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EXPERIMENTAL EVIDENCE AS TO THE VALUE OF STREAM IMPROVEMENT IN MICHIGAN

Clarence M. Tarzwell

The evaluation of the results obtained by stream improvement has received little attention. With the exception of the experimental work carried on in Michigan by the Institute for Fisheries Research, little or no experimental work has been done. The construction phase of the work has been greatly emphasized, however, and numerous papers have been written dealing with the methods of stream improvement. It is believed that more consideration should be given to a study of the permanence and utility of each structure and to the changes produced by stream improvement.

Although the writer has been engaged since the summer of 1930 in the development of methods for the improvement of trout streams, he has not confined himself solely to the devising of methods but has also endeavored to evaluate each device and learn its special value in the improvement of environmental conditions. Many structures were installed merely for experimental reasons in order that they could be rechecked and their action observed and recorded. In 1931, the rechecking and evaluation of the various types of stream improvement devices came to constitute an important part of the investigations.

Three different methods were employed for the testing and evaluation of the stream improvement methods used. The different phases of the experimental work may be briefly listed as follows:

1. The determination of the most permanent, economical and effective structures for different types of streams and different situations

2. The determination of the physical and biological changes produced by each type of stream improvement device

3. The evaluation of the physical and biological changes produced.

In order to carry out these investigations effectively, it was necessary to know the stream conditions before improvement and to take complete notes on the structures which were built. Special forms were devised for taking these notes. Each structure was given a number and tagged with a non-corrosive metal tag and located by paces in relation to other structures. The type, size and materials used in each structure were recorded. The kind and extent of the bottom types such as sand, gravel, rubble, muck and plant beds were noted as well as the depths across the stream at each yard and the number, size and depths of the pools. These notes made it possible to determine at each subsequent examination the extent of the physical changes produced by the structures. Numerous rechecks of the work were made at various seasons of the year to determine these changes and the efficiency of the structures relative to each season. As many as nine rechecks were made. Since it was known that certain bottom types were more productive of food than others, the extent of different bottom types produced was especially noted.

Several methods were used to evaluate the physical and biological changes produced by the improvements. Quantitative studies of the bottom food organisms were made on various bottom types so that the most productive bottom type and the relative productivity of each could be determined. Quantitative bottom counts of the food organisms were also taken at the sites of the barriers before they were installed so that counts could be made some years later at the same place and the effect of each structure determined. In addition to the food counts, quantitative counts of the fish population were made in certain sections of stream before and after improvement. Creel census studies were made in the East Branch of the Black River before and after improvement to determine changes in fishing returns.

PERMANENCY AND EFFECTIVENESS OF STREAM IMPROVEMENT DEVICES

Notes have been taken and rechecks made at all seasons of the year on a total of 2,235 barriers located in eighteen different Michigan streams. In addition, observations have been made on structures in the mountain streams of several western states as well as on the work done in Michigan by ECW. These numerous examinations have supplied data relative to the stability, utility and comparative cost of the different types of barriers; and certain conclusions have been reached in regard to the desirability of the various types of devices which have been used and the materials from which they have been built.

Oak and tamarack have proven best for stakes. Sound dead or fire-killed timber is most desirable. Pine logs or "dead-heads" have proven best for log deflectors, whereas cedar has been most satisfactory for covers. Where the bottom is firm and large stones are available, stone deflectors are to be desired.

The type of stream determines the kind of improvement devices which should be used. Sand bottom streams are not suited to stone deflectors. Streams which flood severely require different structures and more bank protection than streams which are not subject to high water. In streams which have severe ice action, all cover devices should be submerged and all structures should be kept low.

Tree covers, slanting log covers, the various types of submerged bank covers, the underpass deflectors and the various types of wing deflectors made of logs or boulders have proved to be best. It is concluded that the simple log dam with end cribs and the board dam are the most successful types of dams. When dams are placed over soft bottoms such as are found in many Michigan streams, great care must be taken to prevent undercutting. In some streams, Y, A and I deflectors can be used to advantage. Center covers have been found to be satisfactory only to streams which do not have severe floods or ice action. The action of totally submerged center covers is better. It has been found that submerged covers held down with boulders have a tendency to become filled underneath, in streams which carry large amounts of sand. Underpass deflectors are very effective in forming pools. In Michigan, dams often cause deposits of barren sand which covers large areas of productive gravel.

Wing deflectors have proved to be most effective in creating mucky areas, encouraging plant beds, uncovering gravel when it is covered with sand and in producing gravel and rubble riffles. It has been found that one of the chief functions of deflectors is to create bottom types which are more productive of food. All deflectors, however, do not aid food production. Those which have extremely long directors produce large, thin, mucky areas which are not stable. Food counts in such areas show that less food is produced than on the original bottom.

Large boom covers and raft covers have been found to be unsatisfactory on most streams. Rectangular bank covers held by stakes, square covers in the center of the stream, tepee covers and wedge covers when placed at the surface of the water are unsatisfactory in streams subject to heavy ice. All covers in such streams should be submerged.

Wing deflectors, wing jams, slanting logs and trees and bend covers have been found effective for preventing bank erosion. Brush placed below deflectors is very helpful in building bars to narrow the stream.

With the exception of the structures built the first year (1930) in the Little Manistee River in Michigan, only a few have been lost. Since the work on the Little Manistee River was the first to be undertaken many errors were made and about 30% of the structures were lost in five years. During the past five years the loss in the streams under observation has been as follows: East Branch of the Black River, 2.8%; Gamble Creek, 1%; Pigeon River, 10.6%; West Branch of the Sturgeon River, 2%; Salmon Trout River, 4.7%; and Black River, no loss. Stumps and raft covers composed a large percentage of the loss. The relatively large loss in the Pigeon River is due to the heavy ice action.

PHYSICAL AND BIOLOGICAL CHANGES

The efficiency of the various improvement structures in producing desirable physical and biological changes in the stream is considered a measure of their effectiveness.

Deflectors have proven most successful in producing changes in the type of bottom and these changes can be utilized as a measure of the effectiveness of these structures. Since pools and shelter are generally recognized as essentials for good trout production, the success obtained in the production of good pools, the deepening and enlarging of existing pools and the establishment of permanent and effective shelter serves as an important measure of the effectiveness of stream improvement.

The physical changes produced by stream improvement in six streams are summarized in Table No. 1. Since practically all the changes were produced by deflectors, the average changes have been determined on the basis of the number of deflectors. The average increase in average depth and pool depth represents the average amount which each structure increased the average depth of the stream and of the pools. Very often the depth was increased several times the original depth. It will be noted that the deflectors were more successful in some streams than in others. In the East Branch of the Black River, each deflector produced on the average eighty-two square feet of plant bed, 392 square feet of mucky area, 965 square feet of riffle, and uncovered 144 square feet of graveled area. It may be noted that a greater area of plant beds was produced in the West Branch of the Sturgeon than in any other stream. Since the cover devices caused plant beds to form in this stream the average production was obtained by dividing the total number of structures installed.

In the Black River, each deflector produced on the average 2,027 square feet of more productive bottom; whereas, in the Pigeon River, each deflector produced 1,418 square feet of more productive area. In view of the fact that these areas are from four to nine times as productive as the original bottoms, it is apparent that deflectors can be used to increase the production of food organisms.

EVALUATION OF PHYSICAL AND BIOLOGICAL CHANGES PRODUCED BY THE IMPROVEMENT DEVICES

The three methods used for the evaluation of the physical and biological changes produced by stream improvement are creel census, fish population studies and quantitative studies of bottom food organisms. Creel census studies were undertaken on both the

Pigeon River and the East Branch of the Black River but only the returns from the East Branch of the Black River could be used since the returns from the Pigeon River were very meager. The results of the creel census on the East Branch of the Black River are summarized in Table No. 2. It may be noted that the fishing was much improved after the installation of improvement devices.

The results obtained from the fish counts made before and after improvement are not conclusive due to the small number of counts made. The cost of these counts limited their number to four which is too small a number from which to draw conclusions. It is significant, however, that in all instances there were more legal trout in the improved section and the weight per legal trout per mile was greater in the improved section. The average size of the trout was also greater after improvement.

Quantitative food studies carried on before and after improvement have definitely shown that food production is greater on the bottom types produced by the improvement structures than on the original bottom, and that food production is greater after improvement. The counts clearly indicate that the types of bottom produced by deflectors, namely, gravel and rubble, mucky areas and plant beds, are the most productive bottom types. A total of 447 counts were made on six different streams. The results of these counts are summarized in Table No. 3. It will be noted that sand is the least productive. If sand is given the productive rating of 1, the relative productivity of the other bottom types is as follows: marl, 6; fine gravel, 9; sand and silt, 10.5; gravel and sand, 12; sand, silt and debris, 13; gravel and silt, 14; chara and silt, 27; Potamogeton pectinatus, 28; rubble, 29; coarse gravel, 32; chara, 35; mucky areas, 35; medium gravel, 36; Potamogeton filiformis, 43; gravel and rubble, 53; sand and gravel with plants, 67; muck, sand and plants, 67; moss on fine gravel, 89; moss on coarse gravel, 111; moss on gravel and rubble, 140; Vallisneria, 159; Ranunculus, 194; Watercress, 301; and Elodea, 452. These relative productivities clearly show how food production in a sand section is increased by a deflector which uncovers gravel and which produces mucky areas and plant beds.

A number of quantitative counts were made before and after improvement. These were taken in the vicinity of the barriers in order to obtain a direct check on the different structures. The results of these counts are summarized in Table No. 4. These results show that the volume of food organisms were three to nine times as great after improvement.

In addition to the studies made in the vicinity of the barriers, studies were made of food production in certain stream sections of the East Branch of the Black River before and after improvement.

When the improvements were placed in the East Branch of the Black River, two sections of the stream were more intensely improved than the others. These are the sections just below the lower dam which contains barriers 502 to 546 and 627 to 640, and the section just below the upper dam which contains barriers 582 to 614.

The first section of the stream which is just below the lower dam, is fast and has a gravel and rubble bottom. It contains forty-four deflectors, three dams and thirteen covers, or a total of sixty barriers. This section of the stream is 5,634 feet long and has an average width of thirty-six feet, indicating an area of about 202,834 square feet. The barriers in this section produced 9,390 square feet of mucky flats, which is 4.6% of the total area; 1,165 square feet of plant beds, which is 0.5% of the total area; and 62,550 square feet of riffle, which is 30.8% of the total area. Thus the improvements have modified about 36% of the total area of this section of the stream. Since these modified areas are types of bottom which are rich in food, a considerable increase in food production is indicated. The counts made before and after improvement show that on the average the mucky areas below the barriers have four times as much food as the original bottom area. These same counts also show that 4.53 times as much food was found in the riffle areas produced by the barriers as was found in these same areas before the installation of the improvements. Since these counts were taken over all the different bottom types and since the stream bottom in this section is a rather uniform mixture of fine, medium and coarse gravel and some rubble, the food production in this area before improvement is considered as unity. After improvement, however, 30.8% of the area yielded 4.53 times as much food and 4.6% of the area yielded 4 times as much, while 64.6% of the area produced the same amount of food. Thus according to these figures, it is calculated that the improvements have increased the food organisms in this section 122.8%.

The second section which is below the upper dam contains thirty-three barriers, twenty-one of which are deflectors, while the remainder, twelve, are covers. The area of this section is calculated to be 98,838 square feet. Before improvement the bottom in this section of the stream was made up of medium gravel, sand, and muck. The medium gravel covered 17,950 square feet or 18% of the area, the muck covered 5% (a maximum estimate) or 4,942 square feet, while the sand covered 77% or 76,046 square feet. The stream improvement devices in this section of the stream modified a considerable portion of the area. They uncovered 7,740 square feet of gravel, which is 7.8% of the total area; produced 7,142 square feet of riffle area which is 7.2% of the total area; formed 18,455 square feet of mucky area which is 18.5% of the area; and produced 4,582 square feet of plant bed which is 4.6% of the area. Thus the barriers have modified 38.1% of the total area. Using the results of the food determinations, it is calculated that the riffle areas formed by the barriers produce on the average 4.53 times as much food as the same area produced before improvement. By using the results of the food determinations and the averages in the volume and number of food organisms found on each bottom type in the East Branch of the Black River, it is possible to calculate the food production in this section of the stream before and after improvement. The results of these calculations are given in Table No. 5. These calculations show that the volume of food is almost three times as great after improvement.

In conclusion, it may be said that since the barriers have been found to be relatively permanent and efficient in creating physical and biological changes, and since these changes have been found to be beneficial to food production and fish production, stream improvement is considered to be beneficial to Michigan trout streams.

TABLE NUMBER 1

SUMMARY OF PHYSICAL AND BIOLOGICAL CHANGES PRODUCED IN SIX RIVERS

Name of Stream	Little Manistee River	E. Branch of Black River	Gamble Creek
Average Increase in Average Depth	4.11 in.	6.05 in.	3.4 in.
Average Increase in Pool Depth	13.5 in.	10.68 in.	12.2 in.
New Pools	280	128	76
Increase in Pool Area	5,309 sq. ft.	13,744 sq. ft.	
Amount of Gravel Uncovered	37,265 sq. ft.	10,840 sq. ft.	6,454 sq. ft.
Aver. Exposed by Each Deflector	266 sq. ft.	144 sq. ft.	122 sq. ft.
Amount of Riffle Produced	40,690 sq. ft.	72,372 sq. ft.	3,500 sq. ft.
Aver. Exposed by Each Deflector	290 sq. ft.	965 sq. ft.	66 sq. ft.
Mucky Area Produced	21,650 sq.	29,445 sq. ft.	4,565 sq. ft.
Aver. Produced by Each Deflector	154 sq. ft.	392 sq. ft.	86 sq. ft.
Area of Plant Beds Produced	10,980 sq. ft.	6,125 sq. ft.	8,351 sq. ft.
Aver. Plant Bed Produced by Each Deflector	78 sq. ft.	82 sq. ft.	158 sq. ft.

TABLE NUMBER 1 (Cont'd)

SUMMARY OF PHYSICAL AND BIOLOGICAL CHANGES PRODUCED IN THE RIVERS

Name of Stream	Pigeon River	W. Branch of Sturgeon River	Black River
Average Increase in Average Depth	6.7 in.	6.2 in.	1 to 6 in.
Average Increase in Pool Depth	17.1 in.	12.6 in.	2 to 25 in.
New Pools	120	93	17
Increase in Pool Area			
Amount of Gravel Uncovered	26,010 sq. ft.	600 sq. ft.	
Aver. Exposed by Each Deflector	542 sq. ft.	18 sq. ft.	
Amount of Riffle Produced	21,700 sq. ft.	21,600 sq. ft.	4,400 sq. ft.
Aver. Exposed by Each Deflector	452 sq. ft.	654 sq. ft.	734 sq. ft.
Mucky Area Produced	14,640 sq. ft.	8,695 sq. ft.	6,640 sq. ft.
Aver. Produced by Each Deflector	305 sq. ft.	263 sq. ft.	1,100 sq. ft.
Area of Plant Beds Produced	5,730 sq. ft.	72,843 sq. ft.	1,225 sq. ft.
Aver. Plant Bed produced by each Deflector	119 sq. ft.	* 357 sq. ft.	193 sq. ft.

* This is the average for the total number of devices, not just for the deflectors.

TABLE NUMBER 2

SUMMARY OF CREEL CENSUS RETURNS FROM THE EAST BRANCH OF

THE BLACK RIVER

	Before Improvement	After Improvement
Total Catch of Legal Trout	71 fish	250 fish
Total Hours Fished	75.75 hours	167.5 hours
Legal Fish per Hour	.936 fish	1.495 fish
Undersize Fish per Hour	4.74 fish	3.08 fish
Average Fisherman Day	1.64 hours	3.44 hours
Average Legal Catch per Fisherman Day	2 fish	5 fish
Average Size of All Fish Caught	4.7 inches	6.7 inches
Percentage of Failures	19%	7%
Percent of Undersize Trout in Total Catch	79%	68%
Percent of Legal Trout in Total Catch	21%	32%

Table Number 3

Summary of the Average Volume and Number of Bottom Organisms on Various Bottom Types in the Six Streams Studied Based on 447 Bottom Samples

		Rubble	Gravel and Rubble	Coarse Gravel	Medium Gravel	Fine Gravel
Number of Samples		16	12	56	57	15
Petromyzonidae	vol.			.004cc.		
(Lampreys)	no.			.064		
Gordioidae	vol.			.003cc.		
(Horse-hair Snake)	no.			.07		
Hydracarina	vol.		.001cc.	.002cc.		
(Water Mites)	no.		1.47	.94		
Oligochaeta	vol.	.171cc.	.021cc.	.037cc.	.07cc.	.04cc.
(Worms)	no.	4.37	.25	3.31	3.03	.5
Hirudinea	vol.			.078cc.	.20cc.	
(Leeches)	no.	.061		3.67	7.1	
Gastropoda	vol.	.017cc.	.063cc.	.029cc.	.05cc.	.01cc.
(Snails)	no.	1.06	1.9	.86	1.7	.80
Lamellibranchia	vol.	.003cc.	.005cc.	.172cc.	.66cc.	
(Clams)	no.	.27	.175	3.76	28.9	
Decapoda	vol.	.78cc.	.63cc.	.173cc.	.66cc.	.03cc.
(Crayfish)	no.	.186	.67	.215	.2	.1
Amphipoda	vol.			.233cc.	.138c.	.11cc.
(Scuds)	no.			17.7	27.2	13.9
Hemiptera	vol.			.005cc.	.02cc.	
(Bugs)	no.	.137		.143	2.5	
Neuroptera	vol.	.29cc.	.68cc.	.074cc.	.05cc.	.04cc.
(Hellgrammites)	no.	3.8	8.15	.88	1.02	.5
Plecoptera	vol.	.226cc.	.23cc.	.151cc.	.05cc.	.03cc.
(Stone-flies)	no.	6.58	23.13	4.27	5.03	1.0
Ephemerida	vol.	.258cc.	.85cc.	.417cc.	.32cc.	.14cc.
(May-flies)	no.	43.48	265.6	130.6	117.9	7.2
Odonata	vol.	.78cc.	.89cc.	.496cc.	.45cc.	.43cc.
(Dragon-flies)	no.	5.6	8.5	3.44	2.4	2.7
Coleoptera	vol.	.023cc.	.12cc.	.054cc.	.05cc.	.01cc.
(Beetles)	no.	11.9	54.32	24.7	27.1	3.5
Trichoptera	vol.	.812cc.	2.04cc.	1.91cc.	.85cc.	.19cc.
(Caddis-flies)	no.	138.16	563.5	245.7	116.3	14.4
Diptera	vol.	.48cc.	1.04cc.	.424cc.	.51cc.	.12cc.
(Flies)	no.	29.28	293.9	115.04	126.2	8.3
	vol.	3.85cc.	6.93cc.	4.261cc.	4.70cc.	1.16cc.
TOTAL	no.	244.8	1222.2	555.32	462.8	52.9

Table Number 3 (Cont'd)

Summary of the Average Volume and Number of Bottom Organisms on Various Bottom Types in the Six Streams Studied Based on 447 Bottom Samples

		Moss Gravel and Rubble	Moss on Medium Gravel	Moss on Fine Gravel	Sand and Gravel with Plants	Gravel and Silt
Number of Samples		9	1	1	16	5
Petromyzonidae	vol.		4.5cc.		.69cc.	
(Lampreys)	no.		1		.31	
Gordioidae	vol.					
(Horse-hair Snake)	no.					
Hydrăcarina	vol.					
(Water Mites)	no.					
Oligochaeta	vol.	.10cc.			.34cc.	
(Worms)	no.	12.3			34.1	
Hirudinea	vol.				2.08cc.	
(Leeches)	no.	.2			35.25	
Gastropoda	vol.	.02cc.		1.2cc.	.18cc.	
(Snails)	no.	.9	1	12	3.94	
Lamellibranchia	vol.	.002cc.		.8cc.	1.06cc.	
(Clams)	no.	.4		8	48.93	
Decapoda	vol.	2.24cc.			.29cc.	.02cc.
(Cray-fish)	no.	.9			.19	.2
Amphipoda	vol.				.71cc.	
(Scuds)	no.				47.5	
Hemiptera	vol.				.02cc.	
(Bugs)	no.				4.75	
Neuroptera	vol.	1.70cc.				.05cc.
(Hellgrammites)	no.	24.6				1
Plecoptera	vol.	.93cc.	1.2cc.	.1cc.	.08cc.	.01cc.
(Stone-flies)	no.	47.4	31	4	3.68	6
Ephemerida	vol.	1.41cc.	.1cc	.3cc.	.61cc.	.28cc.
(May-flies)	no.	761.2	10	76	231.3	8.8
Odonata	vol.	1.24cc.			.15cc.	1.24cc.
(Dragon-flies)	no.	10			1.18	8.2
Coleoptera	vol.	.35cc.	.05cc.	.4cc.	.07cc.	
(Beetles)	no.	227.6	20	80	4.5	.4
Trichoptera	vol.	8.18cc.	.9cc.	.04cc.	1.6cc.	.11cc.
(Caddis-flies)	no.	2991.3	84	64	92.6	1
Diptera	vol.	2.02cc.	7.5cc.	8.78cc.	.860cc.	.14cc.
(Flies)	no.	458.6	210	484	235.3	7.4
	vol.	18.205cc.	14.45cc.	11.62cc.	8.74cc.	1.85cc.
TOTAL	no.	4535.4	358	728	643.5	27.6

Table Number 3 (Cont'd)

Summary of the Average Volume and Number of Bottom Organisms on Various Bottom Types in the Six Streams Studied Based on 447 Bottom Samples

		Gravel and Sand	Sand Silt and Debris	Sand and Silt	Sand	Chara and Silt
Number of Samples		71	34	14	14	1
Petromyzonidae	vol.	.058cc.	.22cc.	.314cc.		
(Lampreys)	no.	.109	1.0	.71		
Gordioidae	vol.					
(Horse-hair Snake)	no.					
Hydracarina	vol.	.001cc.	.01cc.			
(Water Mites)	no.	.438	6.4			
Oligochaeta	vol.	.029cc.	.09cc.	.006cc.		.5cc.
(Worms)	no.	17.38	9.6	1.9		2
Hirudinea	vol.	.063cc.	.21cc.	.507cc.		1.9cc.
(Leeches)	no.	1.49	.4	2.3		22
Gastropoda	vol.	.076cc.	.02cc.	.01cc.		.08cc.
(Snails)	no.	1.41	1.5	.36	.07	6
Lamellibranchia	vol.	.456cc.	.05cc.	.053cc.	.11cc.	.06cc.
(Clams)	no.	2.64	3.4	6.4	.09	6
Decapoda	vol.	.193cc.	.27cc.			.1cc.
(Crayfish)	no.	.418	3.1			1
Amphipoda	vol.	.003cc.	.01cc.		.01cc.	.52cc.
(Scuds)	no.	.925	.2		1.2	72
Hemiptera	vol.	.012cc.	.01cc.			.3cc.
(Bugs)	no.	.171	4			6
Neuroptera	vol.	.059cc.	.05cc.	.014cc.		
(Hellgrammites)	no.	.112	1.5	.29		
Plecoptera	vol.	.0001cc.		.03cc.		
(Stone-flies)	no.	.125	.1	.64		
Ephemerida	vol.	.114cc.	.17cc.	.28cc.		.07cc.
(May-flies)	no.	36.2	17.8	5		7
Odonata	vol.	.086cc.	.12cc.	.235cc.		
(Dragon-flies)	no.	2.65	1.3	.78	.07	
Coleoptera	vol.	.014cc.	.003cc.	.029cc.		.05cc.
(Beetles)	no.	6.52	3.5	.29		4
Trichoptera	vol.	.557cc.	.16cc.	.032cc.	.001cc.	
(Caddis-flies)	no.	51.5	28.6	.73	.14	
Diptera	vol.	.349cc.	.31cc.	.106cc.	.01cc.	
(Flies)	no.	67.96	66.6	53.7	.21	
	vol.	1.58cc.	1.70cc.	1.367cc.	.13cc.	3.58cc.
TOTAL	no.	189.048	149.4	73.2	1.8	127

Table Number 3 (Cont'd)

Summary of the Average Volume and Number of Bottom Organisms on Various Bottom Types in the Six Streams Studied Based on 447 Bottom Samples

		Muck Sand and Plants	Elodea Beds	Water-cress	Ranun-culus	Vallis-neria
Number of Samples		8	1	3	2	2
Petromyzonidae	vol.	.76cc.	18.28cc.	3.33cc.	8.4cc.	
(Lampreys)	no.	.63	16	2.67	10	
Gordioidae	vol.					
(Horse-hair Snake)	no.					
Hydrăcarina	vol.	.13cc.				
(Water Mites)	no.	17.9			8	
Oligochaeta	vol.	2.8cc.	.04cc.	.306cc.	5.9cc.	.06cc.
(Worms)	no.	20.9	44	198.7	6252	222
Hirudinea	vol.	.15cc.	.36cc.	.067cc.		
(Leeches)	no.	4	4	1.33		
Gastropoda	vol.	.43cc.	4.8cc.	11.23cc.	.9cc.	14.8cc.
(Snails)	no.	58.1	152	214.7	48	744
Lamellibranchia	vol.	1.15cc.	1.4cc.	3.267cc.	1.0cc.	2.3cc.
(Clams)	no.	.88	120	364	14	544
Decapoda	vol.	.49cc.	2.28cc.		3.0cc.	
(Crayfish)	no.	117.6	8		2	
Amphipoda	vol.	.13cc.		2.57cc.		
(Scuds)	no.	.21		206.7		
Hemiptera	vol.			.067cc.	.05cc.	
(Bugs)	no.			4	2	
Neuroptera	vol.		.4cc.	.267cc.	.61cc.	.2cc.
(Hellgrammites)	no.		12	10.6	29	20
Plecoptera	vol.		.44cc.	.053cc.	.05cc.	
(Stone-flies)	no.		24	1.33	3	4
Ephemerida	vol.	.35cc.	18.8cc.	7.067cc.	.855cc.	.06cc.
(May-flies)	no.	99.8	620	244	24	38
Odonata	vol.	.03cc.	.4cc.	.593cc.	2.25cc.	.1cc.
(Dragon-flies)	no.	.13	12	4	8	24
Coleoptera	vol.	.01cc.				
(Beetles)	no.	.75		2.67	9	4
Trichoptera	vol.	.41cc.	1.6cc.	.587cc.	.11cc.	1.0cc.
(Caddis-flies)	no.	16.3	40	12	12	4
Diptera	vol.	1.31cc.	9.2cc.	9.8cc.	1.0cc.	1.1cc.
(Flies)	no.	368.9	844	966.7	329	162
	vol.	8.71cc.	58.8cc.	39.21cc.	25.22cc.	20.7cc.
TOTAL	no.	607.1	2020	2233.3	6777	1940

Table Number 3 (Cont'd)

Summary of the Average Volume and Number of Bottom Organisms on Various Bottom Types in the Six Streams Studied Based on 447 Bottom Samples

		Potamogeton pectinatus	Chara	Potamogeton filiformis	Mucky Flats	Marl
Number of Samples		4	35	40	28	2
Petromyzonidae	vol.	.75cc.	.74cc.	.036cc.	.29cc.	
(Lampreys)	no.	.75	1.1	.28	2.8	
Gordioidae	vol.	.5cc.	.02cc.			
(Horse-hair Snake)	no.	.25	.34			
Hydracarina	vol.			.001cc.	.001cc.	
(Water Mites)	no.			7.32	.57	
Oligochaeta	vol.	.15cc.	.5cc.	.533cc.	.10cc.	.15cc.
(Worms)	no.	1	15.8	403.6	5.7	1
Hirudinea	vol.		1.8cc.	.407cc.	.42cc.	
(Leeches)	no.		19.5	6.45	1.7	
Gastropoda	vol.	.05cc.	.13cc.	.193cc.	.42cc.	.005cc.
(Snails)	no.	1.25	6.1	6.74	9.37	.05
Lamellibranchia	vol.	.18cc.	.27cc.	.38cc.	.39cc.	.005cc.
(Clams)	no.	1	44.32	18.48	27.3	.05
Decapoda	vol.	.49cc.	.28cc.	.664cc.	.007	
(Crayfish)	no.	1	1.4	1.42	.14	
Amphipoda	vol.	.15cc.	.26cc.	.972cc.	.335cc.	.465cc.
(Scuds)	no.	15.1	111.3	21.74	5.22	31
Hemiptera	vol.	~~.003cc.~~	.003cc.	.15cc.	.017cc.	
(Bugs)	no.		.06	27.54	1.14	
Neuroptera	vol.	.086	.06cc.	.048cc.	.215cc.	
(Hellgrammites)	no.	1.5	2	1.5	.38	
Plecoptera	vol.	.015cc.	.03cc.	.006cc.	.005cc.	
(Stone-flies)	no.	.25	1.9	5.2	1.39	
Ephemerida	vol.	.815cc.	.064cc.	.37cc.	1.73cc.	.045cc.
(May-flies)	no.	17	11.74	101.32	31.2	6.5
Odonata	vol.	.25cc.	.06cc.	.454cc.	.56cc.	
(Dragon-flies)	no.	1.25	4.3	3.25	2.65	
Coleoptera	vol.	.005cc.	.01cc.	.024cc.	.019cc.	.03cc.
(Beetles)	no.	.5	.8	6.34	18.5	11.5
Trichoptera	vol.	.027cc.	1.57cc.	.786cc.	.195cc.	.015cc.
(Caddis-flies)	no.	2.75	1.22	78.04	17.7	3
Diptera	vol.	.175cc.	.171cc.	.613cc.	.33cc.	.045cc.
(Flies)	no.	15.25	68	186.7	91.3	16
	vol.	3.66cc.	4.67cc.	5.637cc.	4.67cc.	.76cc.
TOTAL	no.	70	295.08	875.92	214.9	69.1

TABLE NUMBER 4

SUMMARY OF THE DETERMINATION OF FOOD ORGANISMS BEFORE AND AFTER IMPROVEMENT

IN FOUR RIVERS

		North Branch of AuSable River		East Branch of Black River	
Number of Samples		24	40	16	27
Time in Relation to Improvement		Before	After	Before	After
Petromyzonidae	vol.	.036cc.	.16cc.		.133cc.
(Lampreys)	no.	.125	.2		2.5
Hydrocarina	vol.	.0004cc.			
(Water Mites)	no.	.042		.3	
Oligochaeta	vol.	.12cc.	.42cc.	.026cc.	.4cc
(Worms)	no.	1.83	43.1	.56	6.7
Hirudinea	vol.	.68cc.	1.86cc.		.0003cc.
(Leeches)	no.	5.25	39.5		.08
Gastropoda	vol.	.05cc	.25cc.	.02cc.	.092cc.
(Snails)	no.	1.5	5.8	.19	2.7
Lamellibranchia	vol.	.65cc.	3.193cc.		.193cc.
(Clams)	no.	17.8	85.7		2.3
Decapoda	vol.	.74cc.	.60cc.	.04cc.	.075cc.
(Crayfish)	no.	.33	.6	.31	.44
Amphipoda	vol.	.06cc.	.86cc.	.	.001cc.
(Scuds)	no.	3.6	120.7		1.9
Hemiptera	vol.	.009cc.	.19cc.		.009cc.
(Bugs)	no.	1.58	36.1		.93
Neuroptera	vol.	0	0	.14cc.	.73cc.
(Hellgrammites)	no.	0	0	1.08	13.6
Plecoptera	vol.	.03cc.	.095cc.	.1cc.	.54cc.
(Stone-flies)	no.	.67	5	1.4	34.6
Ephemerida	vol.	.190cc.	1.032cc.	.047cc.	.92cc.
(May-flies)	no.	27.5	389.7	3.2	353.4
Odonata	vol.	.225cc.	.58cc.	1.24cc.	1.23cc.
(Dragon-flies)	no.	.33	1.8	7	7.5
Coleoptera	vol.	.007cc.	.056cc.	.001cc.	.157cc.
(Beetles)	no.	2.37	28.1	.36	114.5
Trichoptera	vol.	.280cc.	1.99cc.	.161cc.	2.93cc.
(Caddis-flies)	no.	13.50	170.6	8.7	967.7
Diptera	vol.	.120cc.	1.52cc.	.152cc.	.984cc.
(Flies)	no.	19.70	382.2	7.5	390.3
	vol.	3.139cc.	12.7960cc.	1.93cc.	8.08cc.
TOTAL	no.	105.7	1308.80	30.7	1898.9

TABLE NUMBER 4 (Cont'd)

SUMMARY OF THE DISTRIBUTION OF FOOD ORGANISMS BEFORE AND AFTER IMPROVEMENT

IN FOUR RIVERS

		Little Manistee River		Pigeon River	
Number of Samples			9	8	10
Time in Relation to improvement		Before	After	Before	After
Petromyzonidae	vol.		3.98cc.	.08cc.	1.68cc.
(Lampreys)	no.		3	.4	2
Hydrocarina	vol.				.02cc.
(Water Mites)	no.				15.4
Oligochaeta	vol.		.195cc.	0	2.68cc.
(Worms)	no.		132.4	0	2756.8
Hirudinea	vol.		6.2cc.	0	.12cc.
(Leeches)	no.		.09	0	8
Gastropoda	vol.		8.49cc.	.06cc.	.38cc.
(Snails)	no.		271.2	2.8	35.2
Lamellibranchia	vol.		2.52cc.	.001cc.	.22cc.
(Clams)	no.		274.2	.1	33.4
Decapoda	vol.		.253cc.	1.08cc.	.6cc.
(Crayfish)	no.		.9	1	.4
Amphipoda	vol.		.964cc.	0	.004cc.
(Scuds)	no.		83.1	0	.4
Hemiptera	vol.		.022cc.	0	.01cc.
(Bugs)	no.		1.8	0	.4
Neuroptera	vol.		.49cc.	.003cc.	.48cc.
(Hellgrammites)	no.		5.3	.1	11.9
Plecoptera	vol.		.20cc	0	.16cc.
(Stone-flies)	no.		7.8	0	35.7
Ephemerida	vol.		7.05cc.	.03cc	1.39cc.
(May-flies)	no.		181	1.8	176.0
Odonata	vol.		.264cc.	.02cc.	1.08cc.
(Dragon-flies)	no.		7.6	.5	14
Coleoptera	vol.		.05cc.	.003cc.	.17cc.
(Beetles)	no.		12.4	1.9	68.7
Trichoptera	vol.		.705cc.	.06cc.	2.51cc.
(Caddis-flies)	no.		25.8	11	433.7
Diptera	vol.		6.43cc.	.15cc.	2.13cc.
(Flies)	no.		540.2	9.9	427.0
	vol.	0	37.64cc.	1.49cc.	13.58cc.
TOTAL	no.	0	1547	29.5	4016.4

TABLE NUMBER 5

Food production in a Section of the East Branch of the Black River Before and After Improvement Calculated on the Basis of Determinations of Bottom Organisms in the Stream

	Before Improvement		
Bottom Type	Average Production on 4 sq. ft.	Area	Total Production
Sand	.27 cc.	76,105 sq. ft.	5,137 cc.
Muck	3.99 cc.	4,942 sq. ft.	4,942 cc.
Gravel	2.756 cc.	17,791 sq. ft.	12,257 cc.
TOTAL			22,340 cc.

	After Improvement		
Sand	.27 cc.	48,995 sq. ft.	3,307 cc.
Muck	3.99 cc.	23,397 sq. ft.	23,397 cc.
Plant Beds	5.32 cc.	4,585 sq. ft.	6,098 cc.
Gravel Riffle	12,484 cc.	7,142 sq. ft.	22,290 cc.
Gravel	2,756 cc.	14,719 sq. ft.	10,141 cc.
TOTAL			65,233 cc.