MICHIGAN DEPARTMENT OF NATURAL RESOURCES

FISHERIES DIVISION

Fisheries Research Report No. 1800 *

July 16, 1973

CHANGES IN FISH SPECIES COMPOSITION IN THE AU SABLE RIVER, MICHIGAN, FROM THE 1920'S TO 1972**

By John Scott Richards

* This study was part of an Au Sable River Watershed Study Project financed, through the Michigan Department of Natural Resources, by the Northeast Regional Planning and Development Commission, of the Upper Great Lakes Regional Commission.

** This is a reprint of a thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Resource Ecology, in the School of Natural Resources, The University of Michigan, 1973. Committee members were Professor Frank F. Hooper, Chairman, and Dr. W. C. Latta.

ACKNOWLEDGMENTS

Data for this study were gathered as part of the Au Sable River Watershed Study Project, funded through the Northeast Regional Planning Commission, and completed under the auspices of the Institute for Fisheries Research, Michigan Department of Natural Resources.

Dr. W. Carl Latta guided me in all phases of this investigation. His patience, availability, and interest provided a needed source of encouragement and direction throughout the study. His concern for communication and understanding reflect the highest goals of the teaching profession.

Dr. Frank F. Hooper provided valuable assistance, encouragement, and the opportunity to air my ideas before an interested audience.

Special thanks to Mrs. Margaret McClure for typing the final draft of the study. Thanks also to other members of the Institute for Fisheries Research for their time, opinions, and information.

Dr. Gary Fowler and Dr. Burton Barnes both went far beyond the call of duty at various times in my course work. To them, appreciation and thanks.

Thanks especially to the other members of the Au Sable Study: Gary Coopes, Michael Quigley, George Burgoyne, and Neil Ringler for their ideas, help, patience, and good spirit; Neil for his unflagging zeal as my seine partner, and Gary for his good-natured tolerance and deep committment to the project.

Thanks finally to my wife, Sue, whose encouragement and flexibility made it possible to complete this study and enjoy life as well.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

An ichthyological survey was made of the Au Sable River and its tributaries, as part of a broader study of current economic developments within the watershed and the capacity of the river to absorb the impact of an increase in human population and the accompanying exploitation of resources, without undue deterioration of environmental quality. Fishes have an important role in recreation, and the composition of the fauna will reflect changes due to environmental abuse such as reduced water flow, increase in temperature, chemical pollution, over-enrichment by nutrients, over-fishing, and others.

Fortunately a careful fish survey was made on the river about 50 years ago by Carl L. Hubbs and associates. I repeated the same survey during the summer of 1972, duplicating the gear, river sites, dates and time, as closely as possible. Collections taken in 1972 were compared with the Hubbs' collections by three approaches: (1) a species analysis, (2) a faunal resemblance index, and (3) species diversity; the latter two involve statistical procedures.

Hubbs took 45 species; I took 44; 37 species were the same. Judging from abundance of coldwater species and from the statistical indices, the river system has improved as "trout water" in the central cold-water area: the lower half of the North Branch and Big Creek, the lower half of the South Branch, and the Main Stream from Grayling to the South Branch. On the other hand, quality of trout water has deteriorated above Grayling in both Main Stream and East Branch, in the headwaters of the North Branch, and from Cooke Pond downstream. Most of the river from the South Branch to Cooke Pond has changed little as trout water. For the immediate future, measures which would lower the water temperature during summer months would be favorable to trout fishing, especially in those stream segments where there has been some deterioration during the last 50 years.

INTRODUCTION

The Au Sable River, tributary to Lake Huron, drains approximately 1800 square miles in Michigan's northern Lower Peninsula. It has always been one of Michigan's finest recreational resources, offering trout fishing, canoeing, and camping opportunities unparalleled in the state. In the last 100 years, its ecological resilience has been severely tested by human interference. The first and probably the greatest example of this was the floating of logs to Oscoda during the latter part of the 1800's. The demise of the grayling, the only salmonid native to the system, may have been due in part to this practice (Biennial Report, Michigan Department of Conservation, 1925-1926).. But with the introduction of the brook trout in 1884, the rainbow trout a short time later, and the brown trout in 1891, fishing for trout soon became a popular and successful pastime on the river.

Since the logging era, six major hydroelectric dams have been constructed on the lower end of the river, as well as a number of smaller impoundments throughout the upper end of the watershed. Increased domestic and municipal development on or near the river banks, and greatly increased recreational use have placed added stress on the ecology of the system. Rising concern over the maintenance of water quality, and increasing conflict between riparians, land owners, fishermen, and canoeists prompted the formation of the Au Sable River Watershed Study Project. The data for this paper were gathered as a part of that project.

Of major concern was the question of whether fish populations in the system were being adversely affected by human influences on the watershed. Field reports located in the Institute for Fisheries Research, Michigan Department of Natural Resources, showed that a number of fish collections had been made in all parts of the Au Sable River in the early 1920's by Dr. Carl L. Hubbs and some of his associates. It is ironic that, as was the case in the present study, the collections of Hubbs et al. were initiated because of local concern that the quality of fishing in the river was lower than it used to be. A quote from the Times-News, July 4, 1924 (Ann Arbor News today), concerning the work of Hubbs and an associate was as follows: "The first study to be made by these two experts was of the waters of the Au Sable River, once the greatest trout stream in Michigan, but now one of the worst, because it has been fished to death."

It was proposed by Dr. W. C. Latta, Institute for Fisheries Research, that a selected number of the 1920's fish collections of Hubbs et al. be repeated with the thought that changes in fish species composition between the 1920's and the present might provide some insight into the nature and extent of change in the quality of water and habitat in the system over that period of time.

In particular, the investigation and this report aim to answer three specific questions:

1. Have there been significant changes in fish communities throughout the watershed?
2. In particular, have there been significant changes in fish species composition in good quality trout areas?
3. Do any of these changes indicate differences in water quality, and if so, have they been beneficial or detrimental?

METHODS

Collections

The validity of comparing collections gathered in the same locations at different times rests on the necessity to duplicate sampling procedures as closely as possible. Hubbs et al. left detailed records of the locations of the areas they sampled, the time of day and year of the collections, condition of the water, sampling gear used, and the exact number and in some cases the relative size of the fish species captured. Since all of their collections were made with seines, it was decided that they should be repeated with seines as well. From the collections made in the 1920's, 34 were chosen for repetition. Dr. Carl L. Hubbs, T. H. Langlois, Professor T. L. Hankinson, Dr. J. Metzelaar, and C. W. Creaser in various combinations made the earlier collections. The bulk of these were completed in the summer of 1924, but in addition, two were made by Hankinson in 1916, one by Hubbs and Metzelaar in 1922, two in 1926 by Hankinson and Langlois and Langlois alone, and one in 1927 by Metzelaar. The locations of these sampling sites (Fig. 1) and their descriptions (Table 1) are included.

For the most part, collections in both sampling periods were completed by two men, with occasional teams of three and four doing

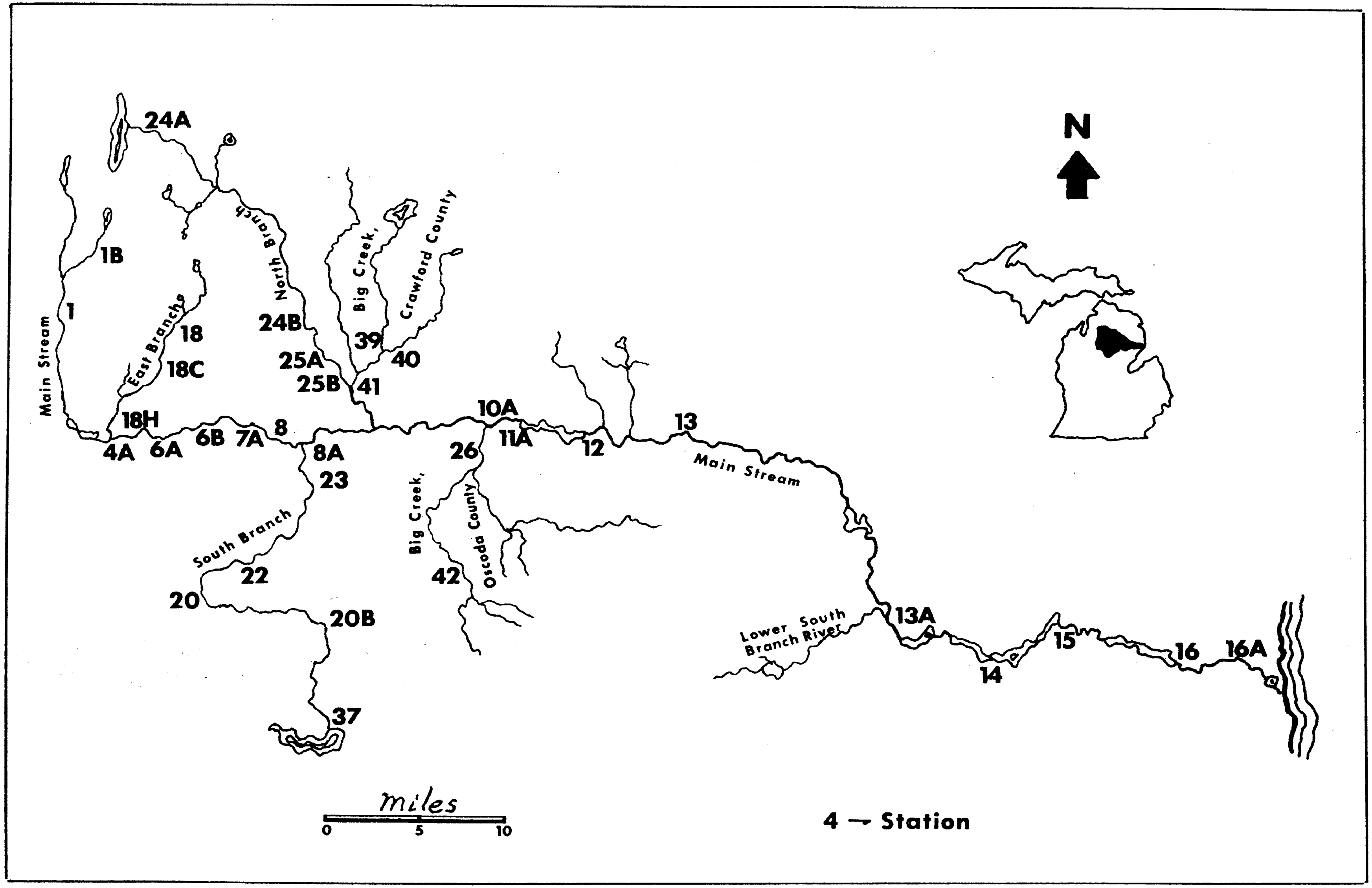


Figure 1.--The Au Sable River system, Michigan, showing the locations of the fish collecting sites for both Hubbs et al., in the 1920's and Richards et al., in 1972.

Table 1.--Station descriptions of fish collecting sites,

Au Sable River System, 1920's and 1972

Stream and Station No.*	Location	T.	R.	Sec.	Habitat type**
Main Stream					
1B.	Bradford Creek	28N	4W	14	CW
1.	Frederick, Co. 612 Bridge	28N	4W	35	CW
4A.	Mouth of East Branch	26N	3W	8	CW
6A.	Wa Wa Sum	26N	3W	11	CW
6B.	1 mile above Stephan's Bridge	26N	2W	6	CW
7A.	1 mile below Stephan's Bridge	26N	2W	4&5	CW
8.	Wakeley Bridge	26N	2W	11	CW
8A.	Stillwaters, below the mouth of the South Branch	26N	1W	8	LR
10A.	Just below the mouth of Big Creek	26N	1E	12&1	LR
11A.	Upper end of Mio Pond	26N	2E	4	LR
12.	Below Mio Dam	26N	3E	7	I
13.	Comins Landing	26N	3E	14&11	LR
13A.	Mouth of Lower South Branch R.	24N	5E	13	LR
14.	Below Five Channels Dam	24N	6E	26	I
15.	Below Cooke Dam	24N	7E	15	I
16.	Below Foote Dam	24N	8E	35	I
16A.	Between Foote Dam and Oscoda	24N	9E	31&32	LR
East Branch					
18.	County Road 612	28N	2W	30	WH
18C.	Hartwick Pines	27N	3W	14&23	CW
18H.	Above hatchery	26N	3W	8	CW

(continued, next page)

Table 1.--concluded

Stream and Station No.*	Location	T.	R.	Sec.	Habitat type**
South Branch					
37.	Mud Lake	23N	1W	8	WH
20B.	Sherman Bridge	24N	1W	8&9	WH
20.	Roscommon M-144 Bridge	24N	2W	5	WH
22.	Chase Bridge	25N	2W	21&22	CW
23.	Smith Bridge	26N	1W	29&32	CW
North Branch					
24A.	Dam 1	29N	2W	7	WH
24B.	Dam 4	27N	1W	8	CW
25A.	Campground between Dam 4 and Kellogg's	27N	1W	16	CW
25B.	Kellogg's Bridge	27N	1W	22	CW
Big Creek					
(Crawford Co.)					
39.	Lowest mile of the Middle Branch	27N	1W	12	CW
40.	Lowest mile of the East Branch	27N	1W	12	CW
41.	Blonde Dam	27N	1W	23	CW
(Oscoda Co.)					
42.	Dirt road	25N	1E	26	CW
26.	County Road 487	26N	1E	12	CW

* Station numbers follow those of the Au Sable River Watershed Study Project final report, Northeast Regional Planning Commission (in press).

** Habitat types as follows:
WH = warm headwaters
CW = cold-water, moderate flow habitat
LR = large river habitat
I = below impoundments

the collecting. The seines used most frequently and effectively by Hubbs et al. and the present party as well, were "common sense minnow seines." In particular, the descriptions of the seines used by Hubbs and company as taken from their field notes (on file, Natural Science Museum, University of Michigan) are as follows:

1. 6-, 8-, 10-, and 12- by 4-foot common sense, 1/4-inch stretched mesh minnow seines.
2. 30- and 50- by 5-foot bag seines, 1/2-inch stretched mesh leads, and 1/4-inch stretched mesh bag.

In place of the 30-foot bag seine, a 25-foot bag seine was used in the present collections, and in addition to the minnow seines listed, a 4- by 4-foot, 1/4-inch stretched mesh minnow seine was also used.

Based on several letters from Dr. Hubbs describing their collecting techniques, the following procedures were followed:

1. All of the 1972 collections were made within 2 weeks of the recorded date for the corresponding earlier collections. This was to insure that gross seasonal fluctuations in fish species composition would not bias the results.
2. Within the area prescribed by Hubbs in his field notes, all habitats were sampled until it appeared that no new fish were being taken. Thus the time spent and the area covered varied according to the characteristics of the location being sampled. In no case did seining efforts last less than 1 1/2 hours, and in some cases considerably more time

was spent. Rarely were more than two collections completed per day.

3. All fish were preserved in 10% formalin, with the exception of trout larger than 5 inches which were measured, recorded, and released.

4. The use of specific seines and seine techniques was dictated by the nature of the habitat being sampled. In general, because of numerous snags, it was impossible to pull a seine downstream any great distance. The most effective technique was for one man to hold a smaller seine in position while the other man drove fish downstream into it. Rarely were large fish captured, especially trout, as they were strong and fast enough to escape before the seines could be pulled out.

The effectiveness of the present seine collections was checked by repeating ten of them using a 230-volt d-c boat shocker operated with two probes. The point of this exercise was to determine whether or not rare species had been missed in seining. The same area was covered in these repetitions as was covered using seines. Again, all fish captured were preserved in 10% formalin for later identification except trout larger than 5 inches which were measured, recorded, and released. The electrofishing runs were all made at the end of the summer. Thus, the time that elapsed between seine and electrofishing samples from the same area varied.

Fish species were identified using Hubbs and Lagler (1970), and occasionally Trautman (1957). All common and scientific names of fish referred to in this paper are taken from Bailey et al. (1970). In cases where the author was unsure of the identity of a specimen, advice from members of the staff of the Institute for Fisheries Research most familiar with that species was sought. The total number of each species was recorded.

Data Analysis

Data were analyzed on several different levels. First, all 34 stations were combined in order to examine gross changes in the watershed as a whole. Next, stations were classified by stream order (size), and habitat type. This was done to give some order to the variety of ecological conditions found in different areas of the watershed. In terms of habitat classification, four general categories were decided upon: warm headwater stations; cold-water, moderate flow stations; large river stations; and below impoundments. Finally, stations were examined individually to determine the nature of localized habitat changes.

Within each of these levels of analysis, several methods were used to detect changes in fish communities. Historically in fisheries work, such methods have evolved from single species approaches (Kolkwitz and Marsson, 1908; Gaufin and Tarzwell, 1952; Cairns and Dickson, 1971) to community structure analysis (Pielou, 1966a, 1966b, 1967, 1969; Margalef, 1968). No single approach is all-encompassing and each has its shortcomings. The use of several types of analysis is therefore of greater value in evaluating fish community changes than the use of only one.

The most basic way to assess change in fish populations is to examine changes in distribution and abundance of the various fish species in question. It is then possible to make qualitative inferences about habitat changes on the basis of the presence, absence, or change in abundance of key species (Katz and Gaufin, 1971; Larimore and Smith, 1963). The relative tolerance or intolerance of these species to specific sets of environmental conditions provides the basis for such inferences. Trautman (1957) was the major source for habitat requirements of the fish species examined. A species will be considered intolerant in this paper when it has been shown to become drastically reduced or disappears as a result of certain environmental changes.

A second tool, borrowed from the field of zoogeography, but of use here, is the faunal resemblance index (Jaccard, 1908; Simpson, 1960). Although there are many forms that this index can take, basically all of them are used to estimate the degree of similarity between two collections. In assessing species shifts over a period of years in a given location, as has been done here, this technique has obvious application. The faunal resemblance index used in this paper is that of Jaccard (1908):

$$\frac{C}{N_1 + N_2 - C} \times 100$$

C = number of taxa in common

N_1, N_2 = number of taxa in first and second collections, respectively

A third approach used in this paper to assess community change is species diversity. The more modern forms of this type of index based on information theory attempt to combine into one value two of the most critical characteristics of a collection: the number of species, and the distribution of individuals within those species. Their obvious advantage is that they reduce a great deal of information about the structure of a particular fish community into one number, which can then be readily compared with other indices. The major drawback of species diversity indices is that they ignore changes in the species list. Thus it would be possible to repeat a fish collection after a period of time and find the species diversity index unchanged, yet several entirely different events could have taken place:

1. The species involved and their numerical distributions have remained the same.

2. The species are the same, but their relative abundance has shifted.

3. There is an entirely new fauna, but it has the same numerical qualities as the original fauna, and thus has the same diversity value.

For this reason, species diversity analyses cannot be properly evaluated unless species changes are examined concurrently, as was done in this paper.

Although there are a variety of species diversity indices in the literature, those based on information theory (Brillouin, 1960; Pielou, 1966a, 1966b, 1967, 1969; Margalef, 1958) seem to be the most reliable. On the basis of Pielou's (1967) paper, it was determined that Brillouin's diversity index, in the body of this paper referred to as H, was the proper index to use for the particular type of collection taken in this study. The formula is:

$$H = (1/N)\ (\log_e N! - \sum_{i=1}^{s} \log_e N_i!)$$

where N = total number of individuals in collection

N_i = total number of individuals in ith species

H is expressed in "nats" per individual referring to the fact that natural logarithms are used.

All diversity calculations were made through the use of a computer program supplied by Paul Eisele, School of Public Health, University of Michigan.

This program also computes a value referred to in the literature as evenness. This value reflects the distribution of individuals in a collection within the species found there. The more equal the distribution of individuals, the greater the evenness. This evenness component of species diversity, referred to in the body of this paper as J , is calculated by the ratio of:

$$\frac{H}{H\ max}$$

where H max is the maximum diversity a given collection of species could have, which would be the case when all species had equal numbers of individuals.

Both species diversity and evenness are measures that are proving useful in detecting community response to environmental stress and perturbation (Wilhm and Dorris, 1966, 1968; Whiteside and McNatt, 1972; Harrel and Dorris, 1968). Stable communities are characterized by high diversity and evenness (Pielou, 1967). The introduction of a pollutant, however, or any chronic stress will tend to eliminate or greatly reduce the numbers of many species in that area. This in turn will favor the increase of a few species more tolerant to that stress (Wilhm and Dorris, 1966). Such changes would be reflected in both lower diversity and evenness in samples taken from polluted areas. Thus it is possible to infer from gross changes in species diversity and evenness over time, that some sort of environmental stress has taken place. By using such an approach in this study, it was hoped that community structure analysis might be useful in determining whether or not the Au Sable watershed has physically changed in the last 50 years, and if so, what the direction of that change has been.

One way of determining the nature of the environmental change that has taken place was to examine changes in abundance of certain groups of species with similar ecological requirements. With this in mind, the three species of trout, the slimy sculpin, and the round whitefish were lumped together as a cold-water group (Trautman, 1957). By doing this, and noting changes in the frequency of occurrence of this group, it was possible to make inferences concerning water quality changes over the (roughly) 50-year period in question. The percentage of the total number of individuals that these five species represented in each collection was calculated. The same was done for warm-water species. Included in this group were bluegill, pumpkinseed, largemouth bass, black crappie, mudminnow, yellow bullhead, and brown bullhead. While these groups are by no means so well defined as to be above criticism, they do follow the literature (Trautman, 1957).

RESULTS

Hubbs et al. took 45 species of fish in 34 locations in the 1920's. In the repeat collections of 1972, 44 species were taken. Of those species present in the 1920's, eight were not found in any of the locations by the present study team. However seven new species were taken (Table 2). Of the original 45 species, 37 are still found in the watershed today.

The following is an annotated species list. Descriptions of the numbers and species of fish found at each location (Table 3) and their frequency of occurrence in different habitat types (Table 4) will not be reviewed here. More specific details concerning location, time, gear, etc. for each seining station are available through the Institute for Fisheries Research, Michigan Department of Natural Resources, Ann Arbor. Most of the following changes span the years 1924-1972; a few span a slightly longer or shorter period depending on the exact date of the earlier collection. Only general trends in abundance and distribution are discussed.

Table 2.--Summary of shifts in species of fish for the entire Au Sable River system from the 1920's to 1972

	Hubbs et al., 1920's	Richards et al., 1972
Number of species taken	45	44
Number of species previously unrecorded (additions)	-	7
Number of species previously recorded	-	37
Number of species previously recorded but not taken (losses)	-	8

Table 3.--Numbers and species of fish taken at each station, Au Sable River, 1920's and 1972.

	MAIN STREAM													
	BRADFORD CREEK		FREDERICK, CO. 612		MOUTH OF EAST BRANCH		WA WA SUM		1 MILE ABOVE STEPHAN'S		1 MILE BELOW STEPHAN'S		WAKELEY BRIDGE	
SPECIES / Station No.	1B		1		4A		6A		6B		7A		8	
Year	1920's	1972	1920's	1972	1920's	1972	1920's	1972	1920's	1972	1920's	1972	1920's	1972
Brook trout	22	4	6	3	3	--	--	15	1	11	--	2	2	1
Rainbow trout	--	--	--	--	7	--	1	2	--	--	5	5	19	--
Brown trout	--	--	--	--	1	--	--	3	1	7	--	4	13	3
Round whitefish	--	--	--	--	--	--	--	--	--	--	--	--	--	2
Mottled sculpin	6	1	39	27	3	12	9	28	23	13	--	56	37	68
Slimy sculpin	--	--	--	--	--	--	--	1	--	--	--	--	--	9
Lamprey larvae	--	--	5	--	--	--	--	--	--	--	--	--	--	--
Central mudminnow	--	--	--	--	11	--	--	--	--	--	--	--	--	--
Northern pike	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Horneyhead chub	--	--	--	--	1	11	3	6	--	--	--	--	1	--
River chub	--	--	--	--	--	--	4	--	2	--	3	--	1	--
Golden shiner	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Lake emerald shiner	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Common shiner	--	1	--	1	52	148	14	6	69	--	2	1	229	135
Blackchin shiner	--	--	--	--	--	--	--	--	--	--	--	--	--	2
Blacknose shiner	--	--	--	--	1	--	--	--	--	--	--	--	4	10
Spottail shiner	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Rosyface shiner	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Spotfin shiner	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Sand shiner	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Redfin shiner	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Mimic shiner	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bluntnose minnow	--	1	--	1	--	1	--	--	--	--	--	--	--	--
Fathead minnow	--	--	--	--	--	--	--	--	--	--	--	--	--	3
Northern redbelly dace	--	--	--	3	2	--	--	--	--	--	--	--	--	--
Finescale dace	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Blacknose dace	--	20	3	83	20	5	6	10	69	7	3	--	1	4
Longnose dace	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Creek chub	--	4	--	2	21	2	--	--	10	--	1	--	--	27
Pearl dace	--	--	--	--	1	--	--	--	1	--	--	--	--	--
White sucker	--	2	--	8	3	19	--	3	69	2	36	9	58	10
Northern hog sucker	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Golden redhorse	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Shorthead redhorse	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Yellow bullhead	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Brown bullhead	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Stonecat	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Brook stickleback	--	--	--	1	2	--	--	--	--	--	--	--	--	1
Rock bass	--	--	--	--	1	--	--	--	--	--	--	1	--	--
Pumpkinseed	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bluegill	--	--	--	--	--	--	--	--	--	--	--	--	--	2
Smallmouth bass	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Largemouth bass	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Black crappie	--	--	--	--	--	--	--	--	--	--	--	--	--	1
Rainbow darter	--	--	--	--	1	1	--	--	--	--	--	--	--	--
Least darter	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Johnny darter	--	--	--	2	41	--	2	--	4	--	--	--	--	--
Yellow perch	--	--	--	--	--	1	--	2	--	--	--	--	1	--
Logperch	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Channel darter	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Blackside darter	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Walleye	--	--	--	--	--	--	--	--	--	--	--	--	--	--

MAIN STREAM

STILLWATERS 8A		MOUTH OF BIG CREEK 10A		MIO POND 11A		MIO DAM 12		COMINS LANDING 13		MOUTH OF LOWER SOUTH BRANCH RIVER 13A		FIVE CHANNELS DAM 14		COOKE DAM 15		FOOTE DAM 16		BETWEEN FOOTE DAM AND OSCODA 16A	
1920's	1972	1920's	1972	1920's	1972	1920's	1972	1920's	1972	1920's	1972	1920's	1972	1920's	1972	1920's	1972	1920's	1972
--	--	--	2	--	--	--	--	--	2	--	--	--	--	--	--	--	--	--	--
8	--	14	--	6	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--
16	--	3	6	5	--	--	--	--	3	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
25	28	131	9	90	1	1	--	114	--	1	--	--	--	--	--	--	--	--	--
1	--	4	2	--	1	--	--	2	--	1	--	--	--	--	--	--	--	--	--
--	--	30	--	4	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--
--	1	4	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	2	--	--	--	--	--	--	2	--	1	--	--	--	--	--	2	--	--	--
--	--	--	--	--	--	--	--	--	----	--	--	--	--	--	--	--	--	--	--
--	--	--	--	1	--	1	--	2	--	--	--	--	--	--	--	2	--	14	--
--	--	--	--	--	--	--	23	--	--	6	--	19	13	111	--	46	--	9	--
--	--	--	--	--	--	--	3	--	--	--	--	--	1	--	--	--	--	--	--
--	5	48	--	--	4	73	544	--	2	92	186	--	--	213	--	194	--	55	--
--	--	--	--	--	--	2	--	--	--	--	--	19	--	401	--	76	--	37	--
--	--	--	--	--	--	--	2	5	--	--	6	7	--	62	1	46	--	20	--
--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	1	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	4	--	10	--	1	--
--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	6	--	--	6
--	--	--	--	--	--	--	--	--	--	--	2	--	--	--	--	9	--	3	--
--	--	--	--	--	--	--	--	--	--	--	--	196	--	229	--	25	--	52	--
--	--	--	--	--	--	--	208	--	--	--	3	--	26	--	25	--	110	--	105
--	--	--	--	--	--	1	17	--	1	2	98	61	5	403	2	18	--	91	--
--	--	--	--	--	--	--	10	--	--	--	--	--	--	--	--	--	--	--	21
--	--	--	45	--	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1	--	3	13	8	48	1	--	--	52	14	--	--	--	--	--	--	--	--	--
--	--	4	--	114	9	11	--	24	--	51	--	--	--	--	--	1	--	--	--
--	--	6	1	--	1	--	19	--	4	3	3	8	--	--	--	--	--	1	--
--	--	11	--	--	--	--	1	--	--	--	--	1	--	--	--	--	--	--	--
3	--	14	15	134	100	29	7	52	74	22	172	25	3	--	163	1	1	56	3
--	--	--	--	--	--	2	6	26	3	14	17	--	--	--	--	44	2	1	7
--	--	--	--	--	--	--	--	--	--	--	4	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2	--	3	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2	--	--	--
--	--	--	--	45	--	--	--	1	--	--	3	--	--	--	--	--	--	--	--
--	--	3	--	3	--	--	1	2	--	--	48	10	35	--	3	44	--	3	--
--	--	--	--	--	--	--	--	--	--	--	--	121	--	1	1	80	--	3	--
--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	1	--	2	--	--
--	--	--	--	--	--	--	2	--	--	--	11	--	1	--	--	8	--	--	--
--	1	--	--	--	--	--	--	--	--	--	6	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--
--	4	3	--	30	4	--	--	1	3	100	7	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	40	--	--	--	--	--	--	--
2	10	--	1	122	20	3	--	22	12	33	6	--	--	21	6	3	1	3	14
--	--	--	--	--	--	--	--	--	--	1	35	--	94	--	151	13	1	9	1
--	--	--	--	--	--	--	25	--	5	9	2	5	26	2	1	83	--	1	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	86	--	--	--
--	--	3	2	35	28	--	44	9	28	58	3	8	2	2	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--

(continued, next page)

Table 3.--concluded

SPECIES	EAST BRANCH						SOUTH BRANCH							
	COUNTY ROAD 612		HARTWICK PINES		HATCHERY		MUD LAKE		SHERMAN BRIDGE		ROSCOMMON		CHASE BRIDGE	
Station No.	18		18A		18H		37		20B		20		22	
Year	1920's	1972	1920's	1972	1920's	1972	1920's	1972	1920's	1972	1920's	1972	1920's	1972
Brook trout	--	--	16	4	10	1	--	--	--	--	1	--	5	13
Rainbow trout	--	--	--	--	21	2	--	--	--	--	--	--	--	--
Brown trout	--	--	--	1	1	5	--	--	--	--	--	--	3	2
Round whitefish	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Mottled sculpin	3	2	26	18	14	7	--	--	7	1	31	15	54	11
Slimy sculpin	--	--	--	--	--	--	--	--	--	--	--	--	--	1
Lamprey larvae	10	--	--	--	9	--	--	--	2	--	22	--	14	--
Central mudminnow	--	7	--	--	1	--	--	--	29	17	13	--	6	--
Northern pike	--	--	--	--	--	--	--	10	8	2	--	--	--	--
Horneyhead chub	--	12	1	--	--	--	--	--	1	--	--	3	--	--
River chub	2	--	--	--	--	--	--	--	--	--	3	--	1	--
Golden shiner	2	--	--	--	--	--	--	4	2	--	--	--	--	--
Lake emerald shiner	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Common shiner	25	43	5	1	21	--	--	1	2	--	2	100	3	33
Blackchin shiner	--	--	--	--	4	--	--	32	--	--	--	--	--	--
Blacknose shiner	--	2	1	2	1	--	--	--	--	--	--	--	--	--
Spottail shiner	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Rosyface shiner	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Spotfin shiner	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Sand shiner	1	--	--	--	--	--	--	--	--	--	--	--	--	--
Redfin shiner	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Mimic shiner	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bluntnose minnow	5	2	--	--	1	--	--	35	--	--	--	--	--	1
Fathead minnow	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Northern redbelly dace	--	--	12	--	119	--	--	--	--	--	--	--	--	--
Finescale dace	--	--	--	--	1	--	--	--	--	--	--	--	--	--
Blacknose dace	1	7	32	177	22	11	--	--	--	--	--	1	--	--
Longnose dace	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Creek chub	1	7	1	8	5	--	--	--	--	--	--	1	4	--
Pearl dace	--	--	7	21	48	--	--	--	--	--	--	--	--	--
White sucker	--	--	13	12	128	13	--	11	--	2	--	--	1	4
Northern hog sucker	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Golden redhorse	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Shorthead redhorse	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Yellow bullhead	--	--	--	--	--	--	3	--	--	--	--	--	--	--
Brown bullhead	--	--	--	--	--	--	6	36	17	--	--	--	--	--
Stonecat	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Brook stickleback	--	--	--	1	1	--	--	--	--	--	--	--	--	--
Rock bass	--	4	--	--	--	--	3	5	3	--	--	--	1	--
Pumpkinseed	--	--	--	--	--	--	2	--	5	--	--	--	--	--
Bluegill	--	--	--	--	--	--	1	46	--	1	--	--	--	--
Smallmouth bass	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Largemouth bass	--	--	--	1	--	--	1	77	--	--	--	--	2	--
Black crappie	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Rainbow darter	--	--	--	--	--	--	--	--	--	--	--	4	5	--
Least darter	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Johnny darter	13	27	9	9	--	--	--	10	63	32	32	38	18	9
Yellow perch	25	16	--	--	--	--	--	49	14	--	--	--	--	--
Logperch	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Channel darter	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Blackside darter	--	--	--	--	--	--	--	1	4	4	1	2	--	--
Walleye	--	--	--	--	--	--	--	--	--	--	--	--	--	--

SMITH BRIDGE		NORTH BRANCH DAM 1		NORTH BRANCH DAM 4		NORTH BRANCH CAMPGROUND BETWEEN DAM 4 AND KELLOGG'S		NORTH BRANCH KELLOGG'S BRIDGE		BIG CREEK Crawford Co. MIDDLE BRANCH		BIG CREEK Crawford Co. EAST BRANCH		BIG CREEK Crawford Co. NORTH DOWN RIVER ROAD		BIG CREEK Oscoda Co. 25N, 1E, SEC. 26		BIG CREEK Oscoda Co. COUNTY ROAD 487	
23		24A		24B		25A		25B		39		40		41		42		26	
1920's	1972	1920's	1972	1920's	1972	1920's	1972	1920's	1972	1920's	1972	1920's	1972	1920's	1972	1920's	1972	1920's	1972
9	30	3	--	5	34	2	1	--	3	5	33	25	15	--	--	5	5	p*	--
28	--	--	--	7	--	5	--	--	--	--	--	--	--	--	--	--	--	--	--
4	17	--	1	10	17	--	18	1	3	--	2	9	5	--	6	--	--	p	2
--	--	--	--	--	--	--	--	--	2	--	--	--	--	--	--	--	--	--	--
80	3	5	3	34	15	50	18	12	10	3	3	3	15	11	14	3	2	p	9
--	8	--	--	--	--	--	9	--	1	--	8	--	5	--	1	--	--	p	5
17	--	--	--	2	1	--	1	--	--	1	--	--	--	--	--	--	--	p	--
2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	p	--
3	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
2	--	--	--	1	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
2	5	6	29	13	--	2	--	5	--	3	--	2	--	6	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	1	--	--	--	--	--	--	1	1	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	2	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	10	--	--	--	--	10	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	6	--	--	--	--	--	--	--	--
10	--	18	19	151	63	252	34	15	252	30	--	--	7	53	23	17	85	--	--
--	--	--	--	3	--	2	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	6	36	55	26	5	10	18	14	3	1	3	--	3	3	--	12	--	--
--	--	--	--	--	--	--	--	1	--	--	--	8	--	--	--	--	--	--	--
41	--	4	8	20	1	39	28	52	9	--	--	--	--	4	3	--	2	--	1
--	--	--	--	--	--	--	--	--	1	--	--	--	--	1	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--
--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	2	--	--	--	--	--	5	2	--	1	--	--	--	--	--	--
--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
2	--	--	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1	--	--	--	1	--	3	20	2	13	--	--	--	--	1	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
10	3	1	37	107	13	6	4	11	8	--	--	--	--	--	1	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

* present

Table 4.--Frequency of occurrence of fish species in different habitat types, Au Sable River, 1920's and 1972.

Fish species	Warm Head-water habitat (5 stations)		Cold-water habitat (19 stations)		Large river habitat (6 stations)		Below impoundments (4 stations)		All stations combined	
	1920's	1972	1920's	1972	1920's	1972	1920's	1972	1920's	1972
Brook trout	40%	--	79%	84%	--	33%	--	--	50%	53%
Rainbow trout	--	--	47%	16%	67%	--	--	--	38%	9%
Brown trout	--	20%	53%	79%	50%	33%	--	--	38%	53%
Round white fish	--	--	--	11%	--	--	--	--	--	6%
Mottled sculpin	80%	80%	95%	100%	83%	50%	25%	--	82%	76%
Slimy sculpin	--	--	6%	53%	67%	33%	--	--	15%	35%
Lamprey (larvae)	60%	--	37%	11%	50%	--	--	--	38%	6%
Mudminnow	40%	40%	26%	6%	33%	17%	--	--	26%	12%
Northern pike	20%	40%	11%	--	33%	17%	25%	--	18%	9%
Horneyhead chub	20%	40%	16%	11%	--	--	--	--	12%	12%
River chub	60%	--	47%	--	50%	--	50%	--	50%	--
Golden shiner	40%	20%	--	--	33%	--	75%	50%	21%	9%
Emerald shiner	--	--	--	--	--	--	--	50%	--	6%
Common shiner	80%	80%	79%	47%	50%	67%	75%	25%	74%	53%
Blackchin shiner	--	20%	6%	6%	17%	--	100%	--	18%	6%
Blacknose shiner	--	20%	32%	16%	33%	17%	75%	50%	32%	21%
Spottail shiner	--	--	--	--	--	--	25%	25%	3%	3%
Rosyface shiner	--	--	--	--	17%	--	50%	--	9%	--
Spotfin shiner	--	--	--	--	--	17%	25%	25%	3%	6%
Sand shiner	20%	--	6%	--	17%	17%	25%	--	12%	3%
Redfin shiner	--	--	--	--	17%	--	75%	--	12%	--
Mimic shiner	--	--	--	--	--	33%	--	100%	--	18%
Bluntnose minnow	20%	40%	11%	21%	33%	33%	100%	75%	26%	32%
Fathead minnow	--	--	--	6%	--	17%	--	25%	--	9%
Northern redbelly dace	--	--	21%	11%	--	33%	--	--	12%	12%
Finescale dace	--	--	6%	6%	--	17%	--	--	3%	6%
Blacknose dace	40%	80%	84%	68%	67%	50%	25%	--	68%	59%
Longnose dace	--	--	11%	--	67%	17%	50%	--	24%	3%
Creek chub	40%	60%	58%	58%	50%	67%	25%	25%	50%	56%
Pearl dace	--	--	32%	6%	17%	--	25%	25%	24%	6%
White sucker	20%	60%	63%	79%	100%	83%	75%	100%	65%	79%
Northern hog sucker	--	--	6%	6%	50%	50%	50%	50%	18%	18%
Golden redhorse	--	--	--	--	--	17%	--	--	--	3%
Shorthead redhorse	--	--	--	--	17%	--	25%	--	6%	--
Yellow bullhead	20%	--	--	--	--	--	25%	--	6%	--
Brown bullhead	40%	20%	6%	--	--	--	25%	--	12%	3%
Stonecat	--	--	--	--	--	--	25%	--	3%	--
Brook stickleback	--	--	21%	26%	33%	17%	--	--	18%	18%
Rock bass	40%	40%	11%	11%	67%	17%	50%	75%	29%	24%
Pumpkinseed	40%	--	--	--	17%	--	75%	25%	18%	3%
Bluegill	20%	40%	--	6%	--	--	--	75%	3%	18%
Smallmouth bass	--	--	--	--	--	17%	25%	50%	3%	9%
Largemouth bass	20%	40%	11%	6%	--	33%	--	--	9%	15%
Black crappie	--	--	--	--	--	17%	--	--	--	3%
Rainbow darter	--	20%	37%	16%	67%	67%	--	--	32%	24%
Least darter	--	--	--	--	--	--	25%	--	3%	--
Johnny darter	80%	100%	47%	42%	83%	100%	75%	50%	62%	62%
Yellow perch	40%	40%	6%	11%	33%	33%	25%	75%	18%	26%
Logperch	--	--	--	--	33%	33%	75%	75%	15%	15%
Channel darter	--	--	--	--	--	--	25%	--	3%	--
Blackside darter	40%	60%	--	--	67%	67%	50%	50%	24%	26%
Walleye	--	--	--	--	--	--	--	75%	--	3%
Total number of species	23	21	30	29	31	31	32	22	45	44

Brook trout.--Introduced originally into the system in 1884. Not much change in abundance or distribution since the 1920's; probably much more abundant prior to the 1920's.

Rainbow trout.--Introduced into the system in the early 1880's. Decreased abundance and distribution possibly due to decreased stocking and increased competition from brown trout.

Brown trout.--Since its introduction into the system in 1891, it has increased in abundance and distribution. Probably best adapted and the most abundant of the three trout species in the majority of habitat conditions in the system.

Round whitefish.--Reported present in the system by Hubbs in the 1920's but not captured by him. Perhaps increasing in distribution and abundance today.

Mottled sculpin.--Widely distributed during both sampling periods. Not much change in abundance.

Slimy sculpin.--Increased significantly in numbers and distribution in good quality trout habitat. Not often found in warmer areas.

Lamprey larvae.--Apparent decreased abundance and distribution should be disregarded. Five species found in the Great Lakes region: American brook lamprey, northern brook lamprey, silver lamprey, chestnut lamprey, and sea lamprey. Taxonomic confusion over ammocoete identification makes species differentiation impossible; present author therefore made no special efforts to collect this organism.

Central mudminnow.--Perhaps a decrease in distribution over-all. A more marked decrease in good quality trout habitat.

Northern pike.--No great change in distribution. Always present in the system in small numbers, and always considered undesirable because of its predatory nature.

Horneyhead chub.--No change; continues to be sporadically distributed today.

River chub.--Present throughout the watershed in fair numbers in the 1920's; none were found in the present collections.

Golden shiner.--Diminished somewhat in abundance in warmer water areas, and particularly below impoundments.

Emerald shiner.--Found only in the Great Lakes (Hubbs and Lagler, 1970). Its rare appearance in two 1972 collections from below impoundments implies that it is probably a bait introduction there. None taken in the 1920's.

Common shiner.--Found in all habitat types in the watershed; appears to have decreased in abundance below several of the impoundments; also appears to have decreased in a number of good quality trout areas.

Blackchin shiner.--Sporadically distributed throughout the watershed; once abundant below the large impoundments, but no longer found there.

Blacknose shiner.--Sporadically distributed throughout the watershed; once almost as abundant as blackchin shiner below impoundments, now found there only rarely.

Spottail shiner.--Only one specimen taken below impoundments in each of the two collecting periods.

Rosyface shiner.--Found in small numbers below impoundments in the 1920's, now absent from the system.

Spotfin shiner.--Rare in the lower end of the watershed in both sampling periods.

Sand shiner.--Found in small numbers at several stations in the 1920's; only two specimens found in 1972 in the lower end of the system.

Redfin shiner.--Found in large numbers below impoundments in the lower end of the system in the 1920's, completely absent today.

Mimic shiner.--None found in 1920's; now quite abundant in the lower end of the system.

Bluntnose minnow.--Found sporadically throughout the system in both sampling periods.

Fathead minnow.--None taken in the 1920's; found in small numbers at three sites in 1972.

Northern redbelly dace.--Localized pockets found with about the same frequency in both sampling periods.

Finescale dace.--Rare in both sampling periods.

Blacknose dace.--Found throughout the system in both collecting periods; particularly abundant in colder-water habitats.

Longnose dace.--Found in fair abundance in 1920's; captured in 1972 at only one location.

Creek chub.--Common throughout the system in both collecting periods.

Pearl dace.--In the 1920's, found primarily in cold-water habitat; decreased abundance there in 1972.

White sucker.--Very common throughout the system in both sampling periods.

Northern hog sucker.--Found in the same sporadic abundance in both collecting periods.

Golden redhorse.--Found in only one location in 1972. None taken in the 1920's.

Shorthead redhorse.--Several specimens in two collections from the 1920's; none taken in 1972.

Yellow bullhead.--Rare occurrence at two warm-water stations in 1920's; none taken in 1972.

Brown bullhead.--Found in locally warm-water habitats on several occasions in 1920's; taken in only one location in 1972.

Stonecat.--Two specimens from one station in 1924; none taken in 1972.

Brook stickleback.--No change in abundance; found in several cold-water areas in both sampling periods.

Rock bass.--Present in greatest abundance in both periods in the lower end of the system; found sporadically elsewhere.

Pumpkinseed.--Present intermittently throughout the system in 1924, appears to have decreased in distribution and abundance.

Bluegill.--Increased somewhat in distribution, particularly below impoundments; increase is probably influenced by recent stocking of the impoundments.

Smallmouth bass.--Rare in both sampling periods.

Largemouth bass.--Present sporadically in both sampling periods.

Black crappie.--Only one specimen taken in 1972. None taken in 1924.

Rainbow darter.--Perhaps a slight decrease in frequency of occurrence in cold-water areas.

Least darter.--Locally abundant at only one station in 1924; none found in 1972.

Johnny darter.--Present in moderate numbers throughout the system in both sampling periods.

Yellow perch.--Increased abundance in 1972, particularly below impoundments.

Logperch.--Present in the lower end of the system in equal abundance in both sampling periods.

Channel darter.--Locally abundant at only one station in 1924; none found in 1972.

Blackside darter.--Present in moderate numbers in non-trout waters in both sampling periods.

Walleye.--Only one specimen taken in 1972; none taken in the 1920's.

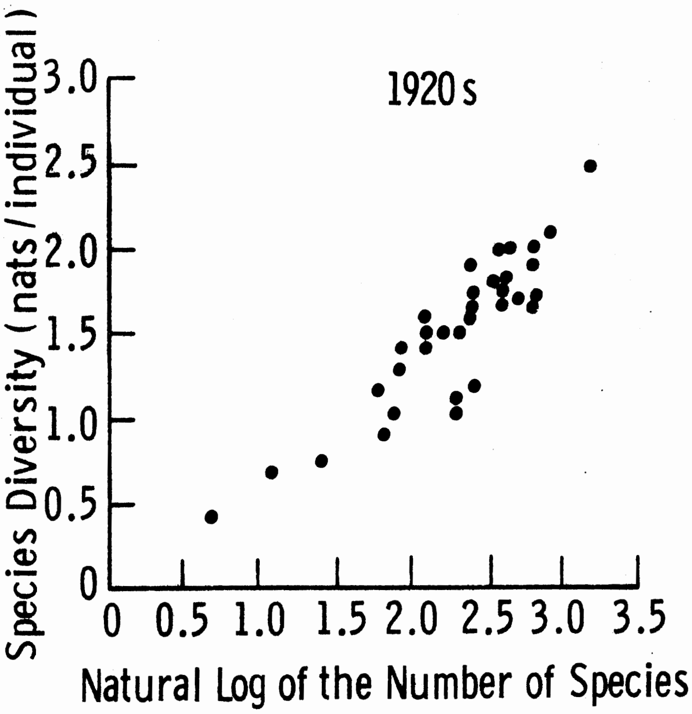
The rest of the results section will be broken down into four parts: an overview of the watershed taken as a whole, a discussion of changes by stream order, and by habitat, and a station-by-station analysis.

Overview

Tramer (1969) demonstrated a method of examining the two major components of species diversity: species numbers or richness, and the distribution of individuals within those species, or evenness. By plotting diversity (H) against the natural logarithm of the number of species in a given set of collections, analysis of the resulting scatter of points allows one to determine the relative effect of each of the components on diversity. If the points lie clustered on a 45° line, the species diversity of the communities in question is closely correlated with the number of species they contain. If the points lie in a scattered pattern around the 45° line, then diversity is most closely correlated with the evenness component. This is of theoretical importance because Tramer (1969) and Pielou (1967) both hypothesize that collections of organisms from rigorous, unpredictable, variable environments will vary in diversity according to their relative abundance patterns, whereas collections from predictable, non-rigorous, stable environments will vary in diversity according to their species richness component.

Tramer's procedure was used with the present data (Fig. 2). A good correlation exists between diversity and the natural log of the number of species for the 1920's collections ($R^2 = 0.80$), but not for the 1972 collections ($R^2 = 0.26$). Using Tramer's reasoning, this overview suggests that over the course of the last 50 years, the Au Sable River as a whole has become a more rigorous, unstable, unpredictable environment for fish. Examination of fish species diversity and evenness trends over the years (Figs. 3-6) shows that in some cases, particularly in the headwaters and the lower end of the Main Stream, there have been marked changes in community structure, while such changes are not evident elsewhere. This adds further weight to the proposition that significant ecological changes have been taking place in the watershed over the last 50 years.

An examination of the species which have evidenced the most significant changes in distribution and abundance throughout the watershed (Table 5) shows an increase in frequency of occurrence of brown trout, slimy sculpin, and round whitefish. As these are all cold-water species (Trautman, 1957), their apparent increase implies water quality changes for the better, specifically, a colder average water temperature in certain parts of the system. The decrease in frequency of occurrence of rainbow trout should be viewed with the knowledge that it probably is not as well suited to the moderate gradient and temperature regime of the Au Sable as the brown trout (Trautman, 1957). The decrease in frequency of occurrence of the pearl dace, longnose



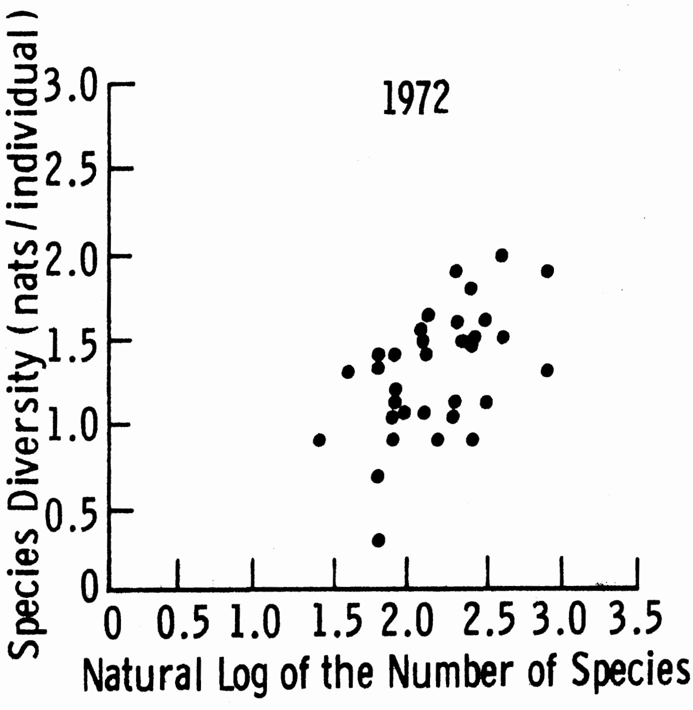


Figure 2. --Species diversity of fish collections and the natural log of the number of species in those collections, all stations combined, Au Sable River, 1920's and 1972.

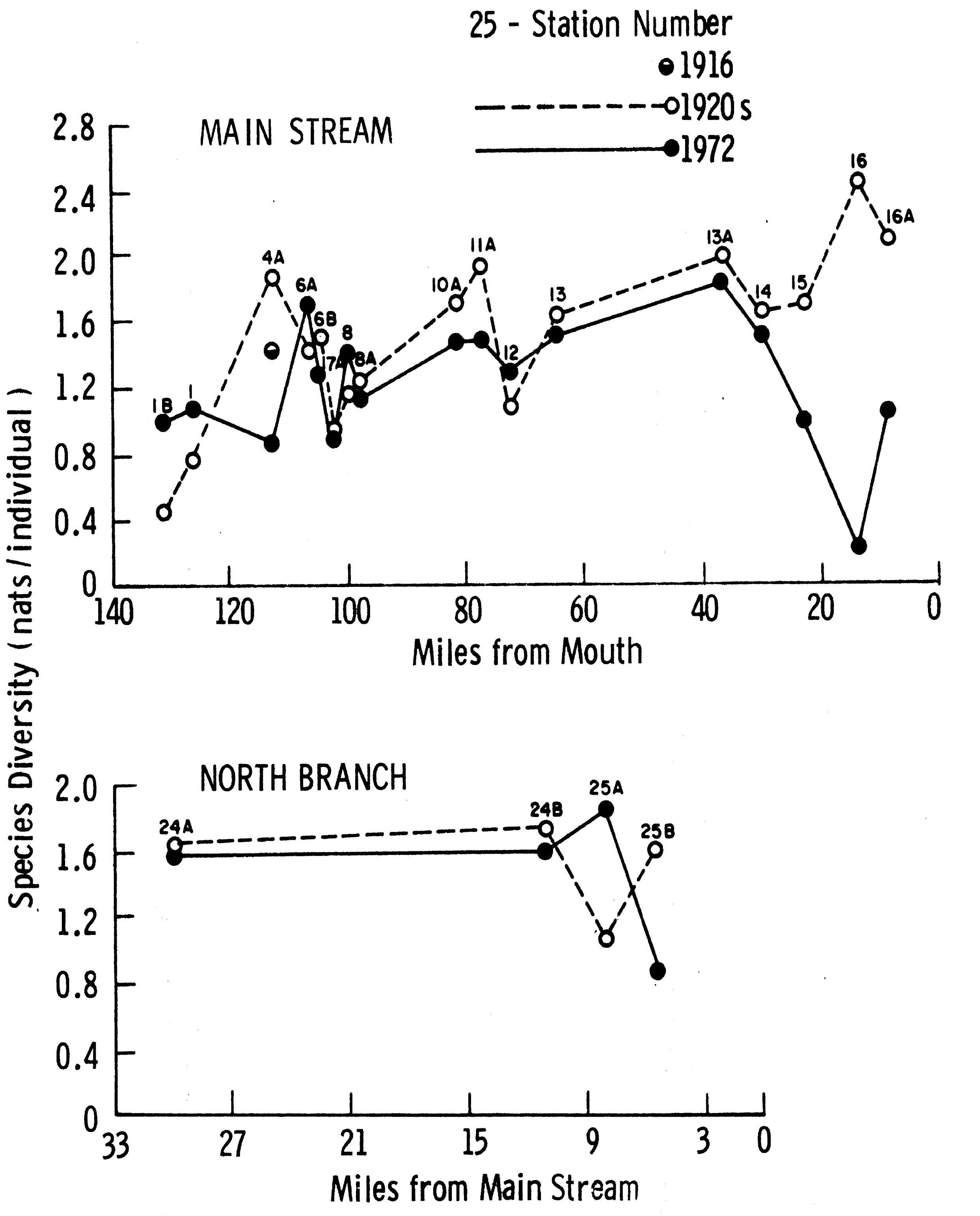


Figure 3.--Fish species diversity at individual stations, Main Stream and North Branch Au Sable, 1920's and 1972.

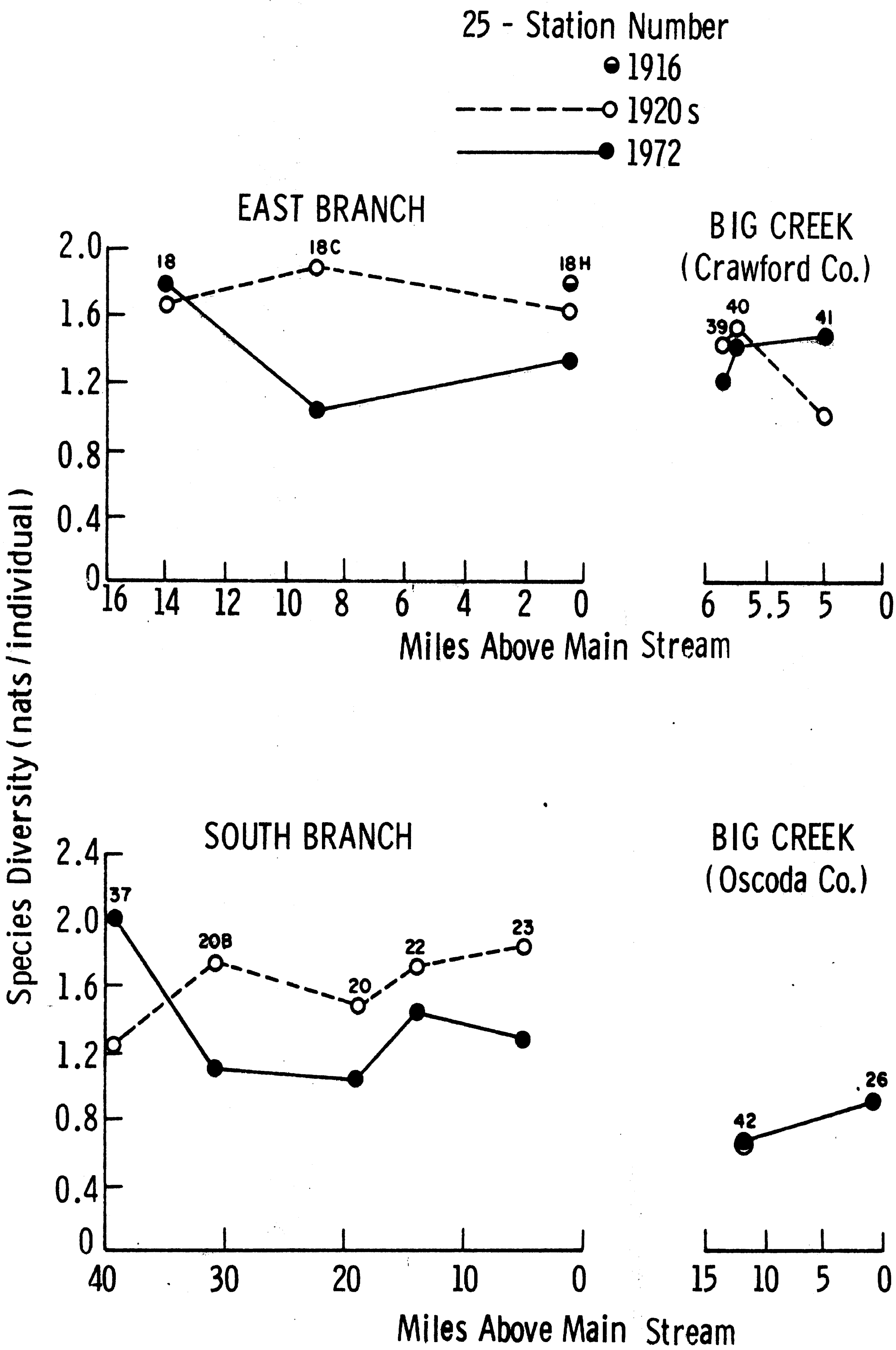


Figure 4.--Fish species diversity at individual stations, tributaries of the Au Sable River, 1920's and 1972.

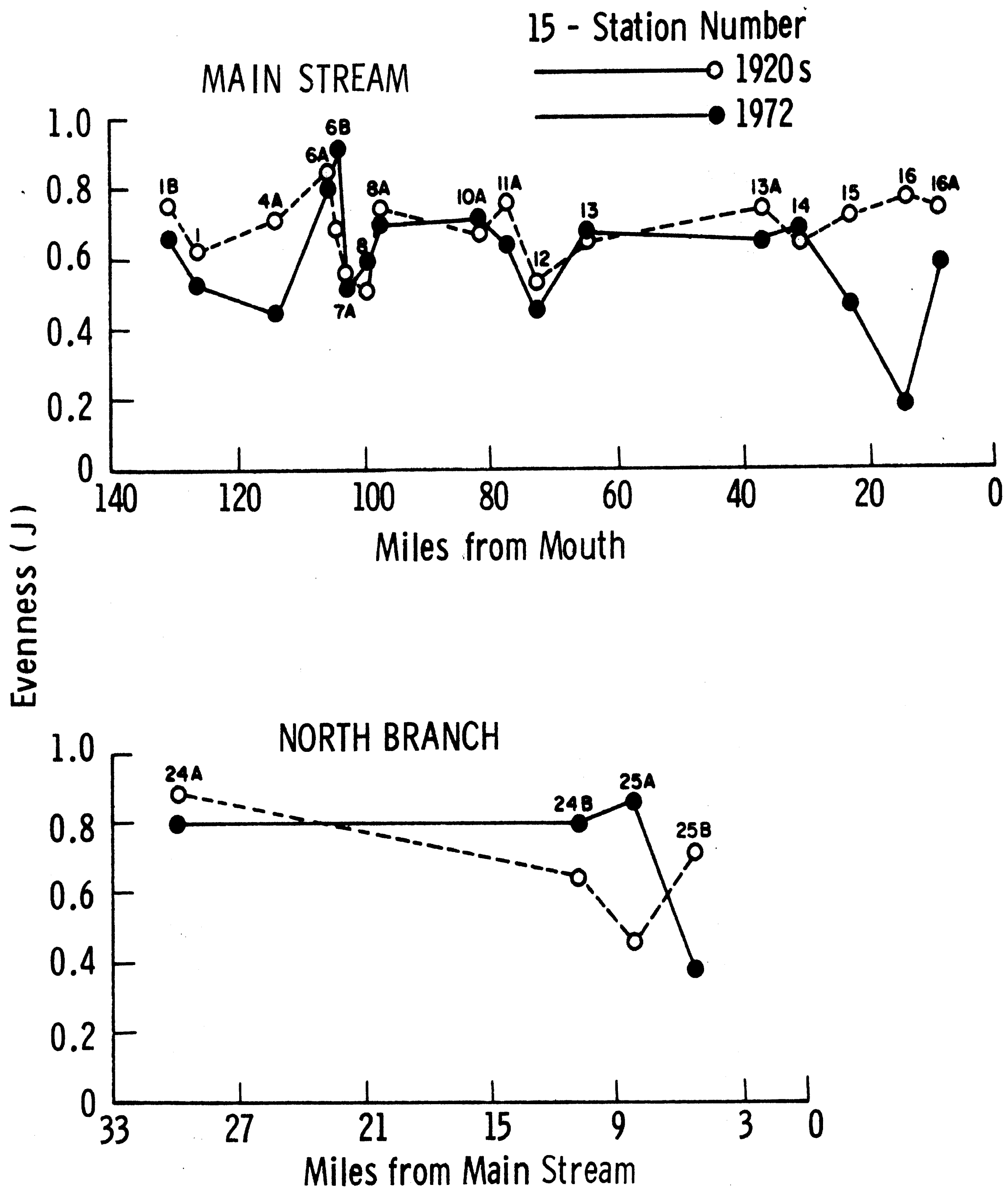


Figure 5.--Evenness of fish collections, Main Stream and North Branch of the Au Sable River, 1920's and 1972.

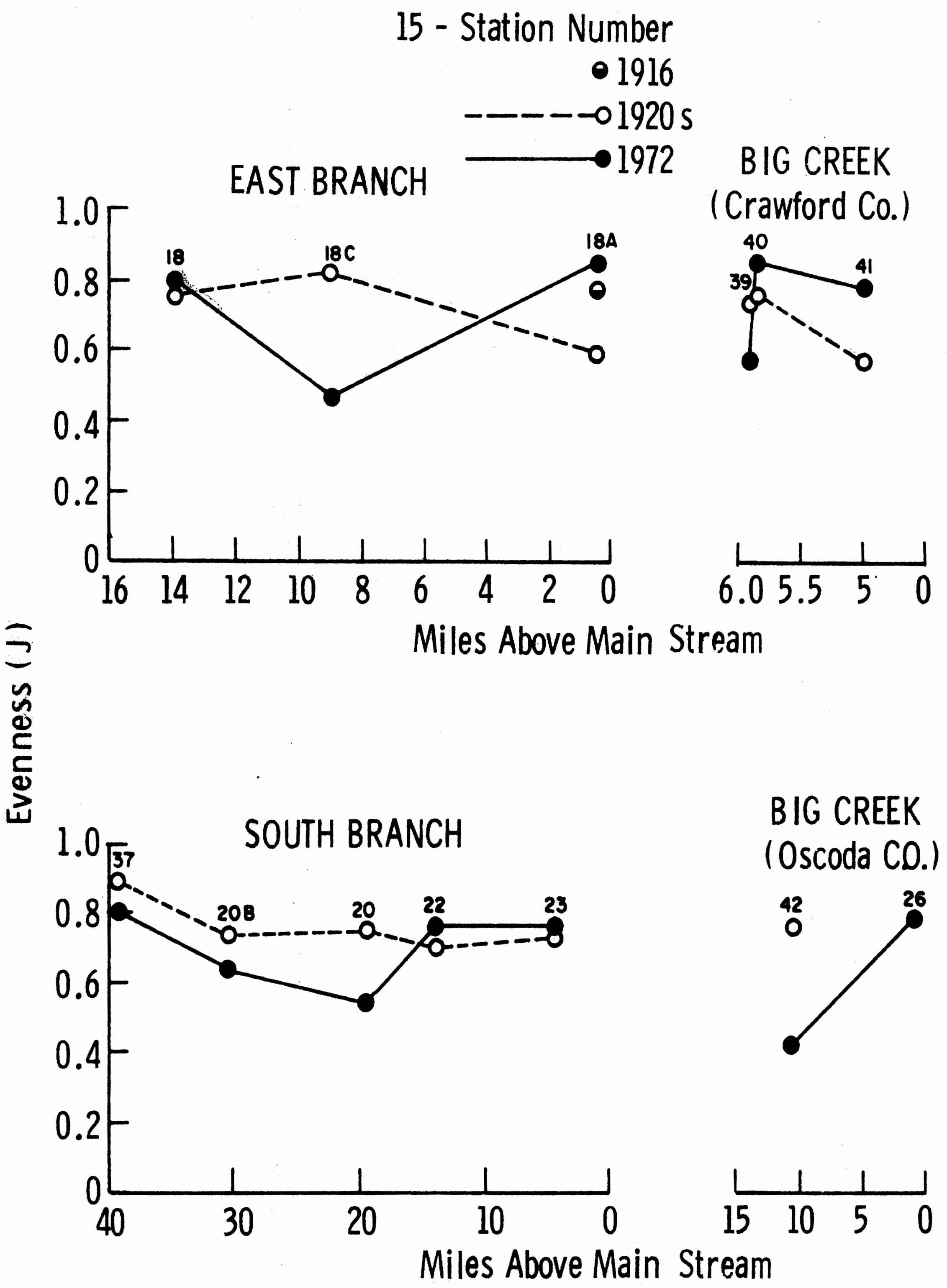


Figure 6.--Evenness of fish collections, tributaries of the Au Sable River, 1920's and 1972.

Table 5.--Fish species showing important shifts in frequency of occurrence in collections from the Au Sable River, 1920's and 1972, all stations combined

Increases (%)			Decreases (%)		
Species	1920's	1972	Species	1920's	1972
Mimic shiner	0	18	Pumpkinseed	18	3
Fathead minnow	0	9	Pearl dace	24	6
Bluegill	3	18	Longnose dace	24	3
Brown trout	38	53	Rainbow trout	38	9
Slimy sculpin	15	35	River chub	50	0
Round whitefish	0	6	Common shiner	74	53
			Shorthead redhorse	6	0
			Rosyface shiner	9	0
			Redfin shiner	12	0
			Yellow bullhead	6	0

dace, river chub, common shiner, rosyface shiner, and redfin shiner, all intolerant of silty bottom and turbid water conditions, coupled with the increase of the mimic shiner and fathead minnow (more tolerant) suggests a general change in bottom type. The decrease in frequency of occurrence of minnow species may also reflect a general lower tolerance to colder water conditions. These hypotheses will be explored further in later sections. It should be kept in mind that knowledge of the habitat requirements of many minnow species is at best general. Therefore, conclusions about water quality changes based on changes in the distribution of these species can only be tentative. It is hoped that examination of these species changes, however, will provide supplemental interpretative data to the other analytical approaches used here.

Stream Order

In an attempt to examine fish community changes with a finer degree of resolution, it was determined that stations should be grouped in some way. Stream order provided the first vehicle. It is a method of ordering the size of different branches of a river system according to the size of the tributaries feeding into them. First-order streams are the smallest, unbranched tributaries. Two first-order streams merging form a second-order stream, etc. Attempts have been made to relate species and community changes to changes in stream order (Huet, 1959; Harrel, Davis, and Dorris, 1967; Harrel and Dorris, 1968; Whiteside and McNatt, 1972). All stations were classified by stream order according to the procedures of Horton (1945) and Strahler (1957). No station was classed lower than second-order, nor higher than fifth-order. The mean species diversity value for each order in both collecting periods was determined (Fig. 7). The only important comparison to make here is within orders. The only order that showed a statistically significant (90% level) change in species diversity was the fifth, which showed a mean decrease. The stations classified as fifth-order are all on the lower end of the Main Stream below the mouth of Big Creek.

This analysis tends to indicate change in the lower end of the system, but nowhere else. It was felt that this conclusion was misleading, however, and in fact, the whole stream-order classification, at least in this case, seems to be misleading. Lumped into any given stream order could be a variety of habitat conditions. In the Au Sable River, it is possible to have tributaries of the same order (Bradford Creek and the East Branch at County Road 612), one with excellent (trout) water quality, and the other without. Grouping by stream order tends to obscure these most crucial differences. It is suggested that where some level of generalization concerning the nature of water quality and corresponding fish species and community changes is concerned, the use of stream order as a means of grouping data can be misleading and should be used with caution. In a similar way, grouping stations by branches of the river (North Branch, East Branch,

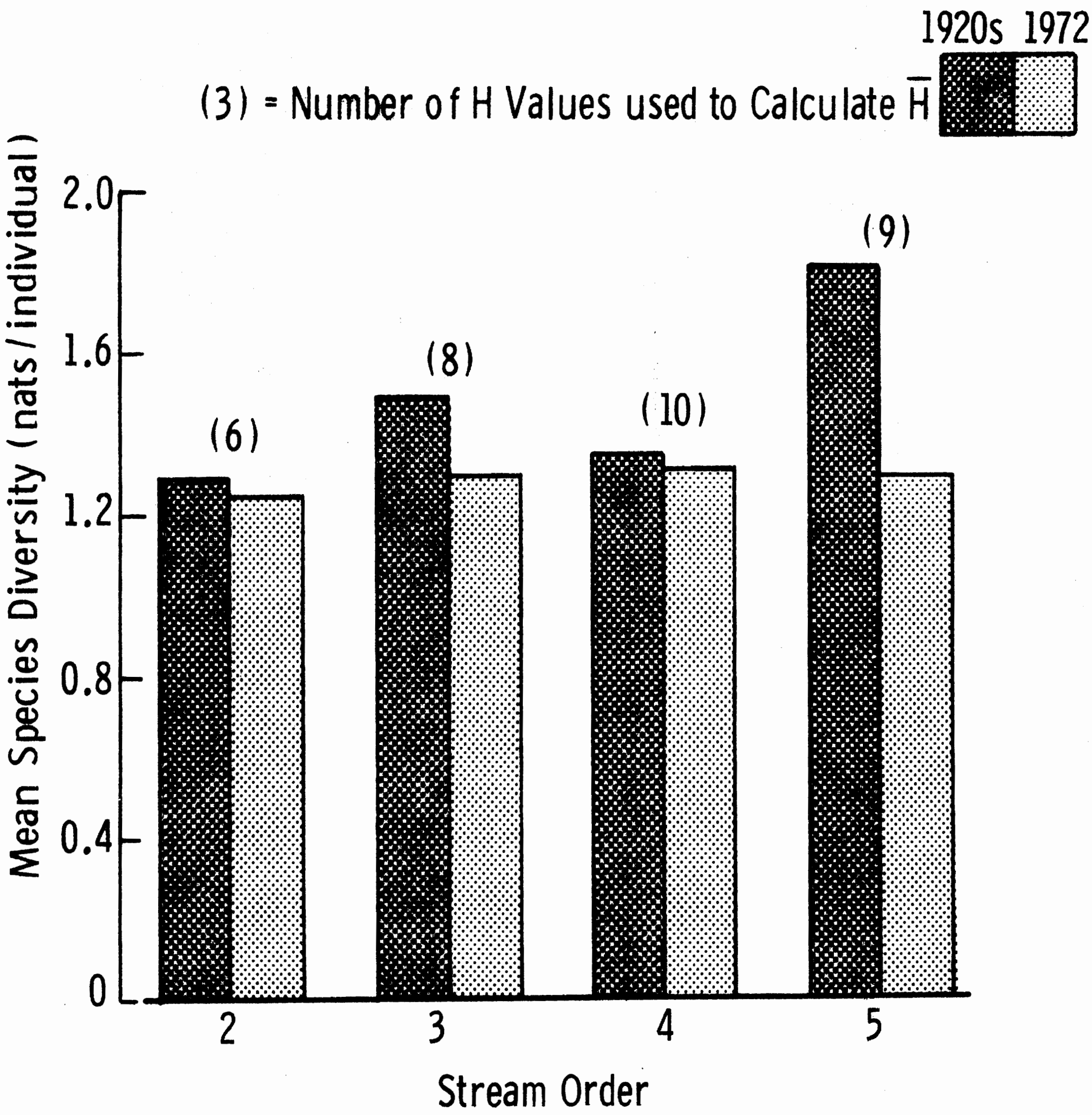


Figure 7.--Mean fish species diversity for stations grouped by stream order, Au Sable River, 1920's and 1972.

etc.) may be convenient, but not biologically sound, as stations on the same branch are often ecologically radically different. The following classification procedure is suggested instead.

Habitat Type

The Au Sable River can be classified into several habitat types. It differs from trout streams in other regions in that its headwaters are primarily outlets from warm-water lakes rather than cold mountain run-off and snow melt. It is in fact only a trout stream because of the basin's underlying strata of glacial drift which achieve a thickness of several hundred feet throughout (Water Resources Commission, 1966), and provide a porous aquifer for the absorption of rainfall and its subsequent release into the watershed as cooled groundwater (Hendrickson, 1966). In many, but not all, cases then, warm headwater tributaries in the Au Sable do not become suitable for trout for miles until sufficient groundwater has entered to cool them down. The extreme example of this would be the South Branch which flows some 20 miles from Lake St. Helen before sufficient groundwater enters to cool it down and make it suitable for trout. With this in mind, the four habitat types determined for the Au Sable as mentioned earlier were: warm headwater areas; cold-water moderate flow areas; large river areas; and below impoundments. The classification of each station is indicated in Table 1.

Warm headwater habitat

It was found that the mean species diversity for the five warm headwater stations was the same in the 1920's as it is today (Fig. 8). The same is true for evenness (Fig. 9) and the mean number of species (Fig. 10). These data imply that whatever water quality and habitat conditions were in the 1920's, they are likely not changed much today, as essentially the same fish community structure is evident in both sampling periods.

The mean Jaccard Index for each habitat was calculated (Fig. 11). Again, a low Jaccard value means low similarity or large changes over time in species composition. It can be seen that the mean values for all habitats are low. This illustrates the fact that this index is extremely sensitive in that it weights the loss of a rare species from a species list the same as the loss of a common one. Thus, shifts in occurrence of several rare species over time could have a marked effect on the Jaccard Index even though the most abundant species might not have changed. With this in mind, it makes more sense in this paper to discuss changes in the Jaccard Index for stations and habitat types relative to each other rather than some arbitrary standard or cut-off point as some have tried to do (Brown, 1969).

It can be seen that the mean Jaccard Index for the warm headwater habitat (Fig. 11) is the second highest of the four habitat types. This can be interpreted as meaning that there have been substantial

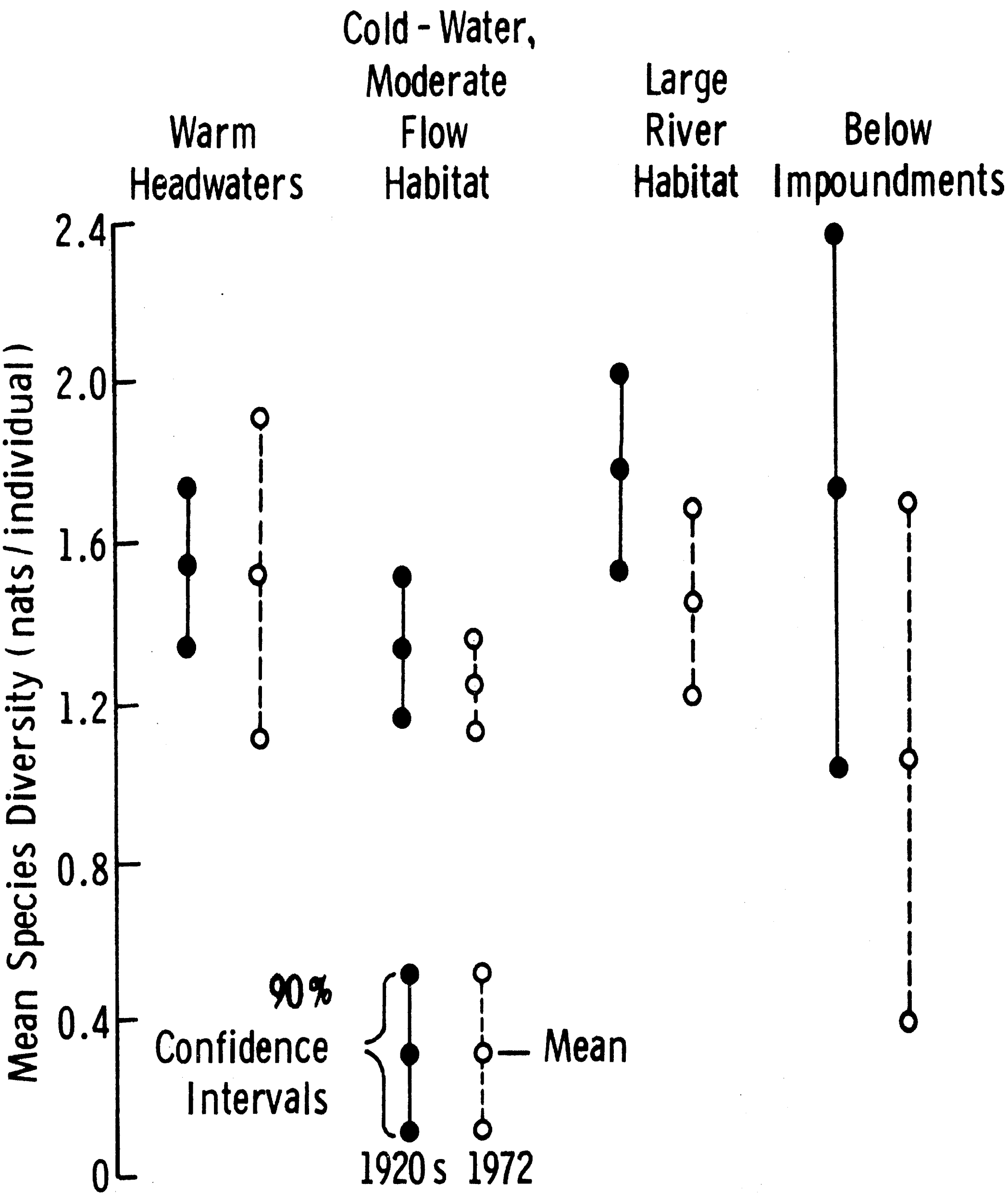


Figure 8.--Mean fish species diversity for collections grouped by habitat type, Au Sable River, 1920's and 1972. Means fall within the given confidence intervals statistically 90% of the time.

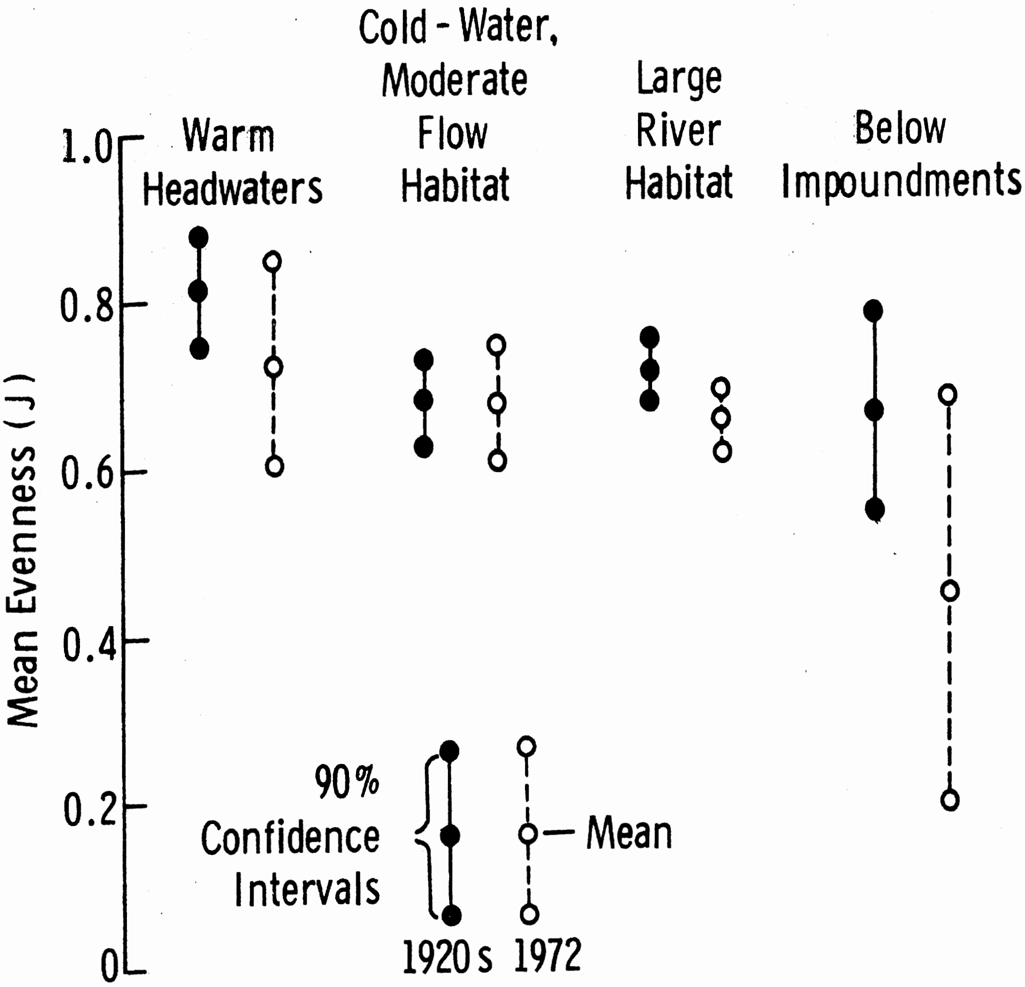


Figure 9.--Mean evenness for fish collections grouped by habitat type, Au Sable River, 1920's and 1972. Means fall within the given confidence intervals statistically 90% of the time.

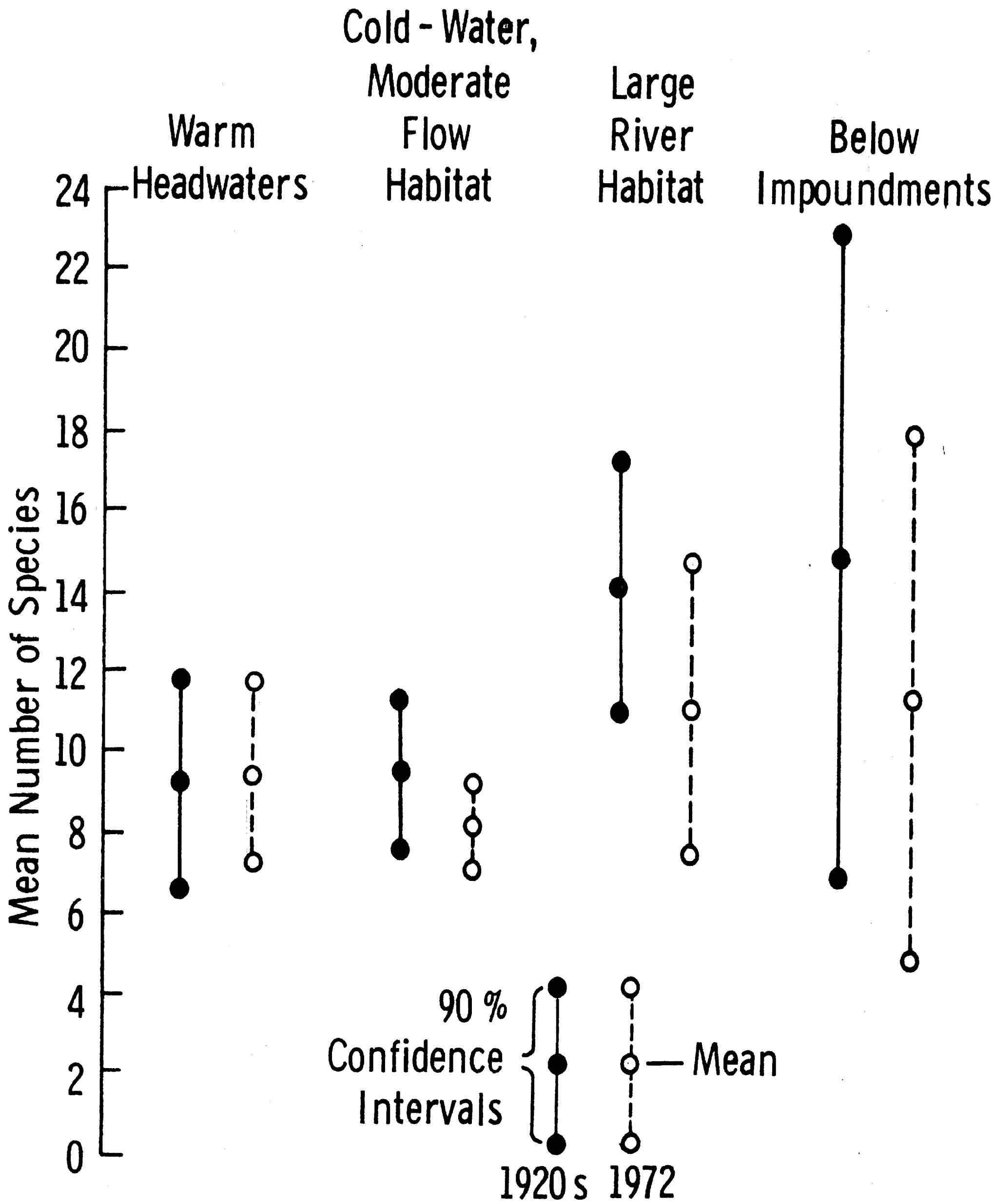


Figure 10.--Mean number of fish species for collections grouped by habitat type, Au Sable River, 1920's and 1972. Means fall within the given confidence intervals statistically 90% of the time.

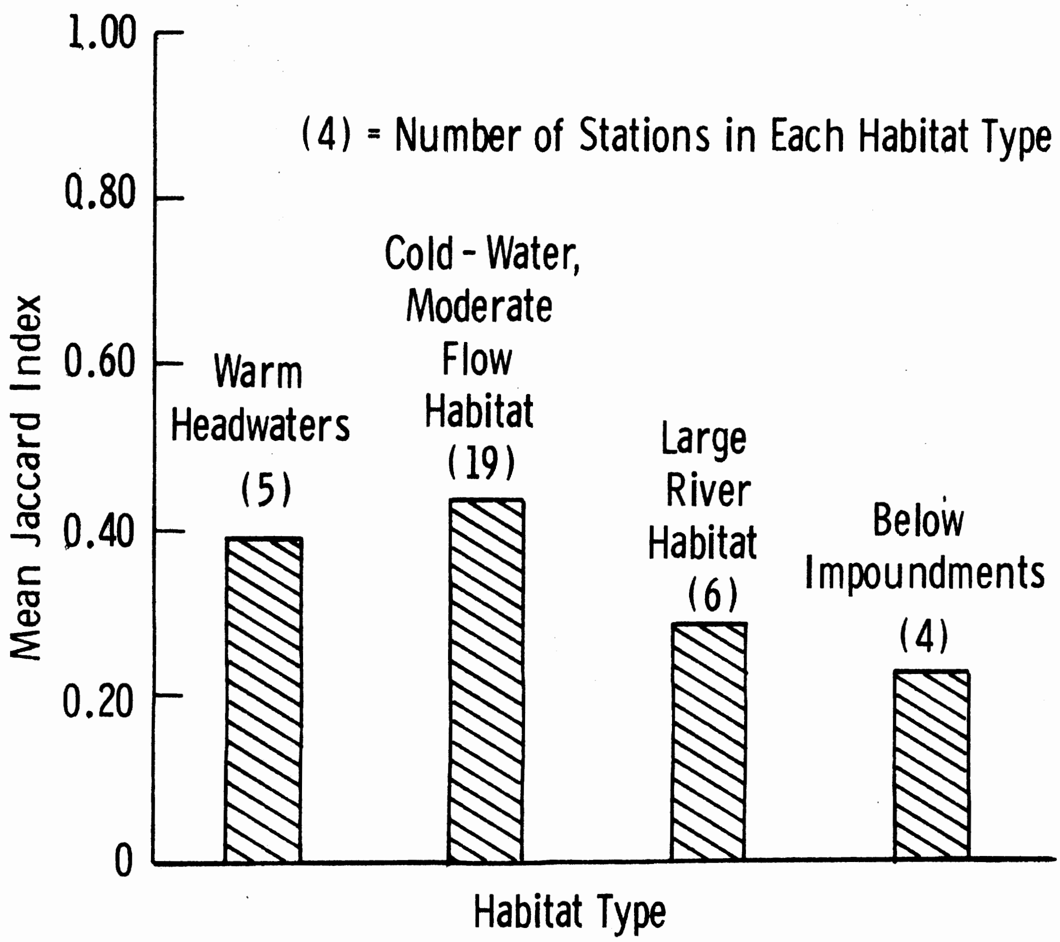


Figure 11.--Mean Jaccard Index for fish collections grouped by habitat type, Au Sable River, 1920's and 1972.

species shifts within this habitat, but they probably were not as great as in other parts of the system.

What were felt to be significant changes in frequency of occurrence of fish species within the four habitat types were abstracted in Table 6. It is possible that in the warm headwater areas, the disappearance of the already (in the 1920's) marginal brook trout, a cold-water species (Trautman, 1957), and the river chub, a silt and turbidity intolerant species might indicate a change in water quality over the last 50 years. But as all species changes are slight, and the number of stations involved is small (five), it would be improper to conclude anything from these data alone except that conditions in the warm headwater areas are for the most part unchanged. In particular, they were poor trout habitat in the 1920's, and remain so today.

Cold-water, moderate flow habitat

It was found that the mean species diversity (Fig. 8), evenness (Fig. 9), and numbers of species (Fig. 10) for the 19 stations that were grouped in this habitat type remain statistically unchanged over the period of time in question. The mean Jaccard Index (Fig. 11) indicates that there has been a substantial species shift within this habitat, but this shift was the smallest change of the four habitat types. Among those species showing an increase in frequency of occurrence in the 1972 collections (Table 6) were brown trout, slimy sculpin, and round whitefish. These are all cold-water species (Trautman, 1957), and their

Table 6.--Fish species showing important shifts in frequency of occurrence in four different habitat types of the Au Sable River, 1920's and 1972

Increases (%)			Decreases (%)		
Species	1920's	1972	Species	1920's	1972
		Warm headwater habitat (5 stations)			
			Pumpkinseed	40	0
			Brook trout	40	0
			River chub	60	0
		Cold-water, moderate flow habitat (19 stations)			
Brown trout	53	79	Blacknose shiner	32	16
Slimy sculpin	6	53	Rainbow darter	37	16
Round whitefish	0	11	Common shiner	79	47
			Pearl dace	32	6
			Longnose dace	11	0
			Northern pike	11	0
			Mudminnow	26	6
			Rainbow trout	47	16
			River chub	47	0
		Large river habitat (6 stations)			
Mimic shiner	0	33	Rock bass	67	17
Largemouth bass	0	33	Golden shiner	33	0
Brook trout	0	33	Slimy sculpin	67	33
Redbelly dace	0	33	Longnose dace	67	17
			Rainbow trout	67	0
			River chub	50	0
		Below impoundments (4 stations)			
Yellow perch	25	75	Pumpkinseed	75	25
Mimic shiner	0	100	Common shiner	75	25
Bluegill	0	75	Longnose dace	50	0
			Blackchin shiner	100	0
			River chub	50	0
			Rosyface shiner	50	0
			Redfin shiner	75	0

increase is an indication that water quality conditions in certain sections of the river have improved for trout. The decrease in distribution of the rainbow trout again probably does not negate this conclusion as decreased stocking over the years, and a lower adaptiveness than the brown trout to general environmental conditions in the watershed are more likely responsible for its decline than a change in water quality.

The decrease in distribution of the blacknose shiner, common shiner, pearl dace, longnose dace, rainbow darter, and river chub, all silt and turbidity intolerant species which prefer a clean gravel and rubble bottom (Trautman, 1957) points to a possible change in bottom conditions. The decrease in distribution of these species might also be a function of a decreased average water temperature regime. Again, such a conclusion remains tenuous because of the paucity of information available on habitat requirements of most minnow species. It is generally accepted, however, that most minnow species fare better in warmer than cooler streams (Spence and Hynes, 1971; Hynes, 1970).

The percentage of the total number of individuals that the five cold-water species (brook, brown, and rainbow trout, slimy sculpin, round whitefish) represented in each collection was calculated (Table 7). If one examines just the cold-water trout stations, it becomes clear that more stations have experienced a marked increase in percentage of cold-water species than a decrease (Table 8). This

Table 7.--Percentage of cold-water fish (brook, brown, and rainbow trout, slimy sculpin, round whitefish) in fish collections, Au Sable River, 1920's and 1972

Station		1920's	1972	Station		1920's	1972
Main Stream				South Branch			
1B.	Bradford Cr.	79	12	37.	Mud Lake	0	0
1.	Frederick	11	2	20B.	Sherman Bridge	0	0
4A.	Mouth of East Br.	6	0	20.	Roscommon	1	0
6A.	Wa Wa Sum	1	28	22.	Chase Bridge	7	22
6B.	Above Stephan's	1	45	23.	Smith Bridge	20	82
7A.	Below Stephan's	13	14				
8.	Wakeley Bridge	17	5	North Branch			
8A.	Stillwaters	45	0	24A.	Dam 1	6	1
10A.	Mouth of Big Cr.	7	10	24B.	Dam 4	5	30
11A.	Mio Pond (above)	2	1	25A.	Campground	2	20
12.	Mio Dam (below)	0	0	25B.	Kellogg's Bridge	1	2
13.	Comins Landing	1	0				
13A.	Mouth L.S.Br. River	0	0	Big Creek, Crawford County			
14.	Five Channels Dam	0	0	39.	Middle Br.	8	77
15.	Cooke Dam	0	0	40.	East Br.	61	52
16.	Foote Dam	0	0	41.	Blonde Dam	0	11
16A.	Between Foote and Oscoda	0	0				
East Branch				Big Creek, Oscoda County			
18.	County Road 612	0	0	42.	Dirt road	20	5
18C.	Hartwick Pines	13	2	26.	County Road 487	-	41
18H.	Hatchery	6	21				

Table 8.--Cold-water moderate flow stations showing a marked change in percentage of cold-water fish species present (brook, brown, and rainbow trout, slimy sculpin, and round whitefish), Au Sable River, 1920's and 1972

Increase (%)				Decrease (%)			
Station		1920's	1972	Station		1920's	1972
6A.	Wa Wa Sum	1	28	1B.	Bradford Cr.	79	12
6B.	Above Stephan's	1	45	1.	Frederick	11	2
18H.	Hatchery	6	21	18C.	Hartwick Pines	13	2
22.	Chase Bridge	7	22	42.	Dirt road	20	5
23.	Smith Bridge	20	82	8.	Wakeley Bridge	17	5
24B.	Dam 4	5	30				
25A.	Campground	2	20				
39.	Big Cr., Middle Branch	8	77				
41.	Blonde Dam	0	11				

supports an earlier conclusion that conditions have seemingly improved for trout in what have traditionally been good trout areas. Changes at particular stations and possible reasons for them are discussed in the next section.

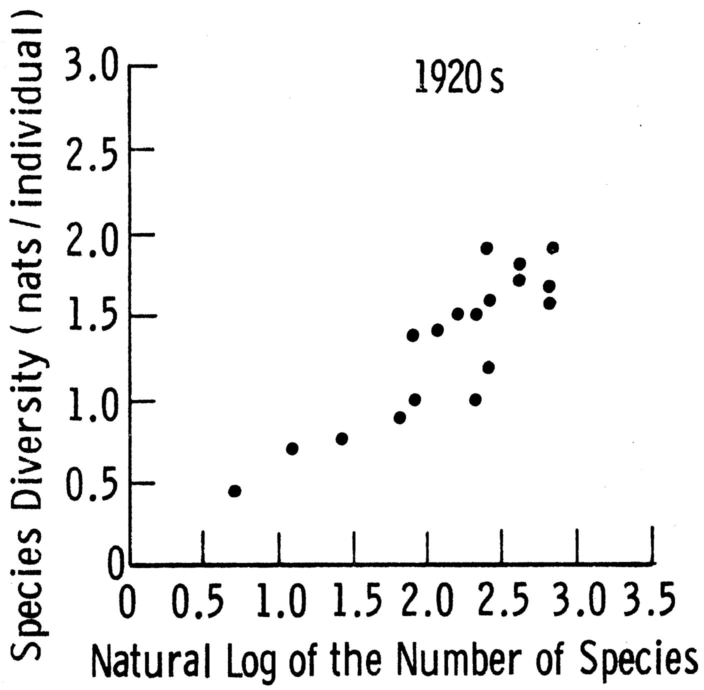
The average percentage of cold-water species found in the 19 cold-water stations in the 1920's was 15% as opposed to 24% in 1972. This difference is not statistically significant at the 90% level, but serves to reinforce the above conclusion that conditions for trout in cold-water areas have improved.

The influence trout stocking might have had on collections in either sampling period was considered. Department of Natural Resources records indicate that no trout were stocked in any of the 1972 collecting sites except Comins Landing (Station No. 13); this fact is noted in the discussion of that station. Records were not available to indicate precise locations of plantings in the 1920's. But even if fingerling plants did bias the collections of Hubbs et al., this would only underscore the fact that conditions have improved sufficiently since then to allow natural reproduction today to outstrip that of the 1920's in many areas, in spite of the latter's boost from stocking.

All of the foregoing seems to indicate an actual improvement in water quality in the traditionally "good" trout areas of the system. If this is true, then it would seem reasonable to predict that Tramer's (1969) method of plotting H against the natural logarithm of the number of species for these cold-water stations alone would produce a closer distribution of points around the 45° line for the 1972 than the 1920's collections. An examination of the data (Fig. 12) shows that this is not the case. There was a much better correlation for the 1920's ($R^2 = 0.79$) than for 1972 ($R^2 = 0.08$). At first glance, using Tramer's hypothesis, this seems to indicate, contrary to all the other evidence that has been presented, that conditions in the trout habitat are worse now than they were in the 1920's. On second thought, however, it is possible that an over-all decrease in average water temperatures, postulated earlier for this habitat, could make this a rigorous environment for many of the species that have diminished here. Cold-water species on the other hand would thrive. That being the case, one would expect a distribution of data points according to Tramer (1969) as was obtained for the 1972 cold-water habitat stations. In summary, conditions for trout in what have traditionally been good fishing areas have improved. Of the four habitat types studied, this cold-water habitat shows the fewest species changes, the greatest community stability, and a change in water quality that has allowed cold-water species to become more abundant.

Large river habitat

Although the mean number of species in this habitat is lower now than it was in the 1920's (Fig. 10), the difference is not statistically significant. However, species diversity (Fig. 8) and evenness (Fig. 9) are significantly (90% level) lower. Relating this trend to findings in



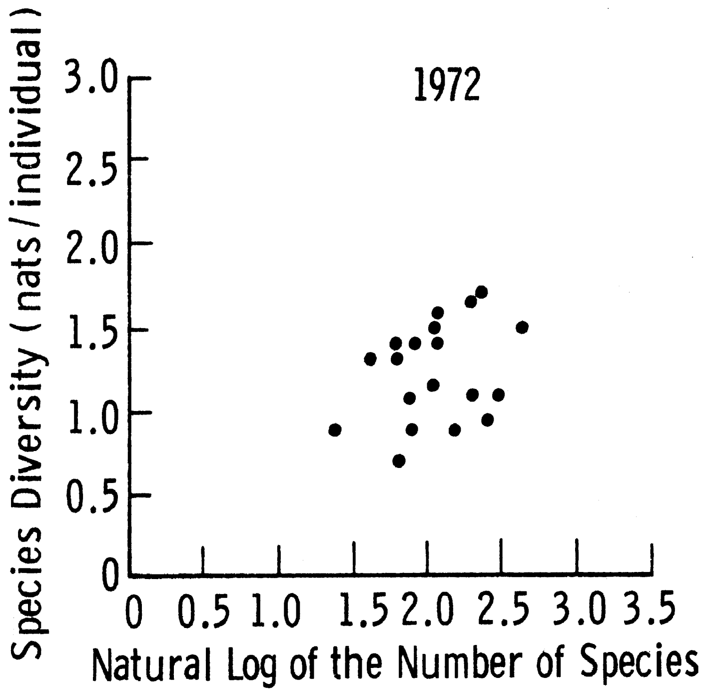


Figure 12.--Species diversity of fish collections and the natural log of the number of species in those collections, cold-water moderate flow stations, Au Sable River, 1920's and 1972.

the literature again, Wilhm and Dorris (1966, 1968) have shown that a pollutional input or ecological stress of some kind usually has the effect of reducing both the diversity and evenness of a community. Coupled with the fact that the mean Jaccard Index (Fig. 11) for this habitat type is the second lowest of the four, the implication is that significant changes in water or habitat quality may have occurred here.

An examination of the particular species involved in these changes is not especially illuminating as to what these changes might have been (Table 6). The increase in largemouth bass should be disregarded as it is probably a function of recent stocking of impoundments (although records were not found showing dates, numbers, etc. of fish stocked in the Au Sable impoundments, it seems likely that such has occurred since the time of Hubbs et al.). The apparent brook trout increase occurred at two stations. In one case (Station No. 10A), the brook trout were taken in the mouth of Big Creek, a cold-water trout stream, and thus were responsive to water temperatures there rather than the Main Stream. In the other case (Station No. 13), the brook trout taken were stocked less than a month before the 1972 seine collection was made, and thus do not reflect natural environmental conditions there. While two silt and sand bottom intolerant minnow species (Trautman, 1957) decreased in distribution (river chub and longnose dace), one increased (redbelly dace). The apparent penetration of the mimic shiner into these areas should be disregarded because of taxonomic confusion at the time of the earlier collections between it and the sand shiner. The latter was reported by Hubbs as being taken in this habitat type. The decrease in the rainbow trout is again probably a function of lesser stocking today and basic habitat incompatibility. There are only six stations in this habitat type, and the above discussions should be tempered with that fact.

Below impoundments

It was found that mean species diversity (Fig. 8), and evenness (Fig. 9) were statistically (90% level) lower in the 1972 collections than in the 1920's for this habitat type. The mean number of species was also lower, but not significantly so (Fig. 10). The mean Jaccard Index was the lowest of all four habitat types (Fig. 11) reflecting the greatest shift in species. An examination of the species involved (Table 6) more clearly indicates a degradation of habitat than was the case with the large river habitat.

A number of species have disappeared (longnose dace, blackchin shiner, river chub, rosyface shiner, redfin shiner), and two others (pumpkinseed and common shiner) have become reduced in their abundance and distributions. The increase in yellow perch and bluegill probably is a reflection more of post-1920's stocking and competitive success of these two species than a change in water quality. The penetration of the tolerant mimic shiner (Trautman, 1957) in large numbers into all four impoundment outfalls, again points to a decline in water quality. As there were only four impoundments sampled, sample size should once again temper this conclusion. But qualitatively, even in view of the small number of stations involved, the areas immediately below the major impoundments seem to have experienced a marked decline in water quality, with subsequent detrimental effects on fish community structure and composition.

Station-by-Station Analysis

The following section will include a description in brief of any major changes that seem to have occurred at each station, along with possible causal factors. For convenience, stations will be grouped by the river branches they are on. To save space, individual tables and figures will not be referred to in the body of the text for each station. Rather, the reader is referred generally to the following list of tables and figures which contain all the information referred to in this section. Species diversity data are found in Figures 3 and 4, evenness data in Figures 5 and 6, percentage of cold-water species in Table 7, percentage of warm-water species in Table 9, Jaccard values in Figures 13 and 14, and shift in fish species in Figures 15 and 16. Attempts to relate changes in fish species composition at a specific station to habitat changes will be limited to local changes only. Habitat changes found throughout the watershed that apply generally are dealt with elsewhere.

Table 9.--Percentage of warm-water fish (bluegill, pumpkinseed, large-mouth bass, black crappie, mudminnow, yellow bullhead, brown bullhead) in fish collections, Au Sable River, 1920's and 1972

Station	1920's	1972
Main Stream		
1B. Bradford Cr.	0	0
1. Frederick	0	0
4A. Mouth of East Br.	6	0
6A. Wa Wa Sum	0	0
6B. Above Stephan's	0	0
7A. Below Stephan's	0	0
8. Wakeley Bridge	0	1
8A. Stillwaters	0	4
10A. Mouth of Big Cr.	2	0
11A. Mio Pond (above)	0	0
12. Mio Dam (below)	0	0
13. Comins Landing	0	0
13A. Mouth L.S.Br. River	0	1
14. Five Channels Dam	20	0
15. Cooke Dam	0	1
16. Foote Dam	10	2
16A. Between Foote and Oscoda	1	0
East Branch		
18. County Road 612	0	5
18C. Hartwick Pines	0	0
18H. Hatchery	0	0
South Branch		
37. Mud Lake	81	50
20B. Sherman Bridge	31	31
20. Roscommon	12	0
22. Chase Bridge	2	0
23. Smith Bridge	2	0
North Branch		
24A. Dam 1	0	1
24B. Dam 4	0	0
25A. Campground	0	0
25B. Kellogg's Bridge	1	0
Big Creek, Crawford County		
39. Middle Br.	0	0
40. East Br.	0	0
41. Blonde Dam	0	0
Big Creek, Oscoda County		
42. Dirt Road	0	1
26. County Road 487	0	0

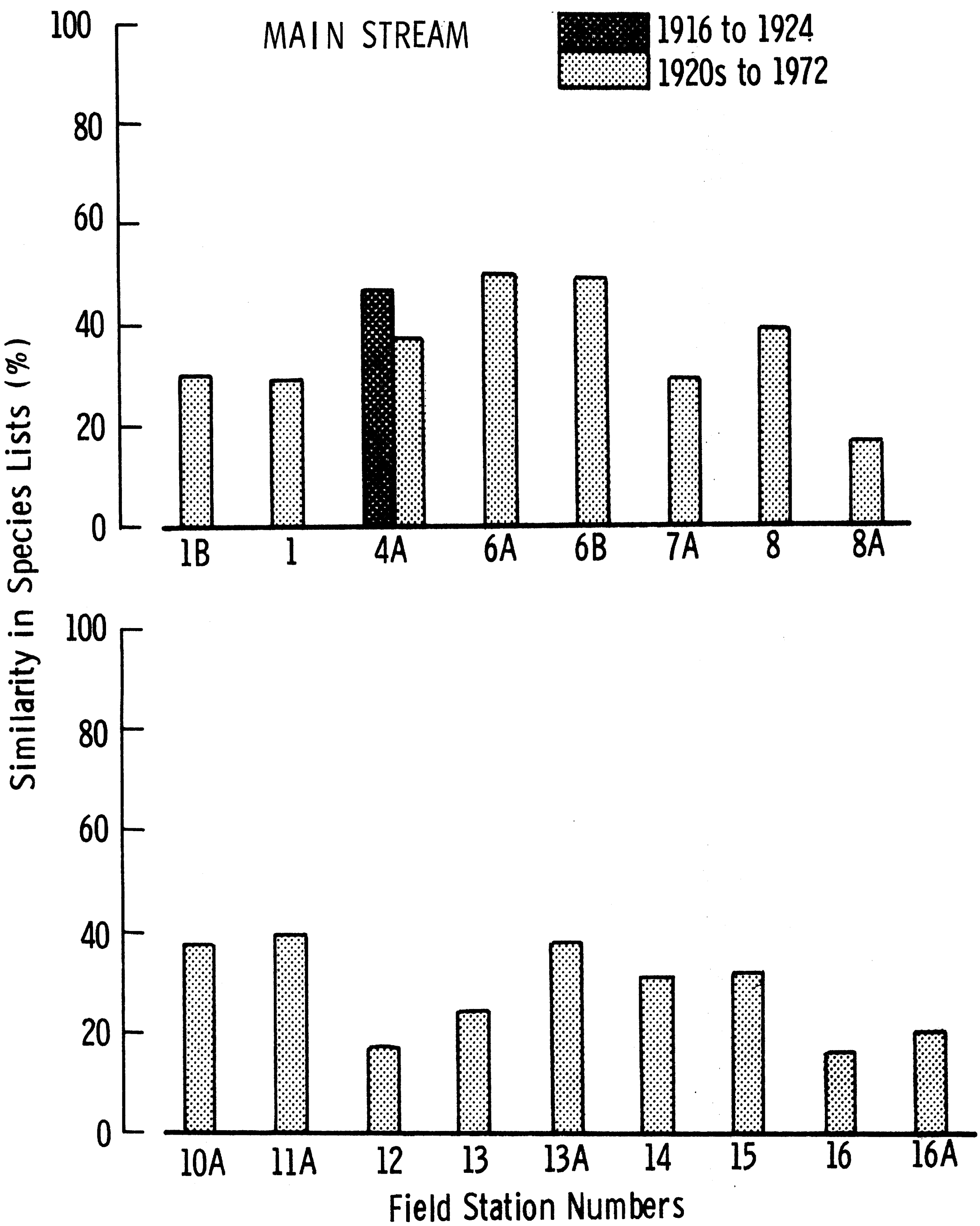


Figure 13.--Similarity in fish species lists as measured by the Jaccard Index, Main Stream Au Sable River, 1920's and 1972.

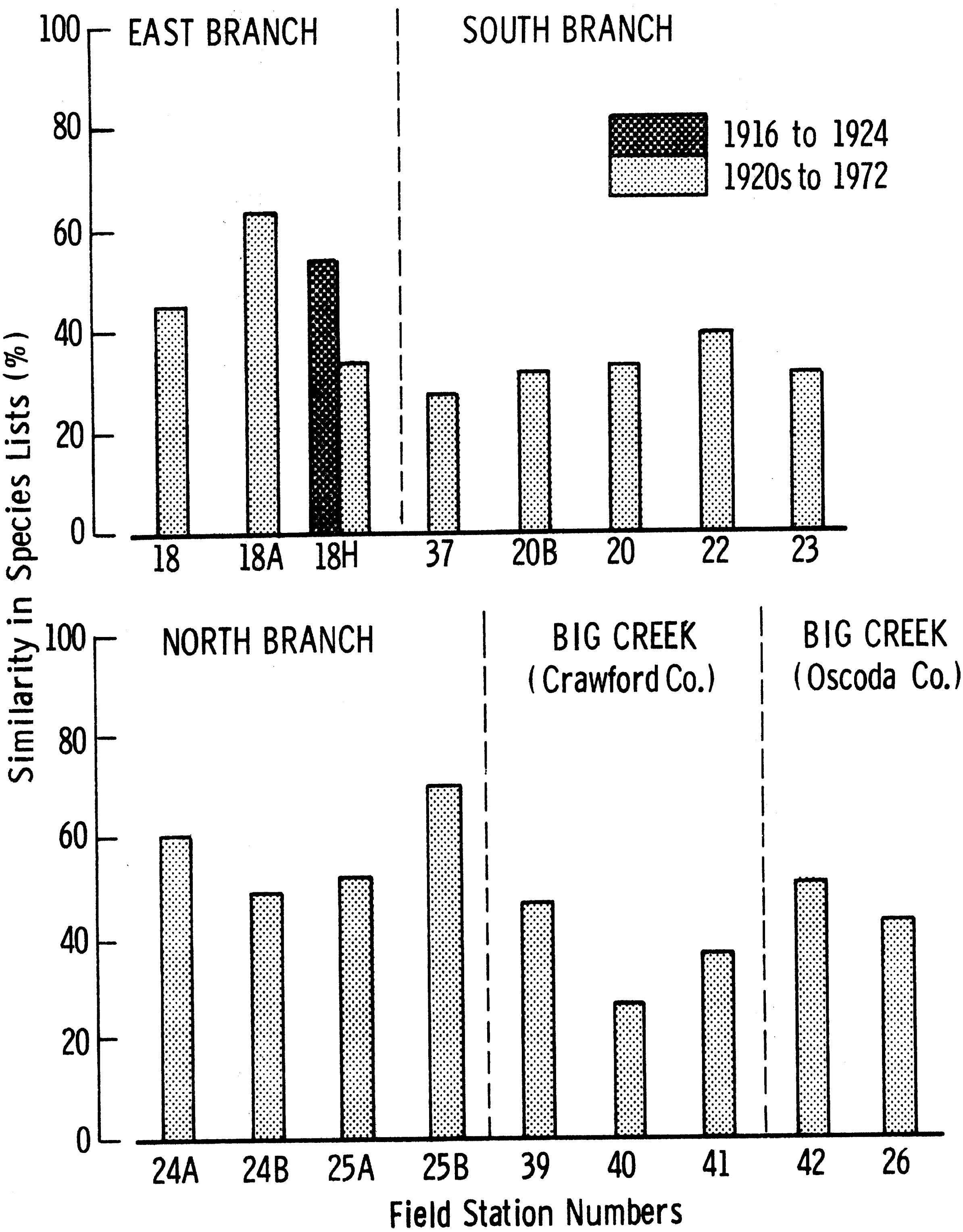


Figure 14.--Similarity in fish species lists as measured by the Jaccard Index, tributaries to the Au Sable River, 1920's and 1972.

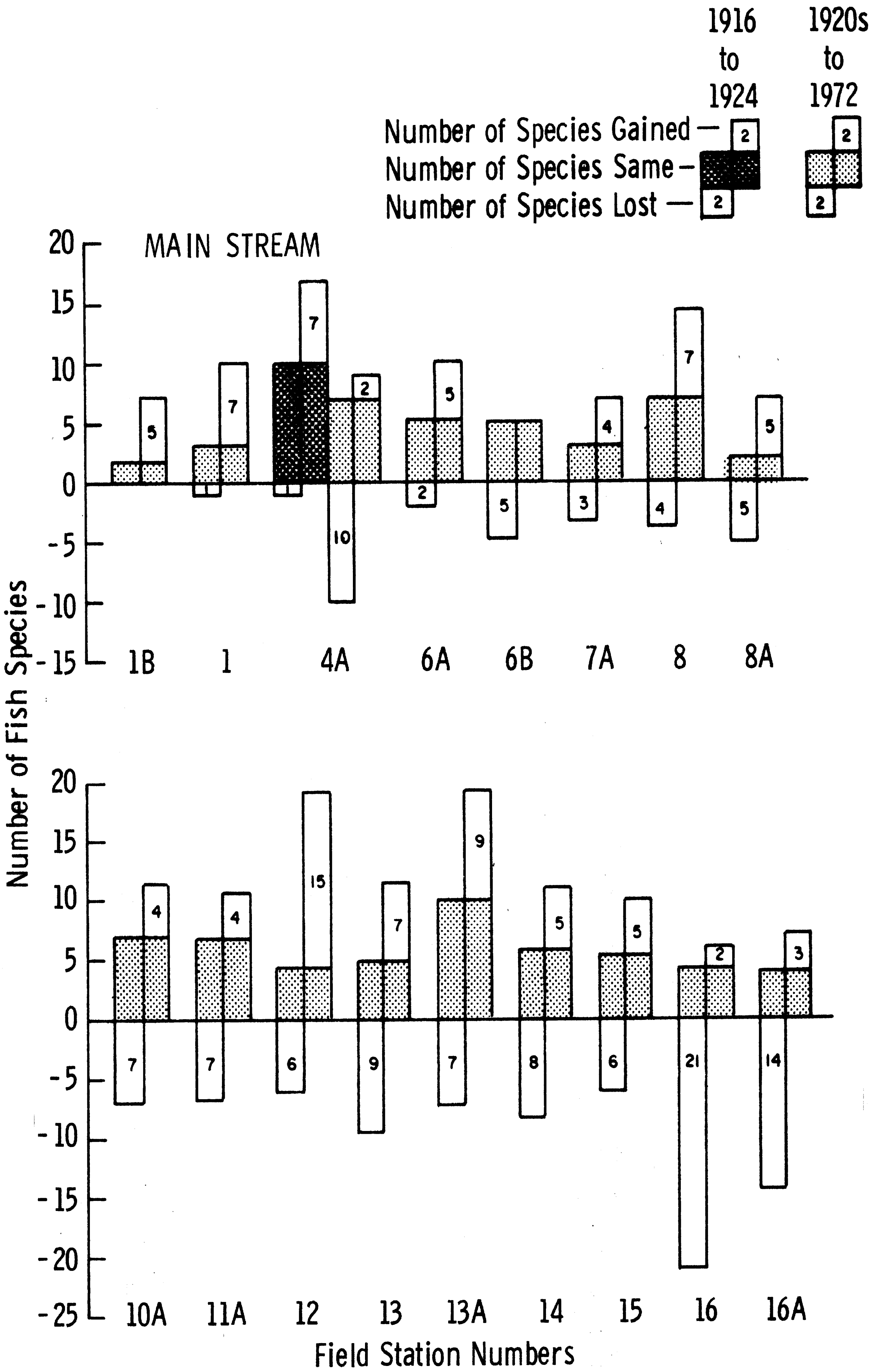


Figure 15.--Shift in fish species, Main Stream Au Sable River, 1920's to 1972.

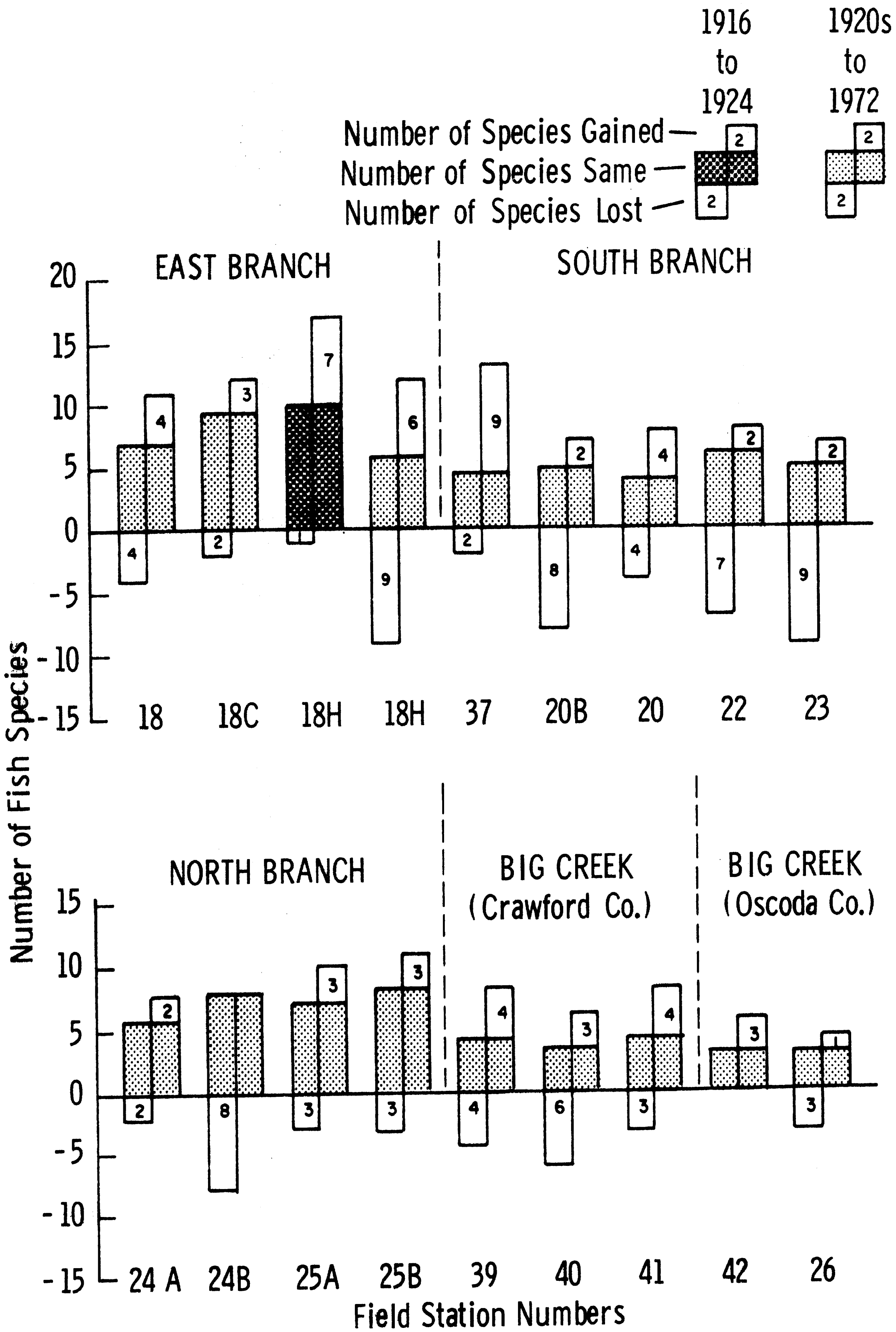


Figure 16.--Shift in fish species, tributaries of the Au Sable River, 1920's to 1972.

Main Stream Au Sable River

1B. Bradford Creek[1]. --An increase in species diversity but no change in evenness was found here. In the 1920's, this station contained only brook trout and mottled sculpin; invasion by five new species since then accounts for the increased diversity, low Jaccard value, and decreased percentage of cold-water species. No warm-water species were taken in either year. The species invading are typical of warmer trout streams: white sucker, creek chub, blacknose dace, bluntnose minnow, and common shiner (Hoover, 1938; Sheldon, 1968). This change from a typical cold headwater trout stream fauna to one characteristic of warmer trout streams implies a warming trend at this station over the years. Probable cause is the building of a road across Bradford Creek just upstream of this station which backs up flow into a large, shallow, exposed, marshy backwater. This, in conjunction with beaver dams in the vicinity contributes to the warming trend. Construction of this road may have contributed significant amounts of sand to this area as well, which could have reduced brook trout spawning areas.

1. Frederick, County 612 Bridge. --Changes here are similar to those in Bradford Creek. Increased diversity, and a low Jaccard Index both reflect the influx of seven new species: white sucker, common shiner, bluntnose minnow, johnny darter, creek chub, brook stickleback,

---

[1] Station numbers follow those of the Au Sable River Watershed Study Project final report, Northeast Regional Planning Commission (in press).

and redbelly dace. No warm-water species were taken in either year, but the percentage of cold-water species decreased. These effects again are typical of a brook trout stream that has been subjected to warming trends.

3. Mouth of the East Branch.--This station is located below the former Grayling sewage treatment plant. Hankinson's 1916 report of a collection made here demanded "stop sewage dumping into stream." Thus, nutrient enrichment has always been a problem here until it was stopped in November of 1971. No trout were taken in 1972 (a few adult browns were taken through electrofishing) whereas all three species of trout were taken here in 1916 and 1924. There was a decrease from 17 to 9 species from 1924 to 1972. This resulted in a much lower species diversity and evenness today, both trends typical of the community effects of pollution. Nutrient input from the sewage treatment plant seems, until recently, to have imposed a chronic stress on this part of the Main Stream. Recovery of fish communities in this area will probably be more substantial over time than the present collection indicates. Other problems associated with habitat quality in this area are the presence of the Old Power Dam below Pollack Bridge, and the Stump Pond above US-27. Both are shallow impoundments with water temperatures below them recorded in the 80's in July and August. Enrichment from the State Fish Hatchery (metabolic wastes), and storm drain and city surface runoff are also problems here.

6A. Wa Wa Sum.--Although species diversity and evenness are about the same here for both periods, a substantial species shift has taken place, resulting in a low Jaccard Index. No warm-water species were taken in either sampling period. Besides the rainbow trout, taken both in 1924 and 1972, three additional cold-water species were taken in 1972: brown trout, brook trout, and slimy sculpin. There was a marked increase in the percentage occurrence of this cold-water group. Indications here are that conditions have improved for trout; a result perhaps, of decreased water temperatures. However, in spite of the poor showing of trout in Hankinson's 1924 collection, this area was considered to be "the best fishing along the river by Rube Babbitt" (unpublished stream survey results, Michigan Institute for Fisheries Research). The removal of nutrient input from the Grayling sewage treatment plant should help this area even more by keeping primary productivity and biochemical oxygen demand at lower levels, provided nutrient inputs from increasing numbers of streamside dwelling septic systems, and increased erosion from recreational access points do not further disrupt things. The indication of improved water quality in this area is supported by the increase in percentage of intolerant insects occurring in bottom samples taken below the sewage treatment plant since the removal of its effluent in November of 1971 (Au Sable River Watershed Study final report, Northeast Regional Planning Commission, in press).

6B. One mile above Stephan's Bridge.--Species diversity remained the same while evenness increased somewhat. Five minnow species found here in 1924 were not found in the present collection. Thus a low Jaccard Index value was calculated. No warm-water species were taken in either year. The same two species of trout, brook and brown, were found both times, but the percentage of the total collection that these represented increased from 1% in 1924 to 45% in 1972. This fact, along with the loss of minnow species, and the increase of evenness of the collection all indicate an improvement of habitat conditions for trout and other cold-water species. It is hypothesized that a lower average water temperature is the major factor responsible for this change.

7A. One mile below Stephan's Bridge.--No change in species diversity or evenness was noted here. But the loss of three species from 1924, and the addition of four species in 1972, indicate a substantial species shift, and a corresponding low Jaccard value. No warm-water species were taken either year, and the percentage of cold-water species remained about the same. This is in spite of the fact that brown and brook trout are now found in this location in addition to rainbow trout, the only salmonid taken in 1924. An electrofishing check of the 1972 seine collection produced only one individual of one species (slimy sculpin) not taken by seine. Over-all indications here are that habitat conditions have not changed much.

8. Wakeley Bridge.--A fairly substantial species shift here (Jaccard Index of 39%) has not been accompanied by significant changes in community structure as measured by species diversity and evenness. The rest of the evidence is mixed. A slight increase in species numbers (11 to 14), and a decrease in percentage of cold-water species (17% to 5%) seem to indicate if anything, a warming trend here. But the invasion of two new cold-water species (slimy sculpin and round whitefish) indicates the opposite. The best conclusion would seem to be that changes in fish distributions and community here indicate no great change in habitat or water quality over the 48-year period in question.

8A. Stillwaters at the confluence of the South Branch.--The fact that species diversity and evenness are essentially unchanged here over the period in question is misleading. The shift in species has been great as reflected by a low Jaccard value. Five of the seven species found by Hankinson in 1924 were not found in 1972, and five new species have invaded. Brown and rainbow trout, and slimy sculpin, all cold-water forms made up 45% of the total individuals in Hankinson's collection. No trout were taken by seine in 1972, and 2 northern pike, 1 largemouth bass, and 1 mudminnow were taken. A subsequent check of this seine collection by electrofishing turned up 1 blackside darter, and 11 brown trout; species not taken by seine. The point remains that the fish community seems to have changed here from that of a cold-water trout stream fauna to one more characteristic of warmer rivers and ponds. This in turn implies rather great environmental changes. Two possibilities occur: Hankinson described this collection as "locally cold-water fauna" (unpublished stream survey report). Perhaps it was not typical then of the Stillwaters area. A second possibility relates to bottom changes. Assuming that the gradient in this area has always been moderate, it has always been a potential settling basin for bedload materials moving downstream. However it has been shown (Latta, 1972) that streams similar in physical character to the Au Sable can cleanse themselves of sand deposition in 5 years. It seems possible that increased erosion points (recreational sites and building projects like the I-75 bridge) in recent years have kept a steady influx of sand and silt moving into the system, much more than would have been the case in 1924 when the river banks had been in the process of natural stabilization for over 20 years after the logging drives. Sand that enters the system faster than it can be removed would settle out in areas like the Stillwaters. The result would be poor spawning gravel and poor primary and benthic production, conditions hostile to trout. Whatever the reasons, it is clear that this area is much less suited for trout than it was in the 1920's.

10A. Mouth of Big Creek.--Little change in species diversity and evenness was evident here. There was a fairly substantial species shift however, and thus a low Jaccard value. Seven species found by Hubbs in 1924 were not found in 1972, and four new ones were. The percentage of warm-water species present in 1924 (1%--four mudminnows) is inconsequential. The presence of cold-water species (7% in 1924; 10% in 1972) should not be misleading. All of these species taken in 1972 were captured directly below the mouth of Big Creek. It is likely that the same was true for Hubbs' collection. Thus these species are reflective of habitat conditions in Big Creek, and not the Main Stream, which is more marginal habitat for trout here. In summary, little change seems to have occurred.

11A. Extreme upper end of Mio Pond backwaters.--A decrease in species diversity and a small decrease in evenness, along with a fairly sizable species shift (low Jaccard value) perhaps indicate a slight degradation of habitat here. No warm-water species were found in either year, and the percentage of cold-water species was especially low in both cases. In 1972, however, no trout were taken, whereas both rainbows and browns were taken in 1924. If there has been a change of habitat here since the 1920's, it is likely due to the same kinds of perturbations postulated for the Stillwaters area.

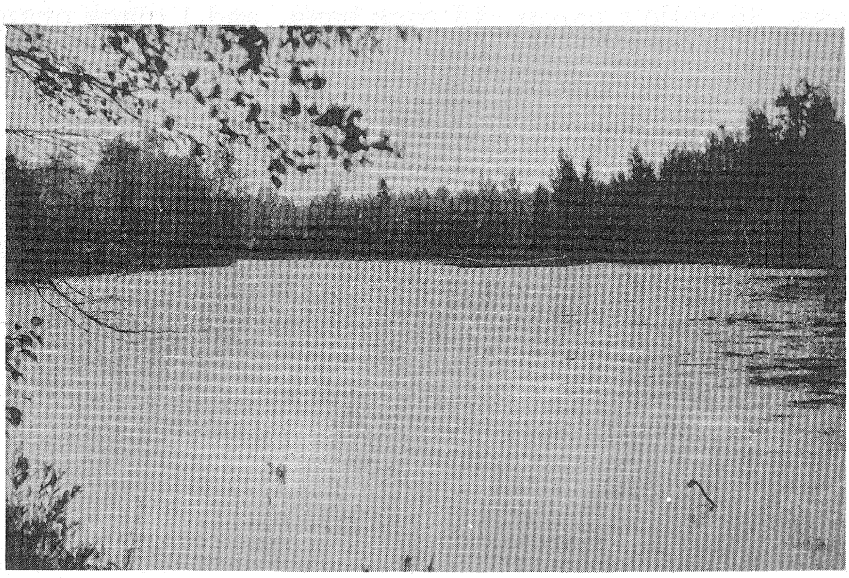
12. Below Mio Dam.--Species diversity and evenness were about the same here for both years. But the exceedingly low Jaccard Index indicates that large numbers of species shifts have occurred here. Six species found in 1924 were not found in 1972, but 15 new ones have replaced them. There were no warm- or cold-water species found in either year. It is interesting that this is the only hydroelectric impoundment sampled in 1972 that showed an increase in the number of fish species present since the 1920's. Unlike any of the other

impoundments, the flow through Mio Dam has not been significantly regulated in 10 years (personal communication, Gary I. Schnicke, District Fisheries Biologist, Mio). This seems to support the widely held notion that stability is an important habitat characteristic for diverse fish communities.

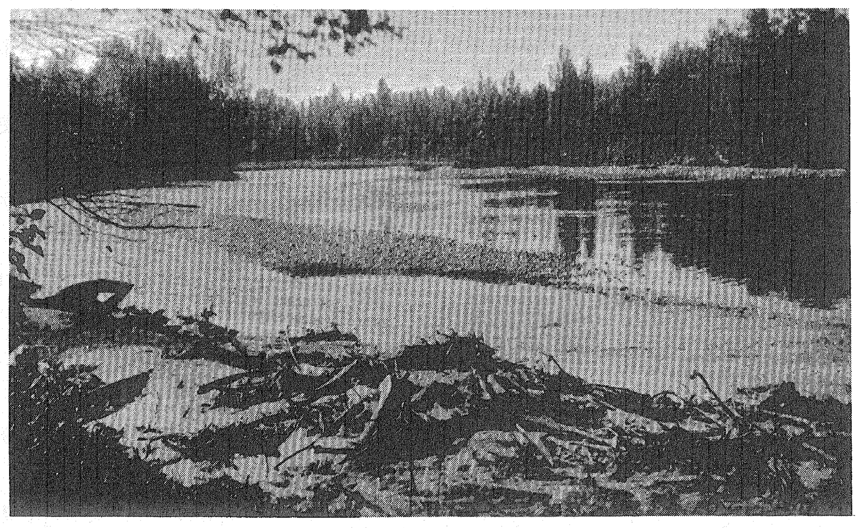
13. Comins Landing.--Diversity and evenness are unchanged here over the period in question. Again, however, a large species shift has occurred, evidenced by the low Jaccard Index for this location. No warm-water species were found in either year. Only 1% of the total collection in 1924 was cold-water species. The apparent slight increase in the percentage of this group in 1972 should be disregarded. All five trout captured were, on the basis of stocking reports and physiognomy, later judged to be recently planted fish, and thus not representative of the true state of nature here. A check of stocking records from the Department of Natural Resources revealed that trout of the size captured had been planted several weeks prior to the 1972 seine collection here. In summary, this water was marginal trout habitat in 1924, and remains so today. This is due probably in great part to the presence of Mio Dam upstream, which contributes warmed, enriched (all water in these major impoundments is drawn from the top) flow to the areas below it.

13A. Mouth of the Lower South Branch River.--No change in species diversity or evenness was noted here. But a low Jaccard Index reflected substantial species shifts. There was no apparent trend in percentage occurrence of either warm- or cold-water species groups. It is interesting that the only game fish taken in 1924 were one each of yellow perch and rock bass. In 1972, 11 smallmouth bass, 6 largemouth bass, 35 yellow perch, 48 rock bass, and 1 black crappie were taken. Although these were almost all young of the year, the potential for a sport fishery seems better here now than it was in the 1920's. However, this area remains unsuited for trout. This is due at least in part to the presence of Alcona Dam some six river miles upstream. The instability of flow caused by the regulation of this dam (Fig. 17) is as much a problem today as it obviously was in 1924.

14. Below Five Channels Dam.--No changes in species diversity or evenness were noted here, but a low Jaccard value reflected substantial species list shifts. Pumpkinseeds made up over 20% of the 1924 collection, but none were taken in 1972. In the latter collection however, 94 yellow perch were taken along with 1 each of smallmouth bass and walleye. No cold-water species were taken in either year. Although only one of Creaser's 1924 collections was used for this comparison, there were two others made the same year in the same location. Examination of these shows that there were even more species in this area than were indicated in the one collection used; 12 more to be exact. This site shows little change, however, since 1924. It is interesting and probably not coincidental that this impoundment is the most river-like and has the lowest surface to volume ratio of any of the major impoundments. As such, it is likely not as subject to



Main Stream Au Sable River below the mouth of the lower South Branch River, 1924. High water level caused by the release of flow through Alcona Dam, 6 miles upstream.



Same location as above, but at low water level, 1924.

Figure 17

the debilitating effects of warmed waters as some of the broader, larger impoundments are.

15. Below Cooke Dam.--This area shows a substantial decrease in species diversity and evenness, and a substantial shift in species (low Jaccard Index) as well. No cold-water species were found either year, and from the warm-water group, 1 bluegill and 1 pumpkinseed were taken in 1972. The rest of the 1972 collection is dominated (85%) by two species: yellow perch and white sucker, neither of which was found here in 1924. When one or two species are greatly dominant in a collection (low species diversity and evenness) as is the case here, this can be indicative of biological stress or pollution (Wilhm and Dorris, 1968). Again, the likely cause of such stress is the presence and operation of the dam here over a period of years.

16. Below Foote Dam.--This station shows the greatest degradation of any station sampled in the system. In 1924, 25 species were taken here; only 6 were taken in 1972. Species diversity and evenness for the 1972 collections are considerably lower than the corresponding values for the 1920's collections, and the Jaccard Index is the lowest of any station in the system. Only 2 new species replaced the 21 lost since 1924. No cold-water species were taken in either year, and the small percentage of warm-water species present in 1924 has been reduced in 1972 to zero. In spite of the fact that rainbow trout (planted), largemouth bass, and rock bass were seen but not captured in 1972, the degradation of the environment as reflected in fish

community changes remains substantial. Again, the major cause would have to be the physical and biological problems associated with the presence and operation of Foote Dam.

16A. Between Foote Dam and Oscoda.--This station shows a marked decrease in diversity and evenness as well. Only 3 new species have invaded to replace the 14 lost since 1924. Neither the warm- nor the cold-water groups of species were represented in significant numbers in either year. This area seems to have become substantially degraded since 1924. Again, the major contributing cause is the presence and operation of Foote Dam several miles upstream. The author, in making his collection, was impressed by the barren sand and clay bottom here, with very little vegetation evident. Here, as much as below any of the hydroelectric impoundments, the difference between high and low flow can be astounding.

East Branch, Au Sable River

18. County Road 612.--Diversity and evenness remain unchanged here. The Jaccard Index reflects a moderate amount of species changes. No cold-water species were taken in either year, and 7 mudminnows were taken in 1972 (warm-water group). This station has always been too warm to support trout. The gradient here is low, the flow moderate, and the water temperature is warmed by extensive marshy backwaters and the several natural warm-water lakes in the headwaters.

18C. Hartwick Pines.--Diversity and evenness have both substantially decreased here, but the species present have remained fairly constant. Thus the Jaccard Index for this station is one of the highest recorded for any station. No warm-water species were taken in either year, and the percentage of cold-water species present dropped from 13 to 2%. An electrofishing check of this station turned up one individual each of two species not captured by seine: mudminnow and slimy sculpin. Brook trout were the only salmonids taken in 1924, but both brook and brown trout are present today. Brook trout are still caught in fair numbers in this part of the system, but probably fewer than in 1924 due to increased competition from the brown trout. As electrofishing only produced 14 trout, 9 more than were caught by seine, it is possible that this section of the East Branch could be experiencing a decline in habitat or water quality conditions for trout. Specific causes for such a trend cannot be offered although increased erosional input may be partially responsible.

18H. Just above the State Fish Hatchery.--A three-way comparison is possible here because of an additional 1916 collection by Hankinson. Diversity was about the same in 1916 as 1924, but declined somewhat in 1972. Evenness was lowest in 1924, and a little higher in 1916 and 1972. There was a fairly substantial addition of species between 1916 and 1924; thus even for that 8-year period, the Jaccard Index is not high. There was a more substantial species shift between 1924 and 1972, and thus an even lower Jaccard value. There were no warm-water species taken in any of the collecting years, but the percentage of cold-water species increased somewhat from 1924 to 1972. The fact that Hubbs took 17 species and 529 individuals in 1924, and only 6 species and 39 individuals were taken in 1972, after nearly a full day of seining, points, with the above evidence, to a general decline in habitat here. Subsequent electrofishing checks revealed that in fact there were very few fish in this area. Talks with Edward E. Schultz of the Grayling Hatchery revealed that some years ago, well after Hubbs' 1924 collection, the area above the Hatchery was dredged and channeled. The result today is a very open, sand-filled channel that has little cover and no gravel. This habitat degradation is probably the major localized cause of the decline in productivity and numbers of fish species here.

South Branch

37. Mud Lake.--Diversity has increased here, but evenness has stayed the same. Nine species have replaced the two not found from the 1924 collection, thus resulting in a low Jaccard Index. No cold-water species were found in either year, as this site is located just downstream of a small warm lake, and a short distance from Lake St. Helen. Warm-water species made up 80% of the 1924 collection, but only 50% in 1972. Hubbs took only 6 species and 16 individuals here as opposed to 13 species and 317 individuals in 1972. Included in the latter total were 36 brown bullheads, 46 bluegills, 49 yellow perch,

5 rock bass, 10 northern pike, and 77 largemouth bass. Most of these game fish were young of the year, but the indications for a warm-water sport fishery here seem as good now or better than they were in 1924. No good reasons can be offered for such an apparent increase in productivity, unless increased development in this low-lying area has meant greater nutrient enrichment.

20B. Sherman Bridge.--Although evenness has remained about the same here, diversity has notably decreased. Eight species from the 1924 collection were not found in 1972, and only two new species have replaced them. No cold-water species were taken in either year, and the percentage of warm-water species taken was identical in both years. The fact that 13 species were taken in 1924, and only 7 in 1972 might indicate a degradation of habitat, although there has been little development in this area since the time Hubbs collected. This section of the South Branch is characterized by a low gradient flow through sandy bottom, marshy habitat, that has been, and always will be, more suited to warm-water species than trout.

20. Roscommon, M-144 Bridge.--Diversity and evenness are both lower here than in 1924, and a low Jaccard Index reflects a substantial species shift. One brook trout was taken in 1924, but none were taken in 1972. Thirteen mudminnows were taken in 1924 as well, but no warm-water species were taken in 1972. The decrease in diversity and evenness here probably reflects a change in habitat or water quality. It would be difficult to say specifically what these changes

might have been. If changes have taken place, they are probably generally related to the effects of increased human perturbation on the watershed around Roscommon. The sewage treatment plant for Roscommon cannot be faulted as it is downstream of this station.

22. Chase Bridge.--Diversity and evenness remain about the same here in both collecting years. Seven species found in 1924 were not taken in 1972, and only two new ones have invaded. The Jaccard value is therefore low. The loss of mudminnows and largemouth bass (warm-water species), plus the loss of several minnow species since 1924, along with the increase in percentage of cold-water species in 1972 (7% to 22%) indicates an improvement in conditions for trout. In particular, these data point toward a decrease in average water temperature here. As this station is on the boundary of the Mason Tract, it is unlikely that the special protection provided this area by Mr. Mason and now the State would have affected conditions here much. Rather, it is more likely that an increase in shade conditions upstream, and in the watershed generally has meant a cooling down of the stream. This trend toward improvement of conditions for trout seems to have occurred in spite of the input of primary treatment from the Roscommon sewage treatment plant upstream.

23. Smith Bridge. This station has seen no change in evenness, but a decrease in species diversity has occurred. Again, significantly more species (9) were lost than invaded here (2). The loss of mud-minnows and largemouth bass since 1924, plus the invasion of the slimy

sculpin, and the dramatic increase in percentage of cold-water species (20% to 82%), indicate again a favorable temperature shift for trout over the years. As this station lies at the end of the Mason Tract, it is likely to have benefited from this added ecological protection as well as the general trend in increased shading and lower mean water temperatures found throughout the watershed.

North Branch

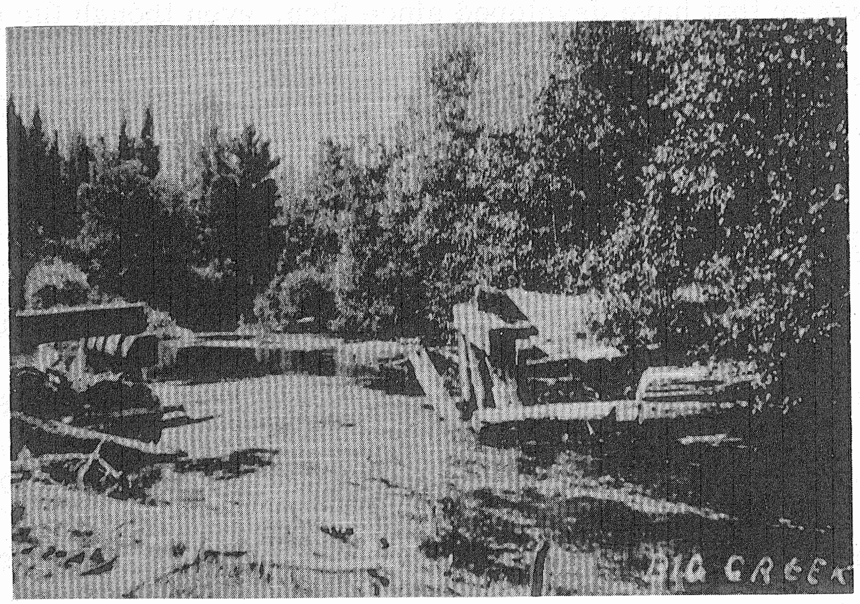
24A. Dam 1.--Diversity and evenness are unchanged here, and there have been few species changes (high Jaccard Index). There was a slight decrease in cold-water species and a slight increase in warm-water species. A talk with a local resident who used to fish Dam 1 as a boy revealed that it used to be good brook trout fishing. Only one brown trout was taken in 1972, however, and no brook trout. As the North Branch begins as the combined outlets of three warm-water lakes, and as there have been several private impoundments built upstream of Dam 1, and as there is evidence of beaver dams in this area, it seems likely that there has been a trend toward an increase in water temperatures here. This seems a reasonable conclusion based on the fact that brook trout were found here when Metzelaar collected in 1924, but are no longer present according to both the local resident who was interviewed and the 1972 collection results.

24B. Dam 4.--No change in species diversity was recorded, but there was a slight increase in evenness. Eight species found in

1924 were not found in 1972, and no new ones have replaced them. No warm-water species were found in either year, but the percentage of cold-water species increased markedly (5% to 30%). Two electrofishing checks of this same area turned up no new species not captured by seine. It appears that this area is improving in conditions for trout. Figure 18 shows Dam 4 as it was in 1924. Anyone familiar with this area will realize how changed it is today. It is much less open, and the channel is less braided and broad, and there is much more bank shade. The removal of this dam and most of the effects of Dam 2 upstream, as recommended by Hubbs, has no doubt had a beneficial impact on the North Branch. The result of all these changes would be to concentrate the flow, thereby exposing more gravel (better spawning and benthic production), and to decrease the average water temperatures--both conditions favorable to trout. Further evidence of a temperature decrease is reflected in the fact that this is one area in the watershed where brook trout (requiring cooler water) are holding their own against the brown trout, if not in fact increasing in their relative abundance.

25A. Campground between Dam 4 and Kellogg's Bridge.--Diversity and evenness have both increased here. There have not been large species shifts; thus the Jaccard Index is fairly high here in comparison to other stations. No warm-water species were taken in either year, but the percentage of cold-water species has increased (2% to 20%). In particular, the slimy sculpin is a post-1924 invader of the

Dam 4 on the North Branch of the Au Sable River, 1924



Blonde Dam (Blounte's Dam in 1924) on Big Creek in Crawford County, 1924. This dam is no longer present.

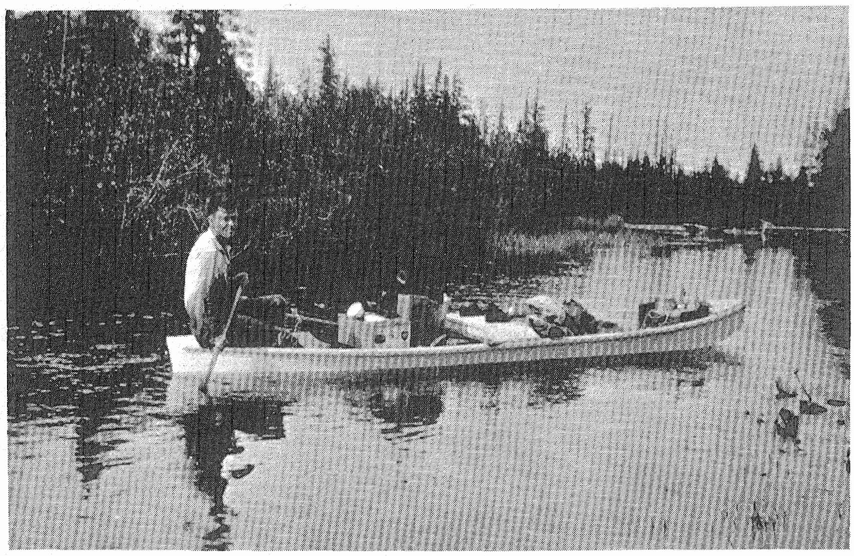
Figure 18

area. The evidence here again points to an improved temperature regime for trout, no doubt for much the same reasons discussed for Dam 4.

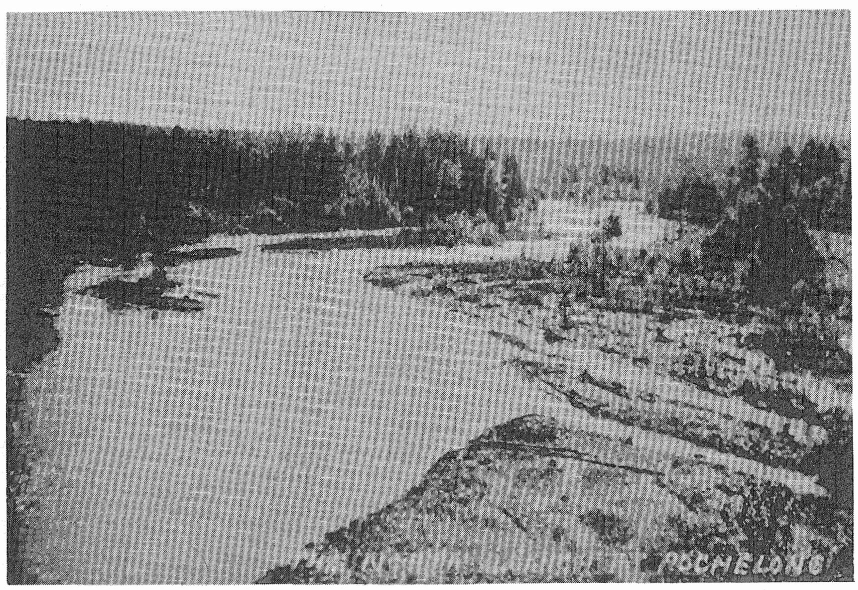
25B. Kellogg's Bridge.--This station has shown both a decrease in species diversity and evenness. There have been relatively few species shifts however, and thus this station has one of the highest Jaccard values of any station. One warm-water species (brown bullhead) was taken in 1924, but none were taken in 1972. The percentage of cold-water species increased only very slightly. Electrofishing, however, revealed that there were many more trout here than were indicated by seining. A picture taken 3/4 mile upstream of Kellogg's Bridge by Hubbs in 1924 (Fig. 19), shows how flat, shallow, and treeless this area was at that time. It would be difficult to believe that this area has not benefited from the bank stabilization and shade cover that have developed since then, even though the data do not indicate it clearly.

Big Creek, Crawford County

39. Lowest mile of the Middle Branch.--Diversity and evenness have not changed here much. Similarly, few species shifts have resulted in a relatively high Jaccard Index. No warm-water species were taken in either year, but the percentage of cold-water species has risen markedly (8% to 77%). Where the brook trout was the only cold-water species present here in 1924, brook and brown trout, and slimy sculpin



Dr. Carl L. Hubbs below Grayling at the start of his Au Sable River fish collecting trip, 1924.



North Branch of the Au Sable River, 1924, 3/4 mile upstream from Kellogg's Bridge.

Figure 19

are found here today. In short, conditions seem to have improved for trout over the last 50 years. A small stream like this would likely benefit much more from post-logging shade growth than a wider stream, as second growth in places provides a complete canopy over the stream, thereby protecting a much greater proportion of the water from the heating effects of the sun.

40. Lowest mile of the East Branch.--Evenness and diversity have remained stable here. Of the nine species taken by Hubbs in 1924, six were not found in 1972, and only three new species were taken. No warm-water species were taken in either year. The percentage of cold-water species was high in both years, but declined slightly in 1972 (61% to 52%). The fact that the slimy sculpin has invaded, however, along with the fact that all six of the species from the 1924 collection not found in 1972 were minnow species, points to a decreased average water temperature here. Again, this is due most likely to increased shade and a general lack of development in this area; both conditions tending to be favorable to trout.

41. Blonde Dam (Blounte Dam in 1924).--A marked increase in diversity and evenness is evident here. A fair number of species shifts is reflected in a moderate Jaccard value. No warm-water species were taken in either collecting year, but the percentage of cold-water species present has jumped from 0% to 11%. An electro-fishing check of this area revealed a very dense concentration of older than young-of-the-year brown trout, which at that size are almost

impossible to capture by seine. When Hubbs sampled here, the dam (used for logging purposes) was still present (Fig. 18), and its warming effects were apparent. Hubbs found no trout, "fish typical for fairly warm creeks. Brook trout reported" (unpublished stream survey, Institute for Fisheries Research, Michigan Department of Natural Resources). The dam is completely gone today, and there is even some confusion as to where it used to be. But the 1972 seining results clearly show the potentially harmful effects of an impoundment on a trout stream, and the fact that areas degraded by them can recover completely over time to the same or better water quality than was present originally. This being a small stream, it has also undoubtedly benefited by increased shade growth.

Big Creek, Oscoda County

42. Dirt Road, 25 N., 1 E., S. 26.--Although diversity remained the same here over the 48-year period in question, evenness decreased markedly. All three species found in 1924 were found in 1972, along with three additional ones. One of these invaders (mudminnow) has been classified in this study as a warm-water species. The percentage of cold-water species present declined from 20% to 5%. Blacknose dace were greatly abundant (over 85% of the total) in 1972, thus accounting for the low evenness in this collection. Presence of a beaver dam upstream from the collection point backed up a considerable

body of water into a shallow, marshy channel; this could be a locally important factor in the apparent warming trend. There has been little human activity in this part of the watershed over the period in question. In many places, the stream is so small that it is completely covered with shade canopy.

26. County Road 487.--This was a non-quantitative collection by Hubbs; thus only species comparisons can be made. Hubbs found six species, three of them cold-water species (rainbow and brown trout, slimy sculpin). Only four species were found in 1972, two of them being cold-water species (brown trout and slimy sculpin). Hubbs recommended trout not be planted here as the creek was too warm and big (unpublished stream survey, Institute for Fisheries Research, Michigan Department of Natural Resources). This seems strange in view of his own seining results. While it was difficult to capture fish at all in this area by seine in 1972 (only 17 individuals taken), 41% of those taken were cold-water species. The absence of mudminnows in our collection which were taken by Hubbs, lends further credence to the proposition that if anything, this area has experienced a decrease in average water temperature since 1924. No specific causes for this trend can be offered; the cooling effects of increased shade growth discussed elsewhere apply here as well.

DISCUSSION

The collection of data in natural biological systems is many times lacking in controls. Such was the case here. Attempts were made to replicate to the greatest degree possible the procedures of Hubbs et al. in the 1920's. To claim that the location, distance, area, time, water quality conditions, etc. were replicated precisely at each station however, would be false. Therefore it is a valid criticism of this study that data collection was less than totally accurate. For this reason, the approach to data analysis has not been to state absolutes, but trends, and these only where there was strong evidence from several analytic viewpoints.

The seining efficiency of the 1972 study crew (Richards, Ringler, Coopes, Quigley) was no doubt of a lesser degree than that of Hubbs and company. However, electrofishing checks of ten of the 1972 seine collection stations revealed no gross oversights. Trout were almost always greatly underrepresented, but undoubtedly the same would have been true of the 1920's collections. As electrofishing checks were completed all at once, the time between the original seine collection and the check varied greatly in some cases. Some of the differences in species lists between seine and electrofishing collections could therefore be due to temporal movements of fish rather than seining inefficiency. In brief, the results of these checks showed the following species oversights: Station 8A--four species missed by seine, none abundant, 4-day lapse between seining and electrofishing; Station 7A--no new species; Station 4A--three species missed by seine, none abundant, 21-day lapse between seining and electrofishing; Station 22--three new species, none abundant, 39-day lapse; Station 18H--three new species, all rare; Station 18C--three new species, all rare; Station 25B--four new species, all rare; Station 41--three new species, all rare; Station 24B--no new species; Station 23--eight new species, six of those rare, 31-day lapse between seining and electrofishing. Based on these results, it was felt that the 1972 seining techniques were reasonably efficient.

Another factor of importance is the influence of cyclical fluctuations in fish populations on the data used here. Such cycles have been demonstrated for trout (Latta, 1972), and presumably act on other species as well. As there is no possible way of determining whether and how much this factor was operating, the author assumed that it was not. This is not entirely presumptuous as it seems likely that if, for example, 1972 was a high point on the trout cycle, and 1924 a low point, then the data would consistently point to improvement for trout over the period in question. As the station-by-station analysis demonstrated, such was not the case.

The station-by-station analysis revealed several trends in fish distributions and community structure which reflect possible changes in the watershed. Two possible changes in particular have been postulated; temperature, and bottom type changes. It is clear that logging had a devastating effect on the watershed. Post-logging fires in this area left much of the watershed denuded. The result was increased nutrient flow into the river system (as in Borman et al., 1968), and an absence or reduction of shade cover along the river banks. This led to a general warming of the waters, the effects of which were probably not improved by new growth and bank stabilization when Hubbs et al. sampled. Such a warming trend would have been detrimental to trout in the system. It is not likely that removal of vegetation in this area resulted in greatly increased run-off, however, as is the case in watersheds with less permeable soils (Hornbeck et al., 1970). If anything, a greater percentage of precipitation entered the system as groundwater after logging, as there would have been little loss to vegetation (personal communication, Dean H. Urie, U.S. Forest Service, Cadillac, Michigan). However, snow melting over frozen soils would have tended to produce the opposite effect in the spring with greater run-off and nutrient leaching into the system. There would have been little vegetation to absorb this input. One might speculate then that the system in the 1920's was less stable in terms of flow, nutrient input, and temperature than it is today.

Since the 1920's, second growth has become much better established throughout the watershed. River banks are much more shaded now. This fact, in addition to the fact that several warming impoundments created by logging dams have been removed, points to decreased average water temperatures in parts of the system. The benefits of increased shade might be expected to be felt most in sections of the system where the channel was the narrowest. Such seems to be the case at several stations on the North Branch (Dam 4, Station 24B; Campground, Station 25A), Main Stream (Wa Wa Sum, Station 6A; 1 mile above Stephan's, Station 6B), South Branch (Chase Bridge, Station 22; Smith Bridge, Station 23), and Big Creek (Blonde Dam, Middle Branch, Station 41). The apparent decline in average water temperatures since the 1920's could help explain the increase in percentage of cold-water species and the decrease in minnow species found at many of these cold-water stations.

In the warm headwater areas, and the lower part of the Main Stream, cooling influences have not been great enough to offset other warming trends, and as a consequence, these areas remain unsuited for trout. The warm headwater areas still receive their inputs from warm-water lakes which, because of their large surface area, would for the most part be unaffected by increased shoreline shading. It seems doubtful that even dramatic increases in shade below these warm-water outlets could offset the warming effects of the lakes.

Such would be the case in wider sections of the Main Stream, and the major impoundments on the lower end of the system as well, where increased shade would have a negligible effect because of the larger surface area of water still exposed to solar radiation. It probably could have been predicted then, that increased shade would have had the greatest effect precisely where it did--in areas where the water was already cool enough to sustain trout (sufficient groundwater), and the channel was narrow enough that a large portion of it would be protected from direct solar radiation.

But temperature changes cannot be used to explain the oftentimes drastic changes in fish fauna in the lower part of the Main Stream. Increased shade probably has had little effect here, as explained above, and the warming effects of the impoundments, built between 1913 and 1924, were as much a factor in Hubbs' collections as the present ones.

The decrease in silt, sand, and turbidity intolerant fish species in the lower part of the Main Stream, and in the cold-water habitat as well, may imply a possible change in bottom type in certain parts of the system over the last 50 years. It seems likely that in the 1920's when Hubbs et al. collected, much of the damage inflicted on the river by logging drives would have been corrected. Erosion points were probably well stabilized, and sufficient time would have passed for much of the sediment, resulting from logging activities, to have been moved downstream. This would have meant that proper bottom conditions were available for many of the gravel- and rubble-dwelling species found in the system in the 1920's, but not found there today. The fact that many of these species are not found in the system today may imply that increased usage of the river in recent years has meant a greater influx of sediment than the river can transport, with the result that it is settling out in low gradient areas. Examples where this might have occurred would be the Stillwaters on the Main Stream, Hartwick Pines on the East Branch, Bradford Creek and Frederick on the upper Main Stream, and Kellogg's Bridge on the North Branch. These areas are all characterized now by heavy sand deposits on the bottom with little gravel evident.

The role enrichment has played in changes in the system since the 1920's has to be considered as well. One might speculate that a moderate amount of enrichment in a trout stream, all other conditions remaining constant, might be beneficial to trout production. But as is usually the case in natural systems, increased enrichment is often accompanied by increased temperatures, biochemical oxygen demand and turbidity. The effects of such changes in a trout stream parallel changes that occur from the headwaters to the mouth of most natural systems. The headwaters of a typical trout stream are cold with low levels of enrichment and a low faunal diversity. Farther downstream, enrichment is greater, temperatures are warmer, and faunal diversity and evenness in fish communities are higher. But with increasing enrichment, temperature, etc. downstream, a point is reached where the system becomes eutrophic, and diversity and evenness decline again (Sheldon, 1968). Based on the data from this study, it appears that most of the Au Sable system is in a moderate state of enrichment where diversity and evenness are high. There are some areas (impoundments) where the decline in diversity and evenness (likely a response to over-enrichment) shows a deterioration of water quality, and other areas (cold-water trout areas) where diversity and evenness have remained constant, yet water quality conditions have changed sufficiently to allow cold-water species to become much more dominant.

The impoundments require further speculation as they offer specific problems of interpretation. The effects on fish populations of warmed, enriched waters drawn from the top of the impoundments in irregular bursts would have been a factor in the 1920's as well as today. The most likely explanation for the changes that have gone on here is biological aging of the impoundments (Hynes, 1970). The aging process of impounded waters evident after the first few years of formation probably was not complete when Hubbs et al. collected in the 1920's, and a greater number of fish species and individuals would have been supported. As nutrients became tied up in bottom sediments and productivity declined, the net effect would have been the elimination of rare species and a decrease in concentrations of fish generally. Such was the case for our collections. Two conditions should be placed on this conclusion. Where instability of discharge has not been a problem for a period of time (Mio Dam), this factor alone has seemingly allowed a greater diversity of species and numbers of fish to survive than was possible previously. In addition, it appears that the surge in productivity of new impoundments can be reduced by the nature of the impoundment. Where a new impoundment is deeper, and has less surface area exposed to solar radiation (Five Channels Dam), all other things being equal, this water will have a less dramatic increase and decline in productivity than broader, shallower impoundments.

Of the destructive effects of most impoundments on trout streams however, there can be little doubt. Whether the lower part of the Main Stream of the Au Sable River held good populations of grayling prior to logging and dam building is questionable. What is certain, however, is that the presence and operation of six major dams on the lower end of this system make 73 miles of river extremely marginal for, or completely hostile to, salmonids today. What is also certain is that the removal of dams from trout streams can be followed after sufficient time, by the restoration of the areas affected to the quality of water and habitat formerly present. This was clearly illustrated in the present study at Station 24B, Dam 4 and Station 41, Blonde Dam.

CONCLUSIONS

1. The cold-water moderate flow habitat has improved over the last 50 years. This conclusion is substantiated by the following reported findings:

    a. No meaningful change in species diversity, evenness, or numbers of species.

    b. The least change in species lists (Jaccard Index) of all four habitat types.

    c. An increased mean percentage of cold-water species.

    d. A decrease in presence and abundance of minnow species.

    The disappearance of certain minnow species may be a joint function of decreased average water temperatures, and bottom changes. Where the average temperature has seemingly increased (Bradford Creek), the trend has reversed, with an increased number of minnow species, and a decreased percentage of cold-water species. Hypothesized increases in sand and silt deposition might be due to increased erosional input and enrichment from human use. Decreases in average water temperature could be attributed to increased shade, and the removal of impoundments since the 1920's.

2. Water quality in the lower part of the Main Stream, including the impounded and large river habitats, has deteriorated, with subsequent deterioration of fish communities. This conclusion is substantiated by the following findings:

    a. Statistically significant reductions in species diversity and evenness.

    b. The greatest shift in fish species (Jaccard Index) of all four habitat types.

    c. A decreased abundance of silt and turbidity intolerant minnow species, and a gain in species tolerant to those conditions.

    It is proposed that these changes are due primarily to the presence and regulation of flow of six hydroelectric dams, whose biologically aged impoundments produce warm, turbid, over-enriched waters, and an unstable environment for the river below. Increased human disturbance might also be playing a part in bottom changes.

3. The warm headwater reaches of the system seem to have remained about the same. The following data support this conclusion:

    a. No change in numbers of species, species diversity, or evenness.

    b. The second smallest shift in fish species (Jaccard Index) of the four habitat types.

c. Possible slight water quality shift at several stations causing very marginal trout habitat to become totally non-trout habitat.

These stations were at best very marginal or non-trout waters when Hubbs et al. collected in the 1920's, and remain so today. As they are the result of warm-water impoundments and lakes for the most part, it is exceedingly doubtful that these areas will ever be able to sustain substantial trout populations.

The following is a summary of the changes in habitat and water quality that have occurred as reflected in fish species composition changes at each station between the 1920's and 1972:

<u>Improved</u>

6A. Wa Wa Sum
6B. Above Stephan's Bridge
37. Mud Lake
22. Chase Bridge
23. Smith Bridge
24B. Dam 4
25A. Campground
39. Big Creek, Middle Br.
41. Blonde Dam

<u>No Change</u>

4A. Mouth of East Branch
7A. Below Stephan's Bridge
8. Wakeley Bridge
10A. Mouth Big Creek

11A. Mio Pond (above)

12. Below Mio Dam

13. Comins Landing

13A. Mouth of Lower South Branch River

14. Five Channels Dam

18. County Road 612

20. Roscommon, M-144

20B. Sherman Bridge

25B. Kellogg's Bridge

40. Big Creek, East Branch

26. County Road 487

Deteriorated

1B. Bradford Creek

1. Frederick

8A. Stillwaters

15. Cooke Dam

16. Foote Dam

16A. Between Foote Dam and Oscoda

18C. Hartwick Pines

18H. Hatchery

24A. Dam 1

42. Dirt Road, 25 N., 1 E., S. 26

RECOMMENDATIONS

While none of these recommendations is new or original, they do come as a direct result of the data from this study. As such, they should only serve to reinforce some of the ideas already being proposed by resource planners for the preservation of the watershed.

1. Removal and prohibition of further impoundments from the system, with the possible exception of Mio Dam (essentially the plan advanced by Gary I. Schnicke, District Fish Biologist, Michigan Department of Natural Resources, Mio). This would allow the establishment of an anadromous fishery over some 73 miles of increasingly non-productive waters. Retaining Mio Dam would insure the separation of this fishery from prime, high quality trout waters upstream.

2. Institution of green belt zoning throughout the watershed at least as stringent, if not more so, than that of Crawford County. Municipal, industrial, and domestic use of groundwater must not become excessive. Septic and other sources of human enrichment (Roscommon sewage treatment plant, in particular), loss of shade, and added sources of erosion that come from development, all must be prevented in order to maintain the water quality necessary for cold-water fish species.

3. Stabilization of erosion sites. In stream improvement work, this should take priority over the construction of trout cover. Of particular concern are recreational access sites. Ways must be found to stabilize these areas, even at the expense of esthetics if necessary. A concrete canoe ramp, although unsightly, would be far less harmful than an eroding sand bank as an access site.

The results of this study show that the Au Sable River is an extremely elastic system that can, and has recovered from rather dire human perturbation. But this should not lull those concerned with it into a sense of false security. It will always need protection; increasingly so with increased use. But if proper steps are taken now, including those generally outlined above, the system should provide indefinitely only the highest quality environment for recreational use.

LITERATURE CITED

Bailey, R. M., J. E. Fitch, E. S. Herald, E. A. Lachner, C. C. Lindsey, C. R. Robins, and M. B. Scott. 1970. A list of common and scientific names of fishes from the United States and Canada (3rd ed.). Amer. Fish. Soc. Spec. Publ. No. 6, 150 p.

Borman, F. H., G. E. Likens, D. W. Fisher, and R. S. Pierce. 1968. Nutrient loss accelerated by clear-cutting of a forest ecosystem. Science 159: 882-884.

Brillouin, L. 1960. Science and information theory (2nd ed.). Academic Press, New York, 320 p.

Brown, S.-D. 1969. Grouping plankton samples by numerical analysis. Hydrobiologia, 33: 289-301.

Cairns, J., and K. L. Dickson. 1971. A simple method for the biological assessment of the effects of waste discharges on aquatic bottom-dwelling organisms. J. Wat. Poll. Cont. Fed., 43(5): 755-772.

Gaufin, A. R., and C. M. Tarzwell. 1952. Aquatic invertebrates as indicators of stream pollution. U.S. Pub. Health Rep. No. 67, 57 p.

Harrel, R. C., B. J. Davis, and T. C. Dorris. 1967. Stream order and species diversity of fishes in an intermittent Oklahoma stream. Amer. Midl. Nat., 78(2): 428-435.

Harrel, R. C., and T. C. Dorris. 1968. Stream order, morphometry, physico-chemical conditions, and community structure of benthic macroinvertebrates in an intermittent stream system. Amer. Midl. Nat., 80(1): 220-251.

Hendrickson, G. E. 1966. Michigan's Au Sable River--today and tomorrow. Mich. Dep. Conserv. Geol. Surv. Div. Bull. 3, 80 p.

Hoover, E. E. 1938. Fish populations of primitive brook trout streams of northern New Hampshire. Trans. Third N. Amer. Wildl. Conf: 486-496.

Hornbeck, J. W., R. S. Pierce, and C. A. Federer. 1970. Streamflow changes after forest clearing in New England. Wat. Res. Res., 6: 1124-1132.

Horton, R. E. 1945. Erosional development of streams and their drainage basins; hydrophysical approach to quantitative morphology. Bull. Geol. Soc. Amer., 56: 275-370.

Hubbs, C. L., and K. F. Lagler. 1970. Fishes of the Great Lakes region. Univ. Michigan Press, Ann Arbor, 213 p.

Huet, M. 1959. Profiles and biology of western European streams as related to fish management. Trans. Amer. Fish. Soc., 88(3): 155-163.

Hynes, H. B. N. 1970. The ecology of running waters. Univ. Toronto Press, 555 p.

Jaccard, P. 1908. Nouvelles recherches sur la distribution florale. Bull. Soc. Vaud. Sci. Nat., 44: 223-270.

Katz, M., and A. R. Gaufin. 1971. A simple method for the biological assessment of the effects of waste discharge on aquatic bottom-dwelling organisms. J. Wat. Poll. Cont. Fed., 43(5): 755-772.

Kolkwitz, R., and M. Marsson. 1908. Oekologoe der pflanzlichen Saprobien. Ber. d. Deut. Bot. Gessel., 26a, 505 p.

Larimore, R. E., and P. W. Smith. 1963. The fishes of Champaign County, Illinois, as affected by 60 years of stream changes. Ill. Nat. Hist. Surv. Bull. 28(2): 299-382.

Latta, W. C. 1972. The effects of stream improvement upon the angler's catch and standing crop of trout in the Pigeon River, Otsego County, Michigan. Michigan Department of Natural Resources, Inst. Fish. Res. Rept. No. 1786, 57 p.

Margalef, D. R. 1958. Information theory in ecology. General Systems, 3: 36-71.

Margalef, D. R. 1968. Perspectives in ecological theory. Univ. Chicago Press, Chicago, Ill., 111 p.

Pielou, E. C. 1966a. Species-diversity and pattern-diversity in the study of ecological succession. J. Theoretical Biol., 10: 370-383.

Pielou, E. C. 1966b. The measurement of diversity in different types of biological collections. J. Theoretical Biol., 13: 131-144.

Pielou, E. C. 1967. The use of information theory in the study of the diversity of biological populations. Proc. 5th Berkeley Symp. on Math. Stat. and Probability, 4: 163-177.

Pielou, E. C. 1969. An introduction to mathematical ecology. Wiley-Inter-science; John Wiley and Sons, New York, 286 p.

Sheldon, A. L. 1968. Species diversity and longitudinal succession in stream fishes. Ecology, 49(2): 193-198.

Simpson, G. G. 1960. Notes on the measurement of faunal resemblance. Amer. J. Sci., Bradley Volume, Vol. 258-A: 300-311.

Spence, J. A., and H. B. N. Hynes. 1971. Differences in fish populations upstream and downstream of a mainstream impoundment. J. Fish. Res. Bd. Canada, 28(1): 45-46.

Strahler, A. N. 1957. Quantitative analysis of watershed geomorphology. Trans. Amer. Geophys. Union, 38(6): 913-920.

Tramer, E. J. 1969. Bird species diversity: components of Shannon's formula. Ecology, 50(5): 927-929.

Trautman, M. B. 1957. The fishes of Ohio. Ohio St. Univ. Press, 683 p.

Water Resources Commission. 1966. Water resource conditions and uses in the Au Sable River basin. Mich. Dep. Conserv., 75 p.

Whiteside, B. G., and R. M. McNatt. 1972. Fish species diversity in relation to stream order and physicochemical conditions in the Plum Creek drainage basin. Amer. Midl. Nat., 88(1): 90-100.

Wilhm, J. L., and T. C. Dorris. 1966. Species diversity of benthic macroinvertebrates in an (sic) stream receiving domestic and oil refinery effluents. Amer. Midl. Nat., 76(2): 427-449.

Wilhm, J. L., and T. C. Dorris. 1968. Biological parameters for water quality criteria. Bioscience, 18(6): 477-481.

Approved by G. P. Cooper

Typed by M. S. McClure