-	12	0.138	2	0.018	12	0.178
Rainbow darter	-	-	3	0.034	-	-	2	0.030
Fantail darter	-	-	4	0.046	2	0.018	3	0.044
Johnny darter	-	-	2	0.023	-	-	-	-
Logperch	2	0.017	2	0.023	13	0.116	53	0.784
Blackside darter	-	-	-	-	2	0.018	-	-
Total	1038	9.026	1016	11.678	645	5.738	1275	18.861
Total Fishing Time (min)	115		87		112.4		67.6	

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16. Abstract (Limit: 200 words) The effects of stream channelization on warm water fish and macroinvertebrate populations were studied in five streams by comparing the biota in natural areas to that in nearby channelized areas. Study streams were the Olentangy, Sandusky, Hocking and Little Auglaize Rivers in Ohio, and Rock Creek in Northeast Indiana. The sport fishery in the study sites of the Olentangy, Sandusky, and Hocking Rivers was documented and an additional channelized study site which had large artificial riffle-pool stream improvement structures was selected in the Olentangy. In general, channelization adversely affected macrobenthos diversity, abundance, and/or biomass, and it caused a shift in species composition from riffle species to less desirable standing water burrowing forms. An exception to this was in the Sandusky River where both channelized and unchannelized areas had riffle areas and bedrock substrates. Gamefish were less abundant in channelized areas, and some channelized areas harbored only large numbers of small non-gamefishes. The sport fishery reflected the fish population inthe area, and channelized areas generally had little fishing activity except during short seasonal gamefish spawning runs in the Sandusky River. The biota in the mitigated area of the Olentangy approximated that of the natural area. The channelized area of the Little Auglaize became dewatered during drought but the area was repopulated from downstream within a year. Repopulation of Rock Creek occurred within a year of channel construction, but species composition was less desirable. (Griswold - Ohio CFRU)

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Schoof R. (1980) Environmental impact of channel modification. *Journal of the American Water Resources Association* 16: 697-701.

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Schlosser I. J. (1987) A conceptual framework for fish communities in small warmwater streams. In: *Community and evolutionary ecology of North American stream fishes* (eds W. J. Matthews & D. C. Heins) pp. 17-26. University of Oklahoma Press, Norman, OK.

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Scarnecchia D. L. (1988) The importance of streamlining in influencing fish community structure in channelized and unchannelized reaches of a prairie stream. *Regulated Rivers: Research & Management* 2: 155-166.

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Rosenvald R., R. Järvekülg & A. Lõhmus. (2014) Fish assemblages in forest drainage ditches: Degraded small streams or novel habitats? *Limnologica-Ecology and Management of Inland Waters* 46: 37-44.

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