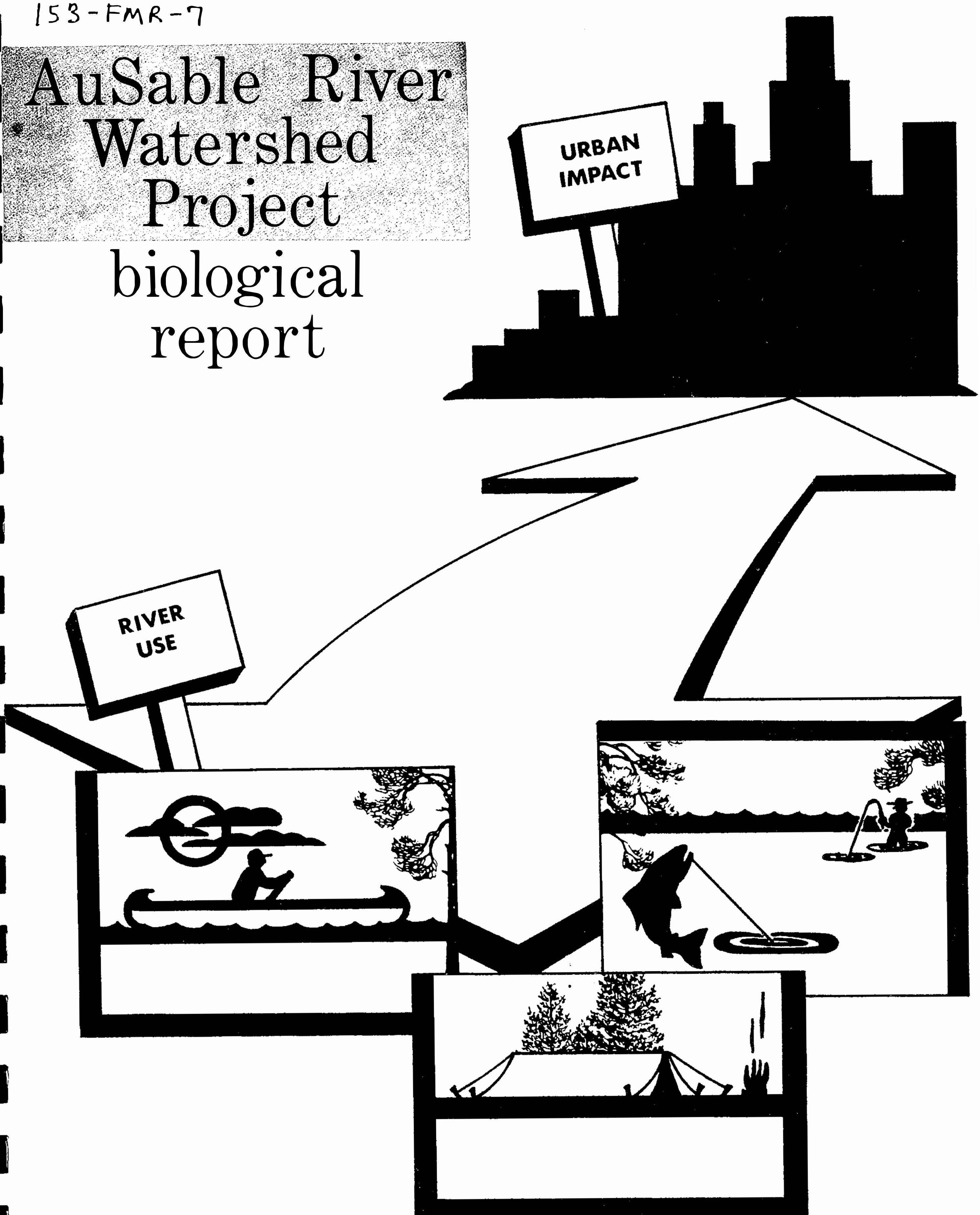
AuSable River Watershed Project

biological report



Michigan Department of Natural Resources

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Fisheries Division

AU SABLE RIVER WATERSHED PROJECT BIOLOGICAL REPORT (1971-1973)

An investigation into the effects of human use and development on the biology of a coldwater river system

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FOREWORD

The Au Sable River Watershed lies on the northeastern slope of Michigan's Lower Peninsula. The gently rolling terrain, consisting mostly of porous glacial outwash plains, assures the river system of a steady contribution of cold groundwater throughout the year. This is the key characteristic in determining the suitability of rivers for recreational use. Because the Au Sable is so uniquely suited for this use, and offers some of the most productive and fishable trout waters in the world, this generous flow of cold, clear water must be maintained through wise land and water use policies. From another point of view, the Au Sable is more than an important river or physical resource. It is the stream where present trout fishing and trout management philosophy have been developed through intensive scientific research and great public interest.

Historically, the Au Sable River Basin has been plundered for the wood products on the uplands and the prolific but vulnerable grayling that dominated its waters. Today, most of the watershed is reforested, an energetic erosion control and habitat improvement program is underway, and after 1973 no more waste water (with the exception of storm runoff) will be discharged directly to the river. Water quality in the Au Sable Basin presently meets standards adopted by the Water Resources Commission for total body contact, recreation use. To perpetuate these characteristics will require the implementation of such measures as strong Greenbelt zoning ordinances, vigilant test-well and surface-water monitoring programs, streambank stabilization, and well designed recreational use. Removal of some key dams along the Mainstream and coldwater feeder streams could greatly improve conditions for intolerant coldwater fish species.

There is every reason to believe that, properly managed, the Au Sable River Watershed will remain an aesthetically pleasing, high-quality recreational resource for the pleasure of many future generations.

The 2-year study, summarized in this report, was concerned with river characteristics which must be watched closely as more intensive human use of the watershed occurs in the future.

The careful reader of this long, fact-laden report will find many conclusions and proposals on how river-use problems should be solved. Most of these proposals are by the principal author, Mr. Gary F. Coopes, who has had much training and experience in both the fisheries and public health aspects of water management. We have high regard for his opinions, while, at the same time, recognizing that the final word on a host of decisions on watershed development will be up to planning and zoning boards.

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AU SABLE RIVER BIOLOGICAL REPORT

-ABSTRACT-

A two-year biological study of the Au Sable River Watershed was conducted between September, 1971, and June, 1973. This study was designed to complement concurrent investigations into the physical, economic, and recreational user characteristics of the basin. The geological and topographical characteristics of the basin encourage a high yield of ground water, resulting in excellent conditions for recreational use. However, use of the system for disposal of sewage and urban-type surface runoff have altered plant and animal communities, and caused changes that are aesthetically displeasing.

There are 67 dams in the watershed ranging from less than 2, to more than 35 feet of head (at power-producing dams). Stressed environs are associated with impounded areas of the river, as reflected by changes in composition of fish and bottom-dwelling insect communities within and below these basins. Large quantities of sediment have been introduced to the river from bridge construction, pipe-line crossings, and access points. Sediment loading is associated with detrimental effects on trout reproduction, trout food organisms, and competition with less desirable species. Increasing development of river frontage for homesites also constitutes a threat to quality of water and habitat.

Overall water quality of the Au Sable is excellent, and those parameters tested were all within standards adopted by the Michigan Water Resources Commission for total body contact. Nuisance growths of algae and rooted aquatic plants have been related to nutrient input from sewage outfalls at Grayling and Roscommon. Small, shallow streams of low turbidity, such as the upper Au Sable, are very sensitive to enrichment, and response in production of aquatic plants is dramatic. The stoppage of effluent discharge to the river at Grayling in November, 1971, has already resulted in favorable changes in certain water quality parameters, and a positive response of sensitive bottom-dwelling organisms. Sewage discharge at Roscommon is also scheduled for diversion from the river. A stream improvement program is well underway to correct erosion problems, and to reduce sediment input along the Mainstream and major tributaries.

A Greenbelt zoning ordinance is in effect over much of the basin, to minimize ecological impact from continued development. With certain amendments, the ordinance could be a meaningful tool in retarding degradation of river frontage and stream ecology. Community development and its associated adverse effects should be restricted to upland areas, away from sensitive areas along the river channel. Recreational use must also be well planned and designed, in order to insure the longevity of this high-quality river system.

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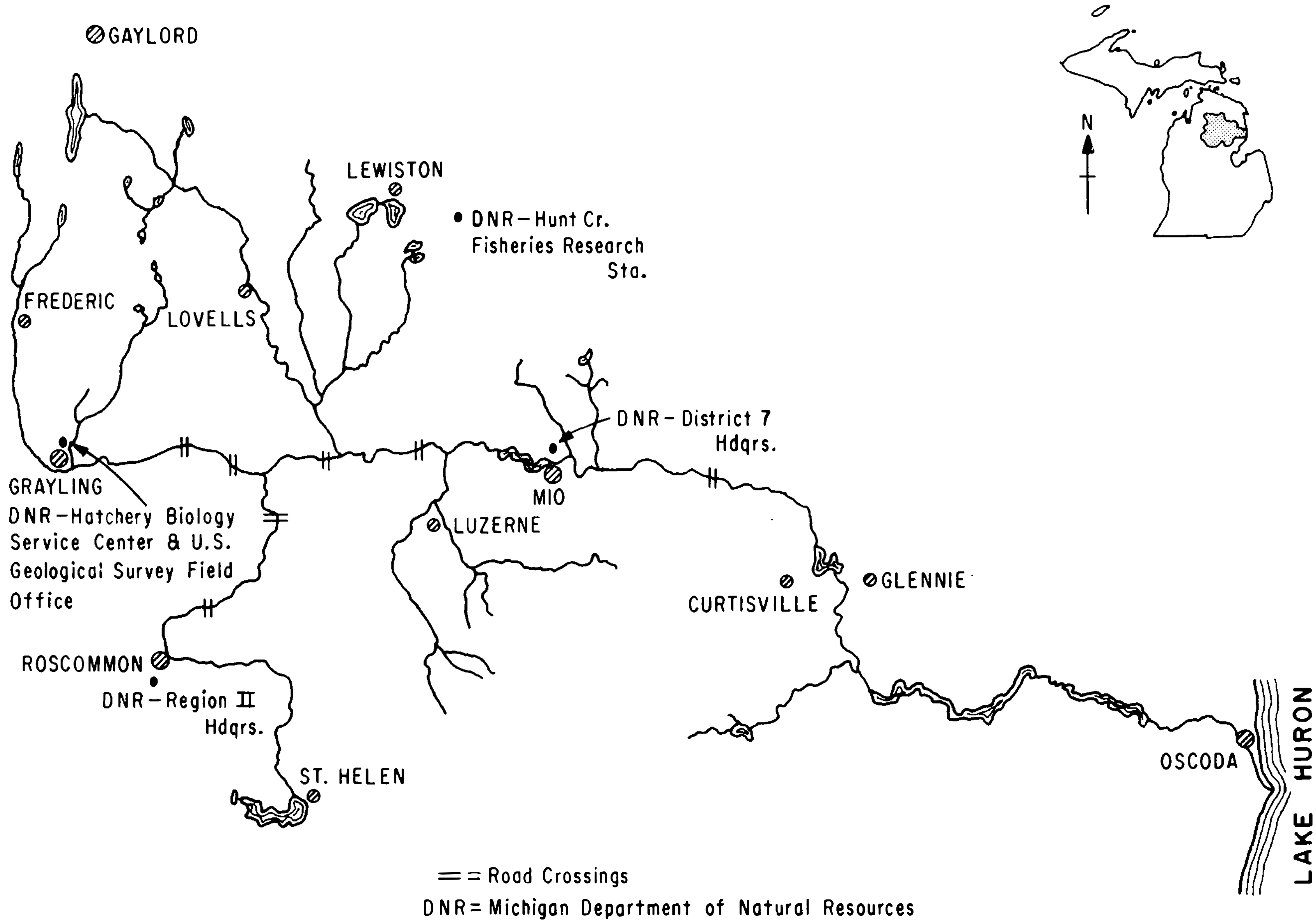

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AU SABLE RIVER BIOLOGICAL REPORT

SECTION I. INTRODUCTION

Objectives of the Study

The broad objectives relate to three "areas" of interest, as seen in the following.

1. Baseline and biological data, including:

   The chemical and physical aspects of water quality.
   The effect of impoundments on habitat and water quality.
   Levels of biological productivity at various points in the river system.
   Temperature regimes in the Mainstream and major tributaries.
   The density, diversity and distribution of bottom-dwelling insects and fish.
   Density of trout populations at various stations.
   Levels of sediment in transport.

2. Effects of human activities in the watershed on river habitat:

   Any unusual water quality parameters and probable causes.
   The qualitative nature of storm water runoff from Grayling and Roscommon and its effects on the river.
   Changes in bottom fauna and fish communities.
   Changes in stream channel below Grayling, due to dredging, filling and sedimentation.
   Long-term changes in the fish fauna, by comparison of collections from the 1920's with collections in 1972.

3. Preparation of management guidelines that would promote the longevity of the Au Sable River System (and other coldwater river systems) by protecting the natural characteristics of both streambed and uplands alike.

   The development of models that would allow more comprehensive management of the Au Sable Drainage, by providing predictive capabilities in assessing the probable results of various management options.

Description of the Watershed

Area Characteristics

The geology, topography and climatology of the Au Sable River Basin determine its suitability for trout fishing and other forms of recreation. The 1966 report of the Michigan Water Resources Commission (WRC) set the annual precipitation in the basin at 29 inches. Some 63% of this is fairly evenly distributed from April to September. The basin is well forested with second-growth pine and mixed hardwoods on the uplands; while cedar, spruce, fir, willow, and alder are most evident in the lowlands. As is common in Michigan, the drainage basin is small (1,800 square miles) with gentle slope. Soils are quite sandy and very pervious to infiltration of water. Under these conditions a high percentage of the precipitation goes to groundwater recharge, rather than to overland runoff to river channels. Consequently, the high groundwater contribution to stream flow (85% of flow at Mio is attributed to groundwater under normal conditions[1]) leads to a relatively stable discharge, even during hot summer months (Table 1). The most important factor in determining the suitability of a stream for trout is the maximum range of water temperature and its associated effects on dissolved oxygen. The influx of groundwater is important in stabilizing stream temperatures. Data in Table 1 demonstrate the stable nature of the Au Sable River, compared to other rivers around the state. The lower the ratio, the more stable the river system.

Table 1. Ratio of maximum to mean flow, for selected rivers in Michigan

Stream	Discharge ratio
Au Sable	3.7 : 1
Hunt Creek	3 : 1
Pine River	9 : 1
Rifle	20 : 1
Rouge	121 : 1
Red Cedar	30 : 1

For a thorough discussion of the interrelationships of the geology, topography and hydrology of upper Michigan watersheds in the Lower Peninsula and their effect on recreational values, the reader is referred to "Hydrology and Recreation on Cold-water Rivers of Michigan's Southern Peninsula," by G. E. Hendrickson and C. J. Doonan.

Early Use of the Watershed

The earliest use of the river was by Indians; then came the fur trappers. Both got fish from the river for food, and the river was an avenue of transportation. By 1860, lumbering was well underway in the

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1 Hendrickson, G. E. 1971. Hydrologist, U.S. Geological Survey. Personal communication. Determined by use of hydrograph records.

watershed, which eventually resulted in denuding of banks and uplands alike. Dams were constructed on the upper mainstream and on major tributaries to create holding ponds and provide a head of water for surging logs on their way downstream. Logs were cut, hauled to the river, and stacked along the banks. When holding spikes were released in the spring, the logs came tumbling and crashing into the stream, digging and tearing into banks and bed. Timing in release of logs was extremely important. If the water was too high, many logs would temporarily or permanently be lost in the swamp. If the water was too low, logs would hang up on riffles and sand bars so that considerable time and effort were necessary to break them loose (Maybee, 1960). Before railroads were used extensively, most logs were driven downstream to mills and shipping at Oscoda. The first railroad was established in 1872 (Grayling), and mills were built in Grayling in 1876, Lovells in 1896, and Frederic in 1912.[2] The establishment of the railway also opened the way for commercial exploitation of the prime native fish of the area--the Michigan grayling--heavy fishing and logging caused the demise of this fine fish. By the 1890's the harvest of pine was mostly over; "mop up" operations on isolated 40-acre parcels were underway; and cutting of hardwoods continued until around 1910. By this time all three species of trout (brook, rainbow and brown) had been introduced to the watershed, and were well established (Fish Commission Reports, 1873-1914).

It is clear that effects of the cutting and moving of logs must have had a severe and lasting effect on stream ecology. Introduction of sediments, silt, and nutrients from cut-over uplands would significantly accelerate eutrophication processes. The scouring effects of moving logs and the unrestrained surface runoff in spring would destroy fish eggs and fish food organisms in the river's substrate. Clear-cutting experiments in a west coast watershed have resulted in stream temperature increases from 16°C to 30°C, and diurnal fluctuation increases from 1.5°C to 16°C (Hall and Lantz, 1968). In this same study the level of suspended sediment increased 3-4 times over pre-logging levels. Dissolved oxygen in surface and intragravel samples dropped 2 mg/l.

Except for a brief try at farming around 1910 (Grayling Centennial Committee, 1972) to fill the economic void following the logging era, the land has been allowed to reforest itself with second-growth cover. Construction of hydroelectric dams during 1913 to 1924 blocked spawning migrations of anadromous fish species, and again disrupted the stream ecology.

In 1933, the "Lovells" fire burned some 30,000 acres of jack pine plain. The fire reached west along the upper east branch, burned the Guthrie Lake area on the northwest corner, and along the north branch on the east from about the "ford" in Otsego County south to Dam 4, over halfway from Lovells to Kelloggs Bridge. Although accounts of the fires made no specific reference to North Branch frontage, it is assumed that considerable bank cover was destroyed.[3]

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[2] Peterson, K. L. 1971. Outdoor sporting editor, Flint Journal. "River of Sands," Trout, Vol. 11, No. 4, 18p.

[3] Lovells fire, 1933. Mich. Dept. of Conservation, Fire Division Report.

Present Use of the Watershed

Chief use of the watershed today is for recreation. However, 59% of the upper watershed is in private ownership, and many persons live in the area, either seasonally or year-round. Greenbelt zoning ordinances are now in effect in Crawford and Otsego counties, in Mentor Twp. in Oscoda County, and in Mitchell Twp., Alcona County. These ordinances are designed to minimize the effects of streamside developments on stream biology and aesthetics.

Six hydroelectric dams from Mio to Oscoda, having pond areas ranging from 250 to 1,800 acres, dominate the character of the lower river. All still produce power today, although Mio Dam has not been regulated (periodically releasing more water to meet peak power needs) since 1964 except for brief periods during recent winters.

Gerth Hendrickson (1963), reported that canoeing became economically important in Grayling in the mid-thirties. By 1963, weekend canoe traffic below Grayling was "almost beyond belief" according to Hendrickson. Quotas, time, and location restrictions were placed on canoeing activity as part of river use rules adopted by the DNR (Department of Natural Resources--Michigan) for portions of the Au Sable, Manistee, Pine, and Pere Marquette rivers in 1972. These rules have been challenged in the courts by the Recreation Canoeing Association (representing most of the canoe liveries in the northern Lower Peninsula) and as of this writing, it appears certain that they will not go into effect during 1973.

While it is common knowledge that stream structures (log jams, sweepers, deflectors) have been removed or disturbed (perhaps unmindful of habitat destruction) by canoeing interests, no documented evidence of such removal could be found except in news articles and letters.[4] It is also true that cottage development has in many cases removed natural bank cover (brush and trees) and substituted fill dirt, lawns, and sea walls. There are at least two areas below Grayling where the river bottom has been dredged to provide fill for building sites in low-lying areas. There are several instances where the river has been channeled across bends or adjacent to the stream channel to develop private ponds supplied with borrowed river water. In all fairness, it should be pointed out that some river front property owners have left buffer zones between cottage and waterway, have left banks in a natural state with modest unobtrusive dock facilities, and have even stabilized existing erosion problems.

Trout fishing continues to be a major recreational use (Fig. 1), as it has been ever since trout were introduced in the late 1800's. While trout are still plentiful, the fishing pressure has increased many times since the "good old days", and the catch is accordingly more widely distributed among anglers, which result in a lower catch rate per fisherman. Fishing pressure, according to District Fish Supervisor Gary Schnicke, has increased appreciably during the past five years. Pressure (competition for space between fishermen) is the highest during the insect "hatches" in

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[4] Wicklund, Roger. DNR fisheries executive, 1965. Letter to Dr. Wayne H. Tody refers to removal of trout cover to allow canoe passage, and recommends a halt to this practice.

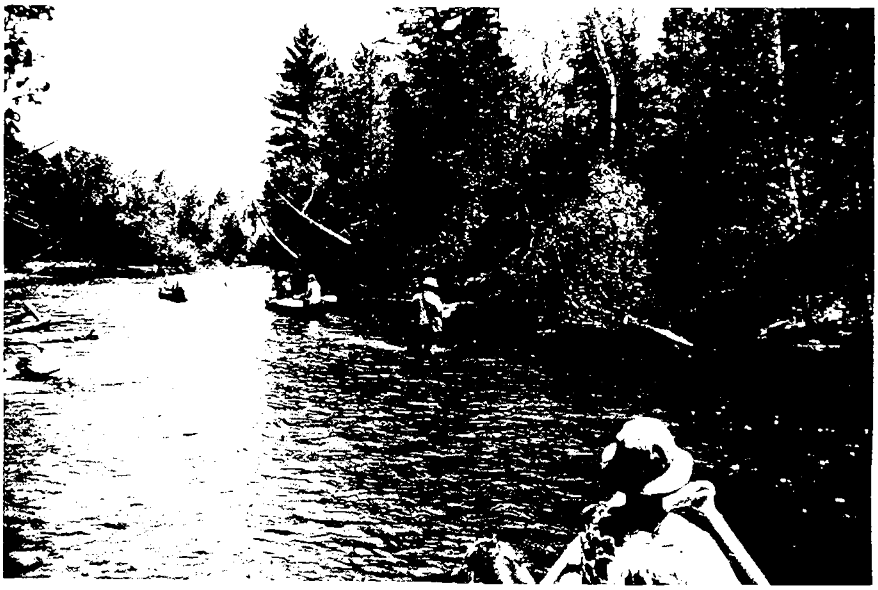

Figure 1. Upper: Fly fishing for trout while floating the Au Sable Mainstream in an Au Sable River boat.

Lower: This scene on the Au Sable South Branch (Mason Tract), is typical of the heavy use of the area by both fishermen and canoeists.

May and June. A census of anglers was carried out during June 2 to July 6, 1973, on the Mason Tract of the South Branch, to determine whether a permit system would be desirable to restrict the number of fishermen using these waters during this part of the season.

Other recreational uses include camping, sight seeing and even swimming during the hot months. It is evident that all uses have an impact on habitat quality. A visual inspection of erosion and litter at access points makes this very clear. Therefore, any controls implemented to protect the river's identity will affect all users.

Water Supply

(Great Lakes Basin Commission, 1971)

Under the Water Resources Planning Act of 1965 (P.L. 89-80), the Great Lakes Basin Commission is engaged in an overall appraisal of water supply requirements in the Great Lakes Region. The subplanning area of northeast lower Michigan includes the Au Sable Basin and 11 counties as follows: Cheboygan, Presque Isle, Otsego, Montmorency, Alpena, Crawford, Oscoda, Alcona, Ogemaw, Iosco and Arenac.

Projections were made for the municipal, industrial, and rural water needs for the sub-basin to the years 1980, 2000 and 2020. Overall water withdrawal increased 15 percent between 1960 and 1970 (to 39 mgd), and is predicted to increase another 11 percent (to 42 mgd) by 1980. By the year 2000 water withdrawal is to reach 55 mgd (up 28 percent); and by the year 2020, total water withdrawal is expected to be some 97 mgd (a 71 percent increase over the year 2000). The yearly increase in water use averages one and one-half gallons per capita per day. Presently, the daily per capita use is 150 gallons, of which 60 are for residential, 20 commercial, 50 industrial, 10 public, and 10 are lost due to inefficiencies in the system.

Potential yields of groundwater can be computed by storage capacity and storage yield relationships. The amount of natural groundwater discharge can be estimated from the base flow of unregulated streams, which represents the outflow of the groundwater system of the area. The seventy percent flow duration level of surface streams is used to determine a sustained yield estimate of groundwater resources. Areas with significant groundwater storage will contribute much of the stream discharge, and have high "70 percent" values on the order of 0.4 to 0.78 cfsm (cubic feet per second per square mile). The Au Sable has the highest value in the subbasin, at 0.6 cfsm. The greatest groundwater potential for the entire Great Lakes drainage lies in North Central Michigan, and in the Adirondacks.

The gross amount of water resources in each Great Lakes Region was judged ample to provide for all future water uses if properly managed. Such management would prevent continuous withdrawal of water in excess of the recharge of a local system. The "construction of wells near streams in order to effect the highest sustained yield, can decrease the flow of streams during low-flow periods" when the demand is the highest. The wells that supply Grayling are near the river, and increased pumpage in the future could reach levels that would effect streamflow. To avoid such a situation, new wells should be further removed from the river channel, as suggested by Gerth Hendrickson, USGS (1966). The most concern noted, regarding pollution of water supplies, was from solid waste disposal, industrial wastes, oil field brines, and road salting.

Of course, all of these potential hazards to groundwater reservoirs are present in the Au Sable Basin. The Beaver Creek field borders on the extreme west side of the basin, and there is some activity in the upper reaches of the North Branch. The only major oil field in the watershed is the Lake St. Helen field. The upper South Branch flows through this field and coincidentally, has the highest chloride levels recorded in the basin. In 1967, after the field was subjected to deep fresh-water injection in order to build up pressure to increase oil production, groundwater samples near Sherman Bridge (downstream from the bridge) jumped from 3 ppm in chloride concentrations to 22 ppm. Mr. Benjamin Gunning, State Field Geologist at Mt. Pleasant, reports that losses of oil and brine from lines crossing the South Branch at McCrea Bridge, occurred on April 6, 1972. These losses required clean-up work downstream, and the location fits well with increases in chloride levels from water samples collected in the upper South Branch.[5]

In regard to road salting, Mr. Tom Herbert, State Highway Department geologist, reported that test wells placed near the I-75 expressway near the Roscommon-Crawford County line (nine wells, all but two of which are within the right-of-way fences) have failed to show any dramatic loading of the groundwater.[6] Concentrations found (16-20 ppm) are close to background chloride levels found naturally in groundwater in the area, according to Mr. Herbert. While literature from other states in the midwest reported levels of chlorides in groundwater near some highways in ranges of 4,000-6,000 ppm, the highest found in Michigan was 3,800 ppm. This was found in ground water in a heavily salted area north of Flint. Herbert states that residual chlorides from use on road surfaces are rapidly washed away and do not normally penetrate frost layers. In this area of northern Michigan, sand is now mixed with salt, and present use is turning more heavily to sand. Salts are most effective in temperature ranges of 25 to 32°F, and are therefore less efficient than sand much of the time.

The Crawford County Road Commission also reports mixing salt with sand in servicing over 200 miles of state and county roads.

While it is doubtful that levels of chlorides presently used on roads in the Au Sable Basin have a serious effect on groundwater supplies, storm water samples from village surfaces in winter revealed that chloride

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[5] Gunning, Benjamin. State Field Hydrologist (Mich.). Report of investigation into chloride levels in Upper South Branch, 5/16/73.

[6] Herbert, Thomas. State Highway Department Hydrologist (Mich.). Personal communication, 1973.

levels were twice as high (73 ppm, average) as samples in summer (36 ppm, average). One sample taken on April 11, 1972, from the storm drain at McMasters Bridge in an area of low habitation, contained 45 ppm chloride. These data indicate that there is a greater potential danger to streams from direct surface runoff of road salt, than from infiltration into groundwater supplies. Monitoring wells is a must for early detection of contamination of groundwater resources.

Although the data for 70% flow duration indicate that the Au Sable River Basin has the "greatest groundwater potential in the Lake Huron Basin," further study is necessary to delineate the size and shape of aquifers. In order to effect long-range planning, it will be necessary to manage aquifers on a regional basis to develop the potential of underground water resources. A network of wells to monitor chemical quality will also be needed to "chart the changing conditions imposed on the hydrologic system by man."

Population increases over the past 10 years (1960-1970) in the upper Au Sable Basin (above Mio) show that people are choosing country living over the major villages (Michigan census, 1970). The population in these villages (Gaylord, Grayling, and Roscommon) increased only 9%, whereas township populations increased by 50% (Table 2).

The 70% flow duration discharge for the Au Sable River at Mio is equal to 1.7×10^{11} gallons in a year. The estimated amount of groundwater pumped from storage in the upper watershed in 1970 (1.4×10^{9} gallons) totals 0.81% of the normal groundwater discharge. Of course most of this withdrawn water is used and returned to the system. In 1960 an estimated 0.62% of the groundwater discharge was withdrawn from municipal, industrial and rural wells in the upper basin. These figures indicate that less than 1% of the available groundwater supply is presently being used, and that most of this amount is directly returned to streams or to groundwater reservoirs. The problem then, involves a deterioration in quality rather than diminished quantity.

While the water withdrawal increased 15% for the 11 counties that make up the sub-basin, as described earlier, the water withdrawal in the upper Au Sable watershed increased by 29% between 1960 and 1970. The demand is increasing faster in the upper Au Sable than in the sub-basin as a whole. The chief danger is having too many wells in close proximity to the stream, which could affect streamflow when low-flow periods and peak demand coincide. During the past 10 years, it appears as though the demand for water has become more stable throughout the year (Fig. 2). The peak activity in July in 1963 in both Gaylord and Grayling has become moderated in 1972, especially in Gaylord. Part of the difference may be from the 6 million gallons the military purchases from Grayling each summer. The reason that the demand for water is now spread more evenly throughout the year, is likely due to the increase in winter activities (especially snowmobiling). Figure 2 also shows that while annual pumpage by Grayling has lagged behind Gaylord the past 10 years, the Grayling withdrawal has increased more rapidly since 1968 to the point where withdrawals by the two cities were nearly the same in 1972. Roscommon wells were equipped with meters in 1971, and 87.3 million gallons were withdrawn in 1972.

Table 2. Population and water pumpage changes in the upper Au Sable Basin (above Mio) between 1960 and 1970. Municipal and industrial water pumpage figures are based on reports from city manager, USGS, and WRC reports. The pumpage based on township population figures are estimates using an average figure of 150 gallons per day per person [1]

County or village	Population 1960	Population 1970	Percentage change	Water pumpage (million gallons) 1960	Water pumpage (million gallons) 1970	Percentage change
County[2]						
Crawford (6)	2,956	4,339	46.8	161	238	47.8
Montmorency (1)	679	1,013	49.2	37	55	48.6
Oscoda (3)	1,591	2,390	50.2	87	131	50.5
Otsego (5)	2,467	4,088	65.7	135	224	65.9
Roscommon (4)	2,290	3,222	40.7	125	176	40.8
Subtotal (19)	9,983	15,052	50.8	545	824	51.1
Village						
Gaylord	2,568	3,012	17.2	124	169	36.2
Grayling	2,015	2,143	6.3	128	102	20.3
Roscommon	876	810	-7.5	64	87	35.9
Subtotal	5,459	5,965	9.2	316	358	13.2
Grand total	15,442	21,017	36.1	861	1,182	37.2

1 Adding industrial pumpage (230 million gallons) from separate wells to municipal and rural figures, an estimated 1,412 million gallons was pumped in 1970.

2 Number of townships in basin in parentheses.

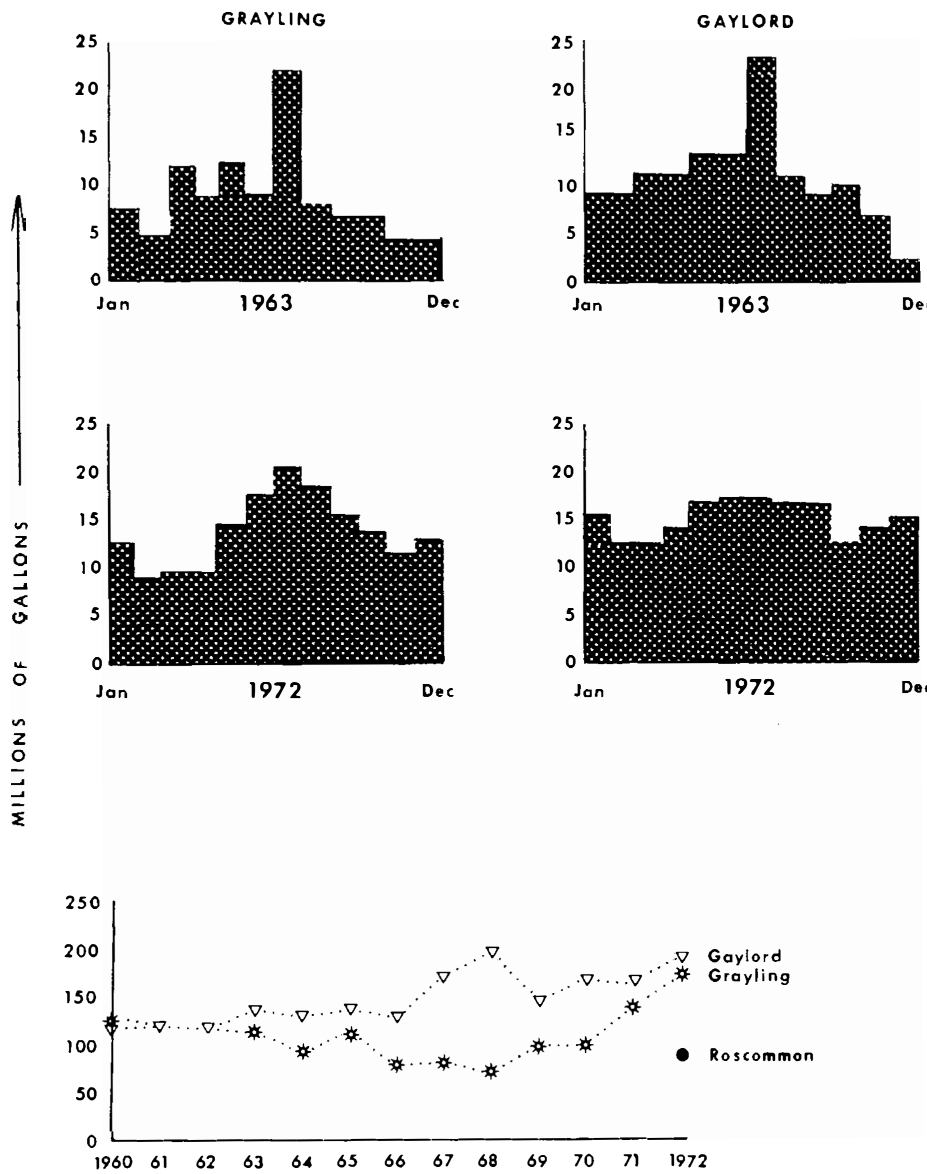

Figure 2. Upper: Comparison of annual municipal water pumpage at Gaylord and Grayling for 1963 and 1972.

Lower: Annual water pumpage from municipal wells in major villages in the Au Sable Basin

Consumptive use of water is defined as that part of withdrawal that is lost to the system because of transpiration and evaporation. The most highly consumptive human use is for watering lawns. Perhaps diversion of water for ponds should be classified as consumptive, as this use causes water temperatures to rise, increases productivity, and effects a loss from increased evaporation.

The following calculations are based on figures furnished by Mr. Melvin Nielson, Grayling Golf Course Official, and Mr. Dale Pettingale, U.S.G.S. hydrologist at Grayling. The pump supplying river water for golf course irrigation has a capacity of 620 gallons per minute. The pump operates for about 8 hours a day excluding Sundays, for a total of 400 hours during July and August. Operating at something less than peak capacity, a total of 12 million gallons are pumped during the 2-month period, averaging 240,000 gallons a day.

Using the above figures, the portion of the available streamflow being utilized during this period (to water the golf course) can be computed. The average daily discharge in July and August at Grayling is 70 cfs or 45.2 mgd. The withdrawal of water for golf course irrigation would then represent 0.5% of the available flow. An expansion of the course to 18 holes could then use 1.0% of the flow. The 70% flow duration at Grayling is 57.2 cfs, or 40 mgd, and the golf course irrigation would then use 0.6% of the flow. Although this represents a small portion of the available flow, increased uses of this type could result in diminished streamflow during summer months. This is because most of the water withdrawn is lost through evapo-transpiration.

Many flowing wells can be found between Grayling and the mouth of the North Branch, and according to geologists this does not presently represent any significant loss of water to the system. However, flowing wells on the north side of Houghton Lake numbered in the hundreds back in the 1940's when cottage development was increasing, and now none are flowing. Accordingly, there is a need to locate abandoned flowing wells (drilled by gas companies, farmers and cottage owners) and cap them to conserve groundwater supply.[7]

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[7] Dyer, S. A. Regional Geologist, Roscommon (personal communication).

SECTION II. METHODS

This section gives the dates and locations of data-collection efforts, techniques and gear used in sampling, and it describes analytical methods and laboratory facilities where appropriate.

Water Quality

Sampling was accomplished on a monthly basis from December, 1971 to November, 1972. Sampling was done at 26 base stations on each collection run; and, for supplemental data, once or more at 28 other locations. Complete collection data are found in Appendix Table I.

Water temperature, dissolved oxygen, and conductance were determined in the field using a pre-calibrated Delta Model 80 oxygen meter, and a temperature-compensated conductivity meter with a direct read-out in μ mhos per centimeter. The nitrate-nitrite nitrogen, soluble phosphate-phosphorus, and chlorides were run on an auto analyzer at, and courtesy of, the Bureau of Sport Fisheries and Wildlife in Ann Arbor. The remainder of the chemical determinations were made at the Institute for Fisheries Research (IFR) Laboratory in Ann Arbor, following Standard Methods (13th ed.). Total and fecal coliform counts were made by the Michigan Department of Public Health in Lansing.

Storm Water

Samples were collected from storm drains at eight locations in Grayling and two in Roscommon during 1972 and early 1973. Tributaries to the South Branch in Roscommon were also sampled at three locations. Thirty-eight samples were collected, all but eight in Grayling. Three runs of river water samples were made above and below entrance of major storm drains to test loading effects on water quality. These samples were processed in the same manner as regular water samples. The Water Resources Commission (WRC) Laboratory in Lansing processed the last two runs in 1973. Storm water collection data appear in Appendix Table II.

Periphyton

Artificial substrate, consisting of a high density styrofoam material, was used to colonize periphytic algal organisms during the period from June 11 to September, 1972. Samples were collected by slicing off a thin veneer of styrofoam from two surfaces, each 3 inches square, one facing upstream and one facing downstream (Fig. 3). The collected "slices" were then dissolved in a 95% acetone solution in a dark bottle, refrigerated, and delivered to the WRC lab in Lansing. There the optical density of the solution was determined, the sample was acidified and corrected for Pheophytin interference, and periphyton was expressed as "chlorophyll A" in micrograms per square centimeter. This measurement represents the primary productivity in terms of standing crop.

Figure 3. Upper: An investigator takes a thin slice of styrofoam substrate that has been colonized by the primary producers (algal cells) in the stream.

Lower: A modified Hess Sampler is being used to collect a quantitative sample of bottom-dwelling organisms.

Benthos

During the summer of 1972, bottom samples were collected with a modified Hess Sampler at 49 sites in the basin. For nine of the locations, three one-square-foot samples were analyzed; while single samples were examined for the remaining 40. Of the 49 sampled sites, 29 corresponded to base stations for water quality, 14 to fish seine-collection areas, and six matched stations used by the WRC in benthic investigations during 1966. Samples at each station were stratified into three water depths of six, twelve, and twenty-four inches with one sample taken per stratum. Where single samples were examined, an effort was made to select the most representative sample for that station. In selecting substrate for sampling, gravel was chosen and vegetation avoided where possible. Substrate type is described in Appendix Tables III, IV and V. All samples were processed during the fall and winter of 1972-73. Insects were floated and strained through a U.S. standard No. 30 soil sieve, and identified at the IFR laboratory in Ann Arbor. Tolerance status was assigned according to tables available in previous WRC reports.

Fish Collections

Electrofishing surveys. Collections were made between 1966 and 1972 using 3-man to 10-man crews, and a 230-volt DC shocker. Shocking time varied from 10 to 60 minutes (ave. 30 min.), depending on the nature of the habitat, size of stream, and purpose of the survey. The number of fish captured ranged from 15 (in a small warmwater tributary, 10 minutes of collection time) to over 300 (East Branch of Big Creek, 50 minutes). All species were identified and counted. Collection locations and classifications are denoted in Figure 17.

Trout population estimates. Baseline stations were first sampled from 1959 to 1963 in the Mainstream (four stations), from 1960 to 1963 in the South Branch (four stations), and from 1960 to 1967 in the North Branch (three stations). These stations are all in the upper river, above Mio, and all were sampled at least three times during this baseline period (Fig. 4). Below Mio Dam downstream to Comins Landing, six stations were first sampled in the mid-sixties and again in 1971. Two complete shocking units were employed, each with a 5-man crew. Sampling was accomplished during a drawdown (water held back at Mio reservoir) to restrict flow and make wading possible. Five stations were also established on the East Branch in 1971. Stations at Stephan's and Wa Wa Sum on the Mainstream were sampled in 1971 and again in 1972 along with all stations in the upper river, excluding the East Branch. Fall populations were sampled and trout population numbers were estimated using mark-and-recapture techniques (Petersen formula). In inch groups where no recaptures were made, actual capture numbers were used as the estimates. The estimates for each inch group were then merely summed to arrive at an estimate of total population number for that trout species. The number of trout per acre was determined by computing the area of stream sampled. This was cone by multiplying the length by the average width of the stream segment surveyed, and then subtracting the area of any islands present. Station locations for the upper watershed appear in Figure 17.

Figure 4. Upper: Electrofishing at the "Pullover" (a trout population estimate station), several miles downstream from Grayling on the Au Sable Mainstream.

Lower: A small minnow seine used during the 1972 fish collections, to duplicate techniques employed by the investigators of the 1920's.

Seine collections. These collections were made during the summer of 1972 for comparison with a similar survey made back in the 1920's. A variety of seines were used according to the characteristics of stream reach sampled, which included: small feeders with heavy cover and many stumps and logs; marshy bayous with silt and dense rooted aquatics; moderate sized streams with shallow riffles and deep pools; large stream areas with log jams, deep holes and swift current. Seines employed were as follows: four-, six-, eight-, and ten-foot common-sense minnow seines averaging four feet in height; twenty-five, and fifty-foot bag seines, five feet in height, were used in the large river situations. Seining efforts were accomplished by two-man teams, or combinations of two-man teams at all stations (Fig. 5). Sampling locations were based on descriptions accounted in records of collections made in the 1920's (Fig. 20). All possible habitat types within these described areas, were sampled. Individual seining efforts were continued until no new species were captured. All fish collected were preserved in 10% formalin for later identification. All trout over 5 inches long were measured, recorded and released.

Impoundment surveys. Four of the largest hydroelectric basins were surveyed, using a combination of experimental gill nets, trap nets, and electrofishing with the boom shocker.

Foote Basin - May 15-17, 1972--Twenty-three man days, ten gill net lifts, eight trap net lifts, and 150 minutes of electrofishing at night.

Cooke Basin - May 22-24, 1972--Twenty man days, eight gill net lifts, eight trap net lifts, and 240 minutes of electrofishing at night.

Alcona Basin - June 12-14, 1972--Sixteen man days, six gill net lifts, eight trap net lifts, 300 minutes of electrofishing at late evening and night.

Mio Basin - July 6-21, 1970--Twenty-four man days, sixteen gill net lifts, fifteen Fike Net lifts, four trap net lifts, 870 minutes of electrofishing.
October, 1970--360 minutes of electrofishing.
July 13-20, 1972--Two man days, 300 minutes of electrofishing.

Mio Basin was surveyed by District 7 personnel, and equipment for all surveys was furnished by District 7. Age and growth data for game fish captured was prepared with technical advice from biologists at the Institute for Fisheries Research. Locations of the hydroelectric basins surveyed for fish population in 1971 or 1972 appear in Figure 19.

Sediment

Six series of samples were collected at Lovells on the North Branch, at Smith's Bridge on the South Branch, and at County Pond 608 on Big Creek (tributary to North Branch).

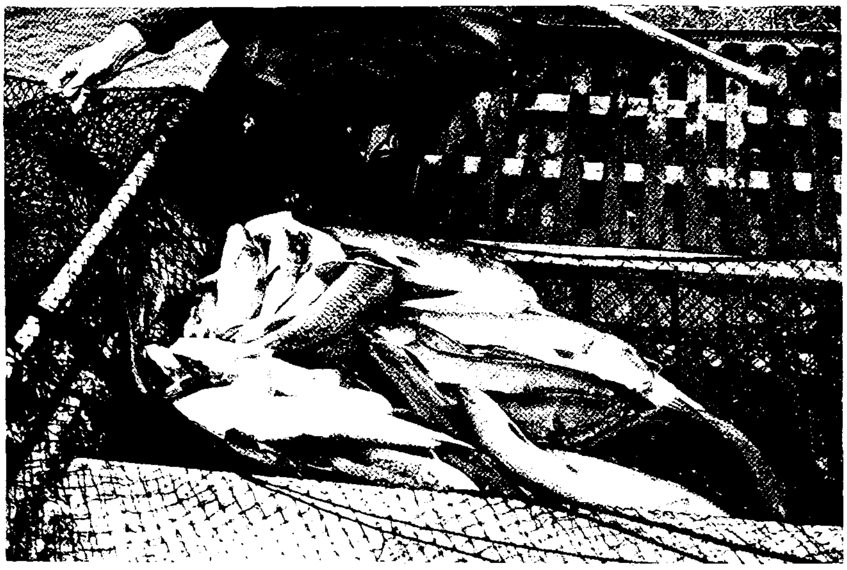

Figure 5. Upper: Floating the Au Sable by canoe, loaded down with gear, to sample fish populations in inaccessible areas on the Mainstream. Many miles of river were so traveled during the 1920's by Professor C. L. Hubbs and associates in making fish collections.

Lower: A trap net lift at Alcona Dam Pond, 20 miles below Mio on the Mainstream, containing mostly rough fish species (white suckers and dogfish).

Mr. Edward E. Hansen, Hydrologist of the Unites States Forest Service (USFS), at Cadillac, provided technical assistance and ran a set of duplicate samples for the Lovells station to help verify laboratory procedures. A DH-48 type sediment sampler (with a 1/4-inch orifice) was used, and the individual samples were collected in 1-pint glass milk bottles. Four to six bottles were collected at each station, depending upon the volume of flow.

Samples were collected over natural rubble bottom types where flow would be most turbulent, so that the largest percentage of sediment (bed load) would be in suspension and available in the sampling zone. The "equal rate of transit" technique was used, sampling at several verticals across the stream width, according to the stream velocity at that point. An attempt was made to collect core samples on the river bottom below Grayling where sediment inputs from the I-75 bridge project had been deposited. No layering could be detected. This was not unexpected, because sand does not core well, and because the sandy bottom is constantly shifting.

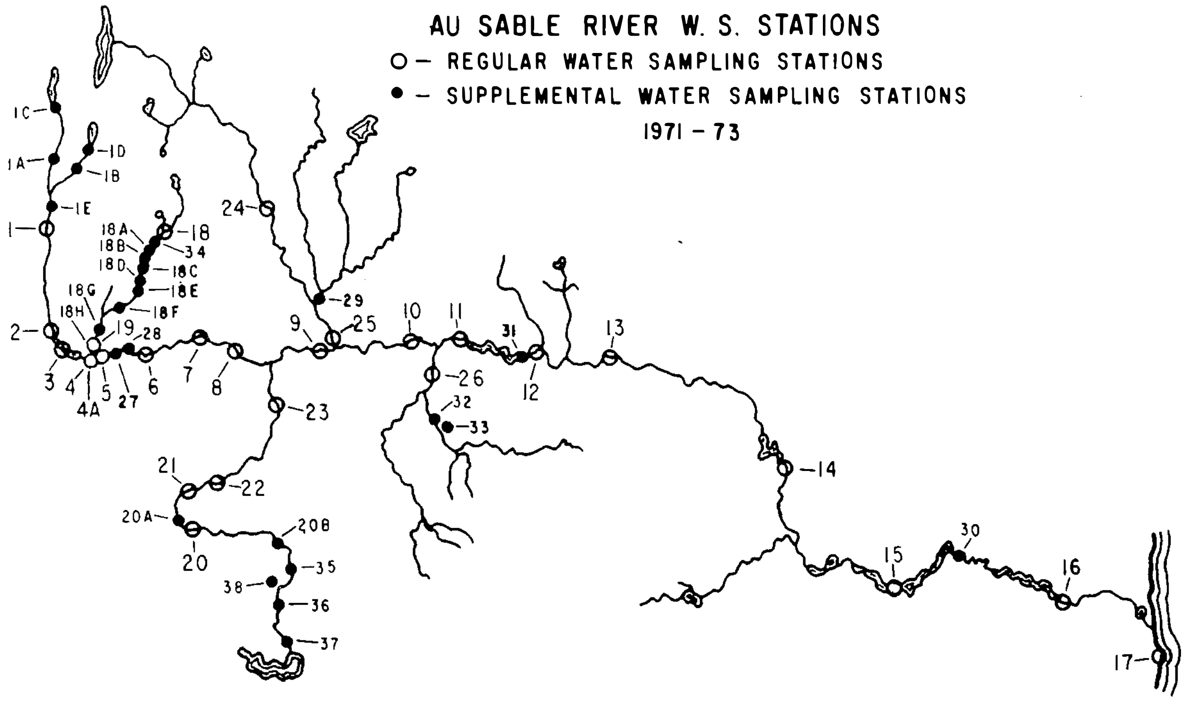

Figure 6. Locations of water sampling stations for the Au Sable River Watershed Project.

SECTION III, PART A. WATERSHED INVESTIGATIONS

Water Quality

Under rules of the Michigan Water Resources Commission (June 28, 1967), the Au Sable River System will be protected for total body contact, except for clearing zones below sewered communities. This will soon apply only to the South Branch below Roscommon. In Table 3 the WRC standards are compared with present conditions in the watershed (Fig. 6).

Table 3. Water quality standards adopted in 1968 by the Michigan WRC for recreational streams in terms of total body contact and intolerant coldwater fish, compared with present conditions in the Au Sable River

Parameter	WRC Standards	Au Sable River, range of
Nutrients	Levels low enough to prevent stimulation of algae, weeds, and slime growth injurious to the designated use.	NO_3+NO_2-N: 2-90 ppb, summer 95-165 ppb, winter Total soluble phosphorus: 11-28 ppb, summer 16-31 ppb, winter
Temperature, dissolved O_2 (for cold-water fish)	Allowable increase of 2°F at edge of mixing zones. D.O. not under 6 ppm any time.	Temperature series indicate up to a 7°F increase from above to below impoundments. D.O. recorded at 5 ppm during diurnal studies.
Chlorides	Monthly average not over 125 ppm.	<15 ppm. Winter sample under ice, in the S. Branch, 29 ppm.
Total dissolved solids	Not over 500 ppm as a monthly average or over 750 ppm at any	(60% of conductance) 180-198 ppm, summer average 167-220 ppm, winter average
pH	6.5 - 8.8	7.6 - 8.4
Total alkalinity	No WRC standard. USDI - not <20 ppm.	110-170 ppm.
Total* coliforms	Not over 1,000 org/ 100 ml.	2,300-11,000 org/100 ml, summer <100-500 org/100 ml, winter
Fecal coliforms	Not over 200 org/ 100 ml.	<10-60 org/100 ml, summer <10-10 org/100 ml, winter

* Not included in Water Resources Commission (Michigan) proposed general rules of October 27, 1973, as Part 4. Water Quality Standards added to The General Rules of the Commission.

Nutrients

References in the literature to levels of nutrients that could stimulate nuisance growths of aquatic plants are scarce. Martin (1972) states that nitrate nitrogen at 100 ppb can cause excessive algal blooms in lakes, when essential concentrations of other nutrients are present. Flowing waters can contain more ammonia and nitrate without problems than can lakes. The Federal Water Pollution Control Administration (FWPCA, 1968) suggests that problems may occur when phosphorus concentrations exceed 100 ppb in rivers, or 50 ppb where streams enter reservoirs. Nitrogen from human sources include waste water, urban runoff, and septic tank seepage. High levels of nitrates are also common in groundwater, where overlying soil types are organic or marshy in nature. This is the situation in the upper headwaters of the Au Sable Mainstream and East Branch where nitrate levels are highest (Fig. 7). Nitrogen is extremely soluble in the nitrate form. Nitrates and nitrites are on the order of three times higher in winter, than during growing seasons when they are quickly taken up by aquatic plants, whereas phosphorus is only slightly higher in winter samples (Fig. 8). This suggests that availability of nitrates may be a limiting factor to plant productivity (Martin, 1972).

Martin further reports that streams from forested areas, with little habitation and little land use, averaged 130 ppb nitrate nitrogen. This is precisely the average value for the Au Sable River in winter when highest nitrate levels are in solution. Averages for soluble phosphorus were somewhat higher in the Au Sable samples. The averages in areas of little use were 7 ppb, compared to 20 ppb for the Au Sable. Although phosphate concentrations in village surface runoff, and the Roscommon WWTP, are high, natural background levels are also higher in the Au Sable Basin than in the "areas of little use" referred to.

Because of low turbidity, shallowness and moderate velocity, the upper Au Sable Watershed is very sensitive to over enrichment. Nutrient inputs from sewage treatment plants at Grayling and Roscommon have stimulated growth of algae and rooted aquatics below both of these communities. Below Grayling (prior to shutdown of the sewage treatment plant) the resultant diurnal oxygen values were below 5 ppm. (Refer to Part B of this section, Figures 36-39, for changes in water parameter values noted since November, 1971, when the Grayling sewage effluent was diverted to a lagoon.)

Temperature and Dissolved Oxygen

These two factors are closely related, as cooler water is capable of holding more oxygen. Au Sable water temperatures are characteristically higher in the headwaters because of large lake surface areas (nearly all of its branches are formed by lake outlets) exposed to warming and the comparatively low volumes of flow, low velocities and groundwater availability (Fig. 9). Other areas of the river where temperatures normally exceed 70^{o}F are in and below impoundments, and in low-lying areas with little groundwater input (Fig. 9).

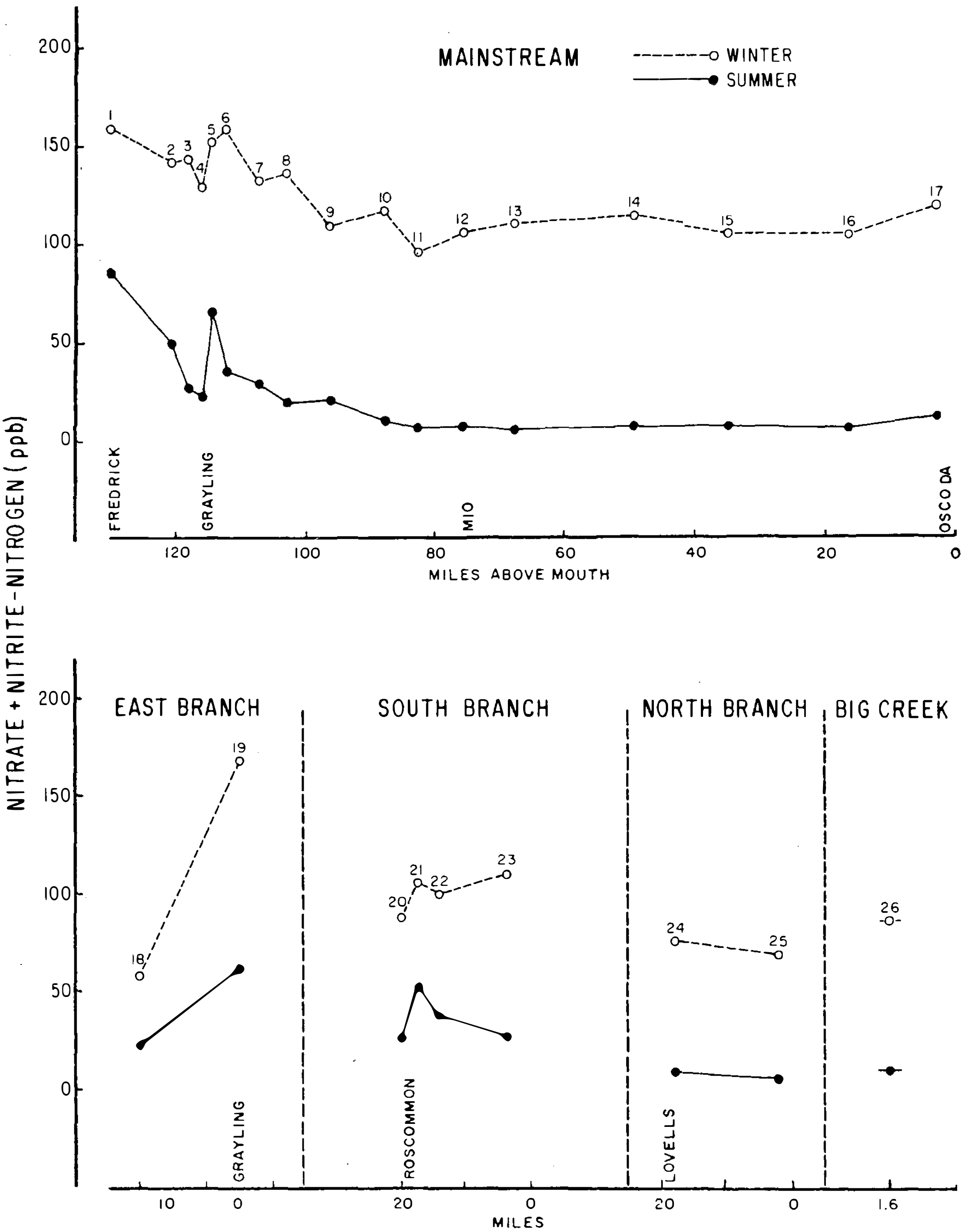

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Figure 7. Averaged winter and summer nitrate-nitrogen levels from monthly water samples

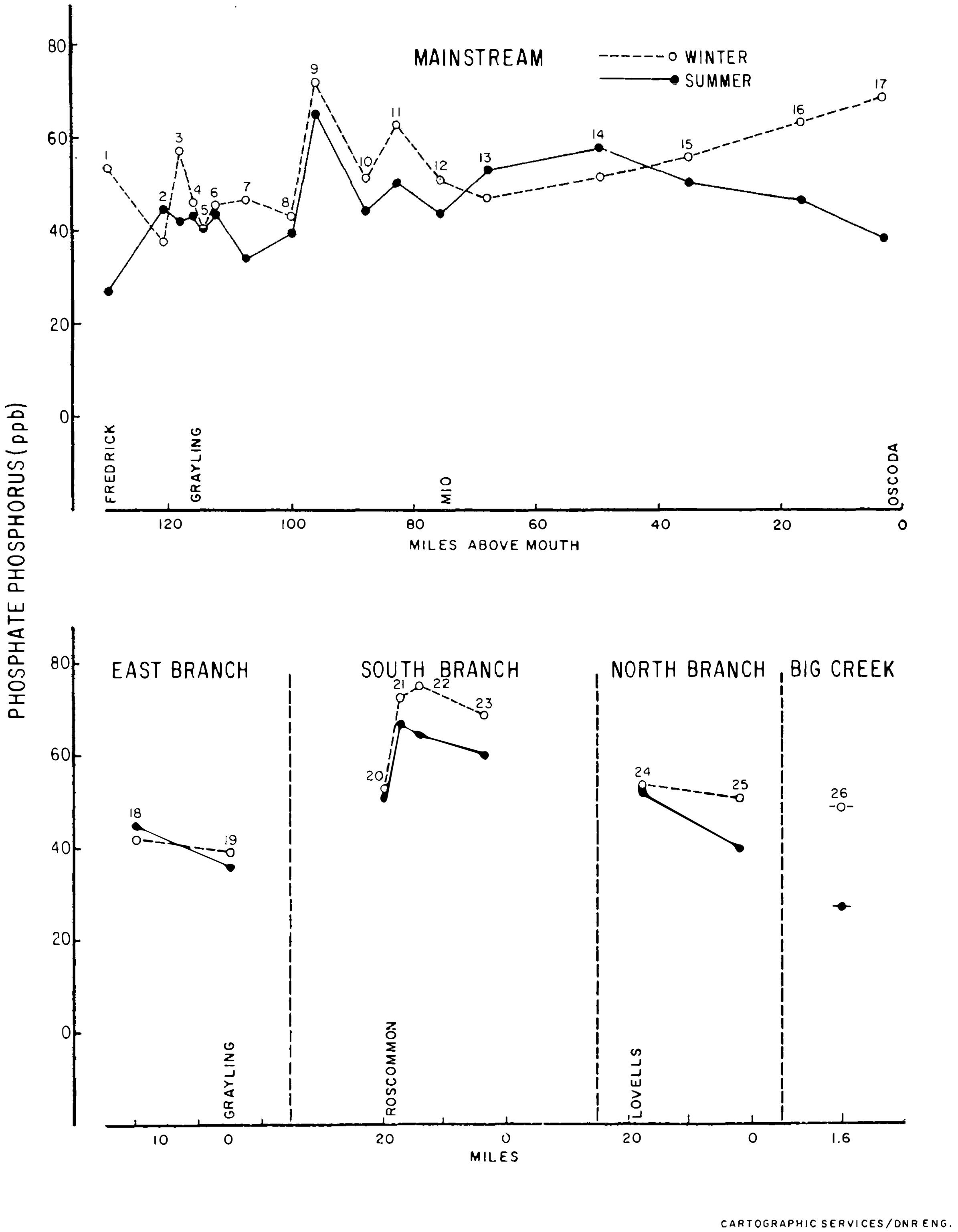

Figure 8. Averaged winter and summer phosphate-phosphorus levels from monthly water samples.

Effluent from treatment plants has increased productivity and thereby depressed dissolved oxygen levels during night-time hours. Sewage effluent at Grayling is no longer discharged directly to the stream, having been diverted to a lagoon in November, 1971. The plant at Roscommon presently has only primary treatment. Construction is under way near Roscommon to build lagoons as part of a spray-irrigation sewage disposal system. The new system is scheduled for completion by October or November of this year (1973) and will be a boon in upgrading the quality of several miles of stream that extend into the Mason Tract.

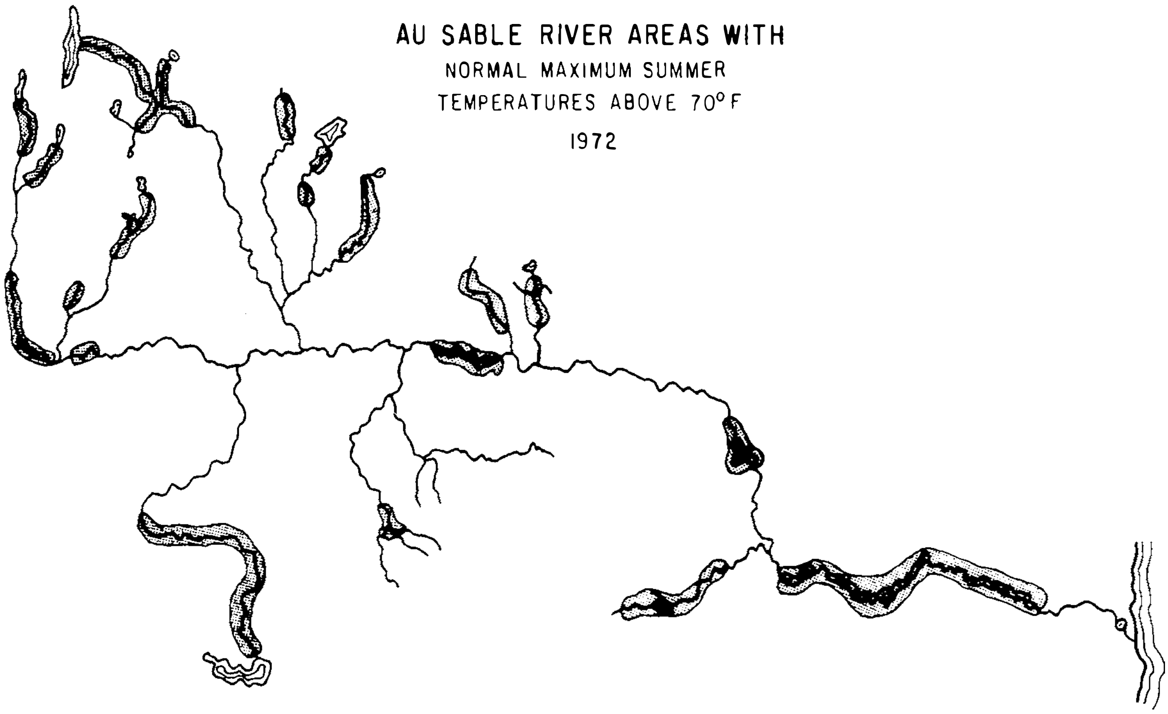

Figure 9. Temperature regimes in the Au Sable River System.

Chlorides

Although chlorides have been relatively high in the upper South Branch, levels in the basin as a whole are well within the WRC standard of <75 ppm (Fig. 11). Natural chloride concentrations appear to be associated with drainage areas. Chloride compounds are readily dissolved from rock material by surface and subsurface waters (WRC, 1970). A concentration of several hundred parts per million is required under most conditions, to impart a salty taste, or to harm aquatic organisms. The lowest concentration reported to be harmful to fish is a 400 mg/1 reading that caused problems with trout (Adams, 1940). For water supply purposes, requirements for industrial supply (<50 mg/1) are the most stringent due to the corrosion of steel (McKee, Wolf, 1963). Therefore, the source is usually of more importance than the quantity, where a sudden increase may indicate pollution. With the exception of the

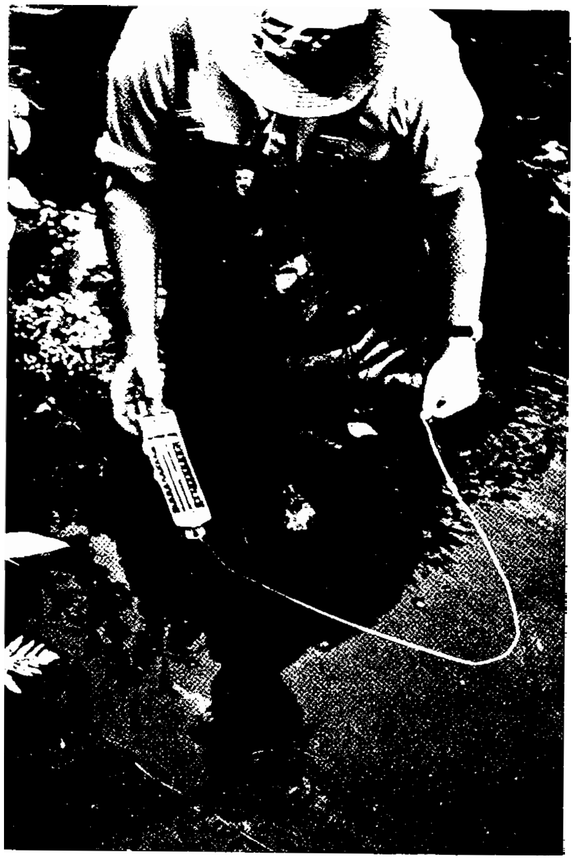

Figure 10. Upper: A fisheries investigator recording maximum-minimum temperatures along the Au Sable Mainstream.

Lower: An investigator using a current meter to measure stream discharge at Pollack Bridge, 4 miles upstream from Grayling.

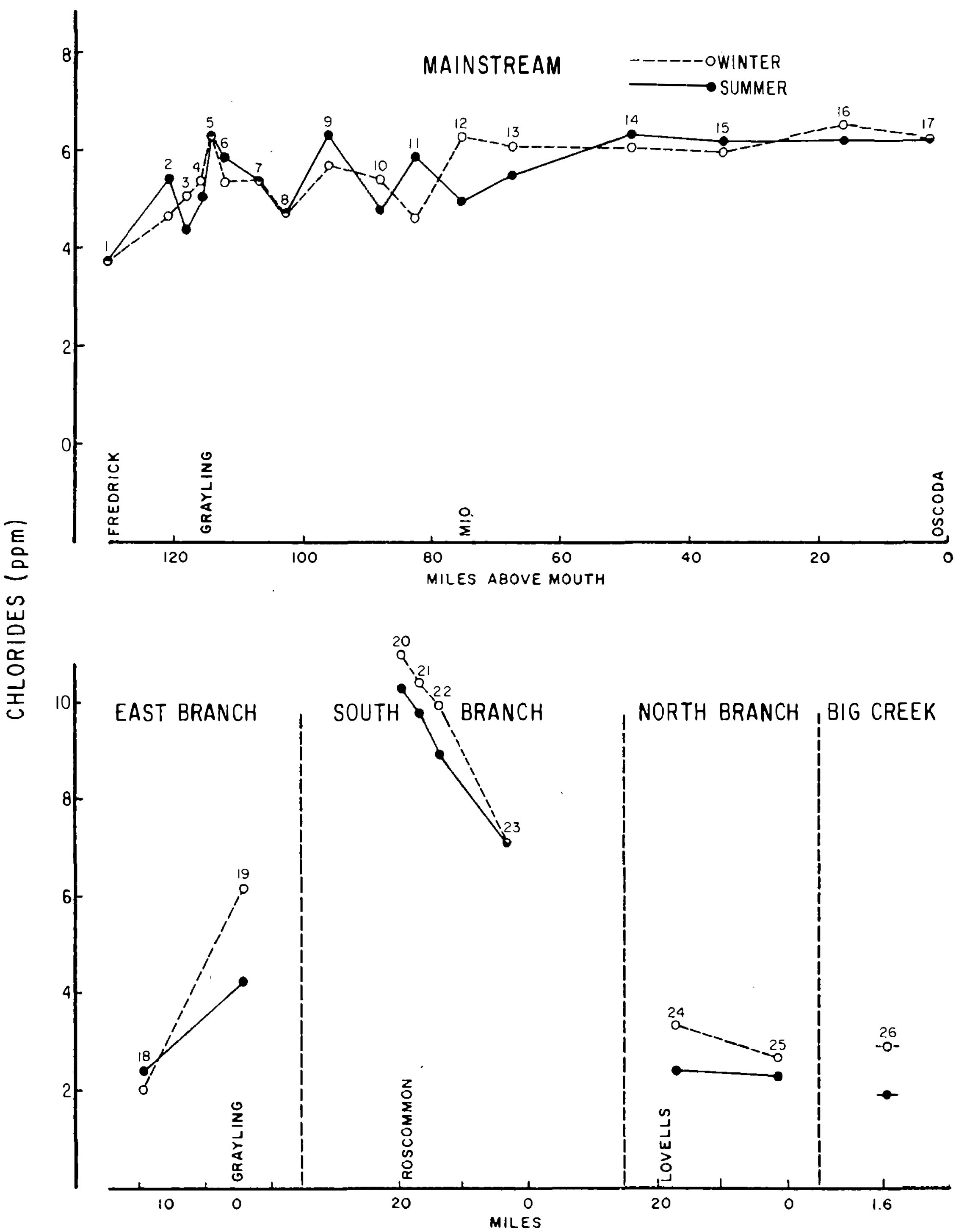

Figure 11. Averaged winter and summer chloride levels from monthly water samples.

South Branch, levels have been slightly higher in winter than in summer. Chlorides are conservative in nature (are not readily used up or tied up in the river system) and increase in a downstream direction. The chloride ion remains unchanged as it passes through the human body, and because chlorides can move great distances laterally through the water table, the movement of septic matter could be traced by plotting chloride (NaCl) concentrations, although there could be some influence from road salting.

Dissolved solids

Concentrations of dissolved solids are low throughout the Au Sable Basin, averaging less than 200 ppm compared to the WRC standard of <500 ppm. Conductance is directly related to concentration of dissolved solids, so that measured concentrations of the latter are about 60% of measured conductivity. Conductance is higher in the upper watershed than in the lower (below Mio) because of a higher level of human use and biological productivity (Fig. 12). The major tributaries all show slight increases in conductance in a downstream direction, reflecting the conservative nature of most dissolved materials. Some areas show the diluting effect of groundwater inputs on the concentrations of dissolved matter, namely below Frederic, Stephans, and Mio on the Mainstream, and the Mason Tract on the South Branch. The FWPCA recommends that "to maintain local conditions, total dissolved solids should not be increased by more than one-third of the concentration that is characteristic of the natural condition of the water." The monthly monitoring program at Stephan's Bridge (WRC) should allow detection of significant changes in water quality in the upper Mainstream (Grayling area).

pH

Measured pH units in Au Sable samples fall in an acceptable range as dictated by WRC standards. Average readings in the South Branch are slightly lower, reflecting input of swampy type of drainage and accompanying acidity. No standard is listed for total alkalinity, though averages fall in a normal range according to the FWPCA (1968).

Coliforms

Total coliform counts (summer) exceed the superceded 1967 WRC Water Quality standard of 1000 orgs/100 ml for all stations sampled, and exceeded the 20% allowable of 5000 orgs/100 ml for about half of the stations sampled (Fig. 13). However, the FWPCA considers fecal coliform counts to be the only reliable index of bacterial contamination when sampling surface waters used for recreational purposes. The portion of total coliforms in water that are of fecal origin may range from less than 1% to something less than 5%. This indicates that total coliform counts are of little value in determining bacterial contamination in the Au Sable River System. Although a relationship between total and fecal organisms does exist, it is not a consistent one because high total counts are not always accompanied by high fecal counts.

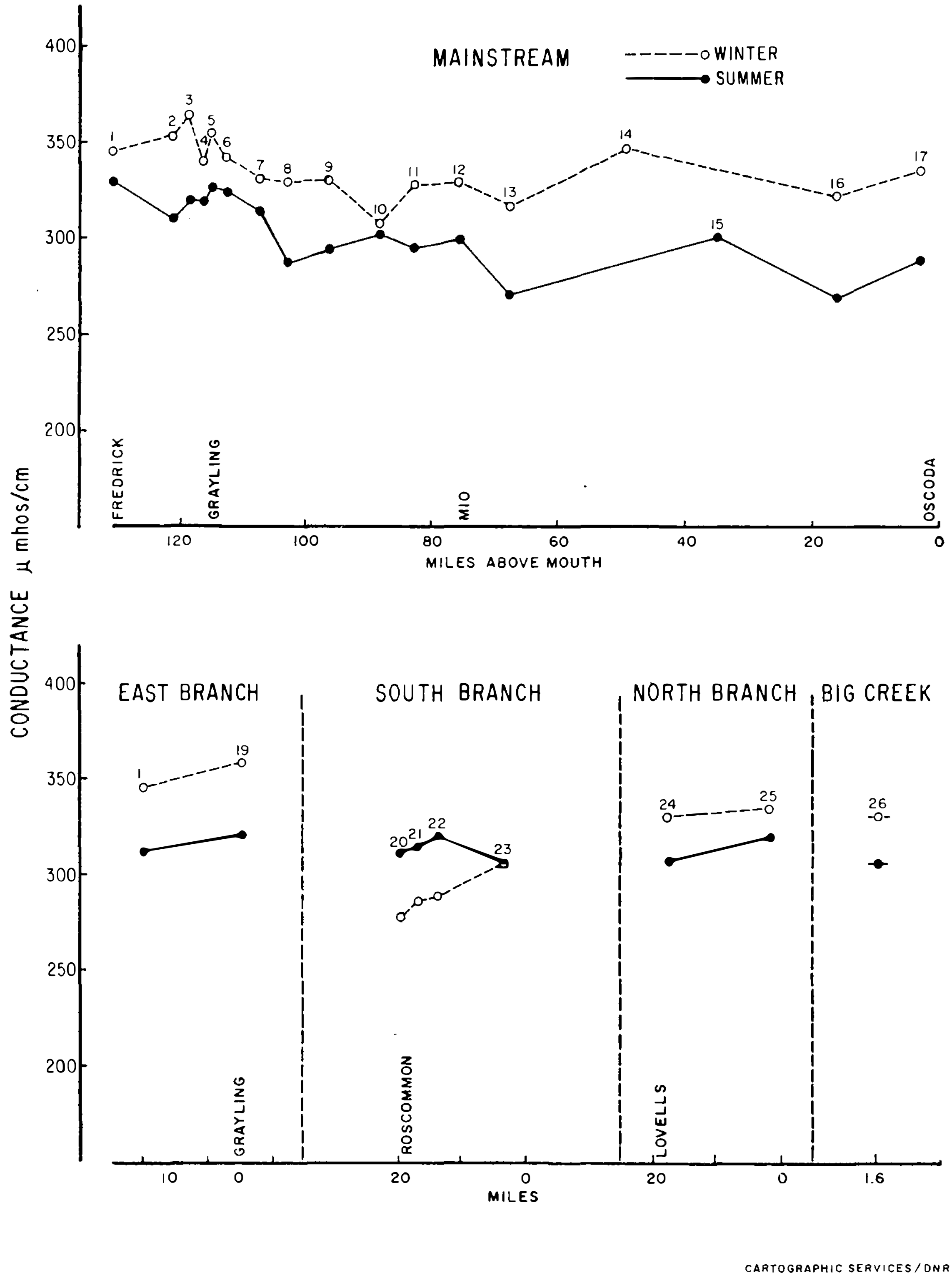

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Figure 12. Averaged winter and summer conductance levels from monthly water samples.

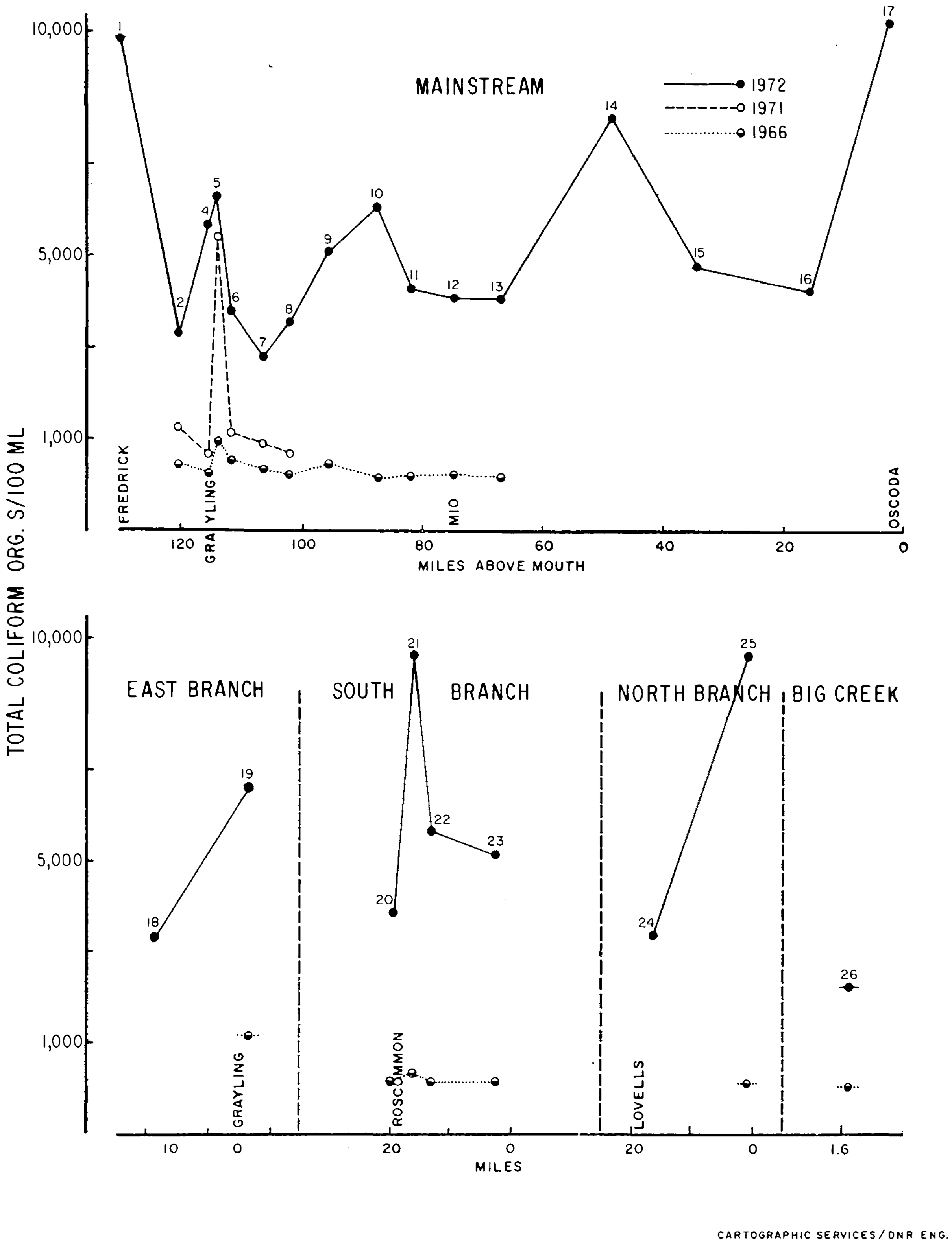

Figure 13. Averaged winter and summer total coliform bacteria levels from monthly water samples.

Samples taken since the Grayling Sewage Treatment Plant was shut down are all well within standards set by the WRC for total body co ct of 200 orgs/100 ml (fecal coliforms).

A similar pattern was found during the Hersey River studies in 1972, where total counts averaged 6,040 orgs/100 ml, and fecal counts averaged 27 orgs/100 ml or 0.5% of the total.[8] The WRC thereby concluded that no health problem existed.

Water Quality Index

The National Sanitation Foundation, in Ann Arbor, is attempting to develop a uniform method for measuring water quality, because a generally acceptable means of communicating water quality between professionals and the public is needed (Brown, McClelland, Deininger, Tozer, 1970). This would consist of a numerical water quality index based on chemical, physical and biological parameters, that would reflect relative conditions existing in surface waters and evaluate the response of these waters to various pollutional inputs.

A panel of persons with expertise in management of water quality was selected for a mail survey questionnaire. The first questionnaire was to establish which parameters should be included, and to rate the significance of each as it would contribute to overall water quality. There was a tendency to rate a parameter on the basis of data available and existing analytical techniques. The second mailing asked the reponders to review their judgment upon inspection of the overall survey results. This was to get a greater "convergence" of opinion. In the third mailing, respondents were asked to assign values between 0 and 100 to possible measurements of each parameter and to draw a curve based on the results. This information was then used to combine these judgments in an average curve, for each parameter, and set 80% confidence limits. Table 4 contains the nine parameters selected and demonstrates the use of the graph. Given a measured value of 2.0 ppm BOD_5, a significance rating of 80 is obtained by locating that point on the curve and reading the rating on the vertical axis (Figure 14). The rating is entered on the chart and multiplied by the weight of the parameter to gain a "quality rating"--in this case 8.00. This is done for each parameter and the individual quality ratings are simply summed to arrive at a water quality index figure between 0 and 100. A stream of better quality would then rate closer to 100 than a stream of poorer quality. Based on this preliminary work it was decided that a "single numerical expression that reflects the composite influence of significant parameters of water quality is possible." Accordingly, a field sampling program is now in progress for refinement of methods and applications. The "WQI" provides a uniform method to assess overall quality of a stream, to compare different points in space and time, to measure progress in water pollution abatement programs, and to improve ecological monitoring procedures.

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8 Mich. Dept. Nat. Res., 1972. The Hersey River Study (unpublished), Bureau of Water Management, Comprehensive Studies Section.

Table 4. A demonstration of how significance ratings are weighted to find a quality rating

Parameter	Measured value	Signif. rating (SR)	Weight (W)	Quality rating (SR) X (W)
D.O.			.17	
F-col			.15	
pH			.12	
BOD_5	2.0 ppm	80	.10	8.00
NO_3-N			.10	
PO_4-P			.10	
Temp.			.10	
Turb.			.08	
D.S.			.08	
				Total* = WQI

* A number between 0 and 100

A modification of parameters and methodology was necessary to arrive at a WQI suitable for the Au Sable Study. Turbidity values were not available from most water quality investigations in Michigan, including the Au Sable, and total solids are quite variable according to physical factors such as turbulence. It was therefore decided to use chlorides (a parameter not dependent upon, or influenced by, other parameters used), and conductivity (a measure of dissolved solids and dependent upon the sampling point and technique than total solids) in place of the aforementioned parameters. Because the Au Sable is primarily a trout stream, it was reasoned that measured values for D.O. and temperature, directly in ppm and °F respectively, would be more meaningful. Table 5 is the resultant WQI chart used in the Au Sable Study, and the values used were taken from WRC calculations for the river at Oscoda.

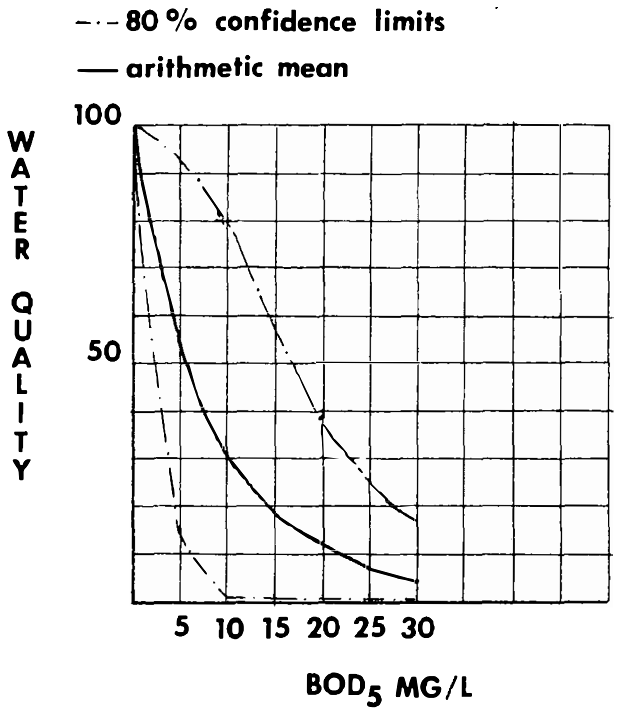

Figure 14. Demonstration of Water Quality graph using BOD (the 5 day measure of biological oxygen demand) to illustrate the conversion of measured values to a significance rating.

Table 5. Completed Water Quality rating chart for the Au Sable River at Oscoda (from WRC data, 1966)

Parameters	Meas. values	Signif. rating (SR)	Weight (W)	Quality rating (SR) X (W)
D.O. in ppm	7.3	92	.17	15.64
F-col orgs/100 ml	17.0	88	.15	13.20
pH units	8.3	96	.12	11.52
BOD_5 ppm	2.0	80	.10	8.0
NO_3-N ppm	0.0	100	.10	10.0
PO_4-P ppm	0.2	70	.10	7.0
Temp °F	71.8	69	.10	6.9
Chlorides ppm	2.0	96	.08	7.68
Conductance mhos/cm	300.0	80	.08	6.4
			WQI =	86.34

The D.O. values recorded represent the lowest observed values over a 24-hour period, and the temperatures represent normal maximums recorded during summer months. These would be the most critical values from the trout's point of view. Other values are normal or average levels. This procedure was exercised for all of the Au Sable River "base" stations, with the results given in Table 6. These values are presented graphically in Figure 15. The lowest indexes recorded were above and below the Shellenbarger area below Grayling, as expected. The parameter most responsible for these lower values is dissolved oxygen. The oxygen sag in this area extends below 6 ppm for extended periods during growing seasons. The highest values were at Parmalee Bridge on the Mainstream and Co. Rd. 487 on Big Creek. McMasters and Parmalee rated high on the basis of low maximum temperatures and high 24-hour D.O. values. The McMasters station also had the highest phosphate concentrations, along with Steckert and Chase bridge stations below the WWTP on the South Branch. However, these values were considered inconsequential by a majority of the experts, and thus a value of .07 ppm has a significance rating of 93. The Big Creek station had high ratings for all parameters. This stream measures up as a top-quality trout feeder stream. The major tributaries (East, North, and South branches) all rate between 89 and 93 (WQI) except the Steckert (85) and Chase (89) stations below the influence of the WWTP on the South Branch.

Further comparison is possible by reviewing studies of other watersheds in Michigan (Fig. 15). The WQI values for the Grand River fell between 48 and 74, and for the Kalamazoo, between 55 and 80. The Red Cedar (below Williamston) rated 47 and the Rouge 44. At the other end of the scale, the upper and lower Jordan rated 95 and 94, respectively. Based on a before and after study on the Hersey River (tributary to the Muskegon River) when the WWTP in Reed City was upgraded to secondary treatment and phosphorus removal, the WQI rose from 63 to 81. This indicates a significant improvement in water quality. Since no

Table 6. Water Quality Index figures (WQI) for Au Sable River Watershed, with averages for stream sections

Station	WQI	Station	WQI
Mainstream		East Branch	
Kolka Creek	91.56	Co. 612	90.94
Bradford Creek	86.34	Hospital Bridge	91.87
Frederic	89.54		
Pollack Bridge	89.46	South Branch	
M-93 (M-72)	89.28		
Maple Street	89.44	M-144	90.38
I-75	87.71	Steckert Bridge	84.95
Allison Residence	80.23	Chase Bridge	89.01
Harland Residence	81.00	Smith's Bridge	92.73
Burtons Landing	84.41		
Keystone Landing	89.84	North Branch	
Stephans Bridge	90.35		
Wakeley Bridge	91.71	Lovells	89.01
McMasters Bridge	92.44	Red Dog	89.73
Parmalee Bridge	93.29		
*PAS (Co. 606)	87.09	Big Creek	
Mio	92.14		
Oscoda	86.34	Co. 487	93.73

* Public Access Site

Section	Number of observations	WQI range	WQI average
Big Creek (Co. 487)	1	---	93.73
East Branch	2	90.94 - 91.87	91.41
North Branch	2	89.01 - 89.73	89.37
Mainstream (upper) headwaters - Grayling	5	86.34 - 91.56	89.24
Mainstream (lower) Mio - Oscoda	2	86.34 - 92.14	89.24
South Branch	4	84.95 - 92.73	89.22
Mainstream (middle) Grayling - Mio	11	80.10 - 93.29	87.94

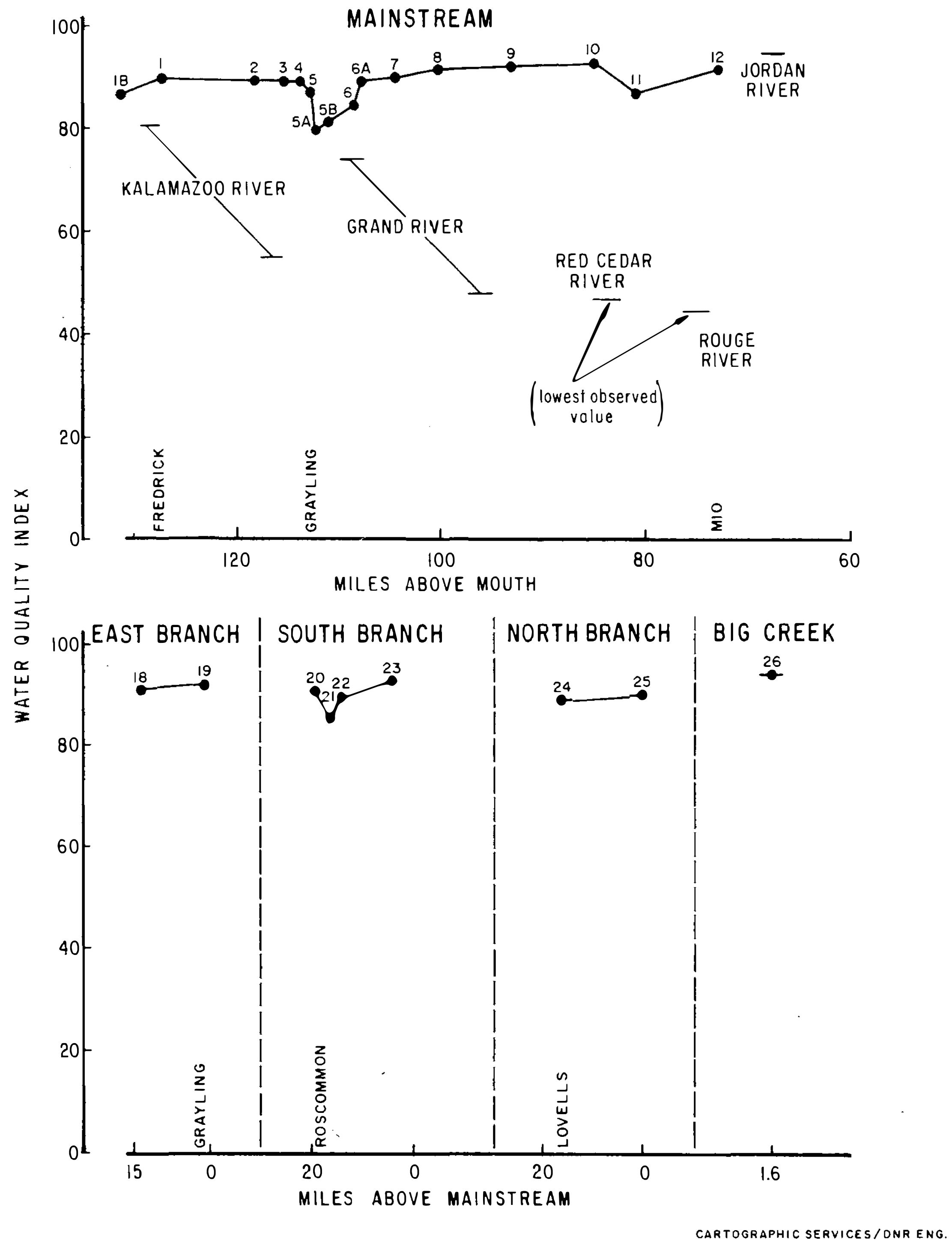

Figure 15. Water quality index for Au Sable River stations, and some other Michigan Rivers.

previous information was available for fecal coliforms, chlorides, and conductance, these parameters had to be assigned the same values as "after," resulting in a higher "before" WQI than was likely the case. In general terms, the water quality index (WQI) appears to provide a much needed "handle" for comparison of water quality in different watersheds, as well as within a watershed. While this index is tuned to compare conditions for trout in particular, it can be used in a more general sense to compare river systems throughout the state.

Storm Water Runoff

According to the EPA (Environmental Protection Agency) there are six principal types of constituents in storm water runoff including: algal nutrients (chiefly nitrogen and phosphorus); oxygen demanding matter; coliform bacteria; suspended solids; heavy metals; and pesticides. These materials come from industrial, residential, and commercial areas, automobiles, litter, animal droppings, sodium and calcium chlorides, and organic matter (EPA-R2-72-081, Nov., 1972). Table 7 compares the range of storm water values for those parameters tested with that of receiving waters. Storm drains were sampled under a variety of conditions including: light, moderate, and heavy rains; and snow melt. Winter and summer samples were collected to check seasonal differences. Nitrate values for storm water ranged up to 2 1/2 times higher than river water (Table 7), while phosphates were 25 times higher. Chlorides were 10 times higher, BOD five times higher, total and fecal coliform organisms were on the order of 1,000 and 100 times higher, respectively, and the conductivity was almost twice as high as for river water.

Depressed BOD readings were suspected due to the increase in the COD to BOD ratio in storm runoff. This is a result of constituents in storm water that would affect bacteria and their ability to break down organic matter (Martin, 1972).

Table 7. Levels of storm water constituents compared with levels found in the river water samples

Constituents	Values for storm water runoff (range)	Values for river water (range)
Nitrate + Nitrite - N	175 - 500 ppb	100 - 175 ppb
Phosphate	750 - 2200 ppb	20 - 80 ppb
Chloride	50 - 100 ppm	3 - 10 ppm
5-day B.O.D.	1.8 - 14.0 ppm	0.5 - 2.5 ppm
Conductivity	130 - 678 mhos/cm	150 - 365 mhos/cm
Total coliforms	up to 1.4 million per 100 ml	up to 1.5 thousand per 100 ml
Fecal coliforms	up to 8.6 thousand per 100 ml	up to .1 thousand per 100 ml

Samples collected near the beginning of very heavy rains produced higher nitrate levels, but lower phosphate and chloride concentrations than during moderate rainfall after some time (2-3 hours) had elapsed. This suggests that because nitrates are more readily soluble and more loosely bound to soil particles, they are more readily released to surface runoff. Rainwater contains nitrates (Martin, 1972), but probably not enough to account for the differences.

Seasonally, winter samples were somewhat higher in phosphates and chlorides than summer samples, while nitrates remained about the same. Total coliform bacteria counts were higher in summer samples than winter, whereas the opposite was true of fecal coliform counts. This is reasonable, because snow cover would reduce area of soils subject to surface runoff, while animal feces could still be exposed. Colder water temperatures in winter months also result in a longer survival period for fecal coliforms in river water.

The drain on the north side of the US-27 bridge at Grayling produced the highest collective values for all those parameters tested, while the drain on the north side of State Street, also in Grayling, was second highest. These drains receive most of the runoff from the streets of downtown Grayling, and it is logical that they would have the highest concentrations. Grayling storm drains had higher values for constituents tested than did Roscommon drains. One grab sample was analyzed for the drain at McMasters Bridge, 16 miles east of Grayling on the Mainstream, for comparison. Here parameters were predictably lower, because of the more sparsely populated drainage area, although chlorides were high due to road salting.

Martin (1972) reports on average concentrations of constituents in storm water runoff from a 27-acre residential and light commercial area (Grayling surface area serviced by storm drains would be somewhat larger) with separate storm and sanitary sewers as: 360 ppb total phosphate phosphorus; 530 ppb nitrate nitrogen; and 17 ppb BOD. Average concentrations in Grayling drains were similar for nitrates (335 ppb), lower for BOD (6.4 ppm), but twice as high in phosphates (764 ppb). These differences evidently play a role in loading effects on the Mainstream. Comparison of samples, collected above and below Grayling during moderate rainfall and snow melt in January and March, 1973, failed to show any dramatic loading effects on the river proper with the possible exception of total phosphate (Table 8). However, there is reason to believe that tests made during low-flow conditions or rapid thaw accompanied by rainfall, would show such effects (refer to section IV for demonstrations). Mr. Robert Larson, USGS Hydrologist at Grayling, used nine different runoff periods at the Grayling Gaging Station where storm water runoff could be separated from streamflow data.[9] He found that storm sewers could contribute from 10 to 27% of the total discharge for brief periods (5 minutes or less). There would be variations in runoff corresponding to the time of year, effects of vegetation, and

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[9] Larson, R. W. USGS Hydrologist, Grayling. Letter to Gary Coopes, IFR, Ann Arbor, March 23, 1973.

Table 8. Results of storm water samples collected in the three major Grayling drains and in the river above and below the drains in January, 1973. The lower portion lists results for samples collected at the same river sites in March, 1973

Date and ppm	M-72 above Grayling (in river)	US-27 storm drain (N.side)	US-27 storm drain (E.side)	Maple St. storm drain (N. side)	Below Penrod's (in river)
1/18/73					
Sol.Ortho- (PO_4-P)	<0.01	0.05	0.11	0.05	<0.01
Total PO_4-P	0.02	0.80	1.6	0.46	0.05
NO_3-N	0.16	0.19	0.22	0.26	0.16
NH_3-N	0.04	0.08	0.10	0.14	0.04
Chloride	5	110	120	63	5
3/5/73					
Total PO_4-P	<0.02	(Storm drain samples not available)			<0.02
NO_3-N	0.21				0.19
NH_3-N	<0.01				0.01
Chloride	3				6

infiltration rates. He (Larson) estimates that an intense early spring storm, with frost present and coupled with the 7-day Q10 flow (40 cfs), could result in nearly 40% of the discharge coming from storm sewers. Subsequently, during periods of low flow, the diluting capability of the receiving waters of the Au Sable at Grayling would be cut nearly in half.

The EPA (Sandoski, 1972) reports that runoff from city street surfaces is similar in many respects to sanitary sewage, and that runoff during the first hour of a moderate to heavy rain storm "contributes as much, or more, of a pollutional load than sanitary sewage during the same period." It also provides a significant source of nutrients for aquatic plant growth, often carries materials toxic to aquatic organisms, and can create a health hazard from bacterial pathogens. There is presently no law in Michigan governing the quality of storm water entering watercourses, except for adequate headwall to prevent siltation. The present movement is toward putting them in! Some observations and possible solutions will be discussed in Section V.

Periphyton

The ability of a river system to support (grow) primary producers, is indicative of the richness of that system. These producers are chiefly tiny algal organisms that attach to surfaces (rocks, stems, leaves) in the stream and convert (photosynthesis) dissolved nutrients into food matter. This food matter forms the basic level in the "food chain" that ultimately supplies energy to fish.

Four factors are of prime importance in determining the amount of "food" so produced: sunlight, water temperature, stream current velocity, and nutrient availability.

Artificial substrates were placed at selected sites in the Au Sable system in order to colonize these producers and measure their productivity. The samplers were so placed that a maximum degree of uniformity in terms of sunlight exposure and current velocity would be realized, and that resultant productivity would reflect differences in temperature and nutrient availability. The "food" so produced is directly related to chlorophyll produced (enzyme systems involved in the photosynthetic process). The measure of accrued chlorophyll over a period of time, then provides a means to compare primary production at different points in the river. These primary producing communities can provide a sensitive index of water quality conditions.

Ten stations were selected on the Mainstream from above Grayling to below Mio, and at the lower end of major tributaries (Fig. 16). The substrates were allowed to colonize (were exposed) an average of 14 days before sampling. Six sampling runs were accomplished between June 11

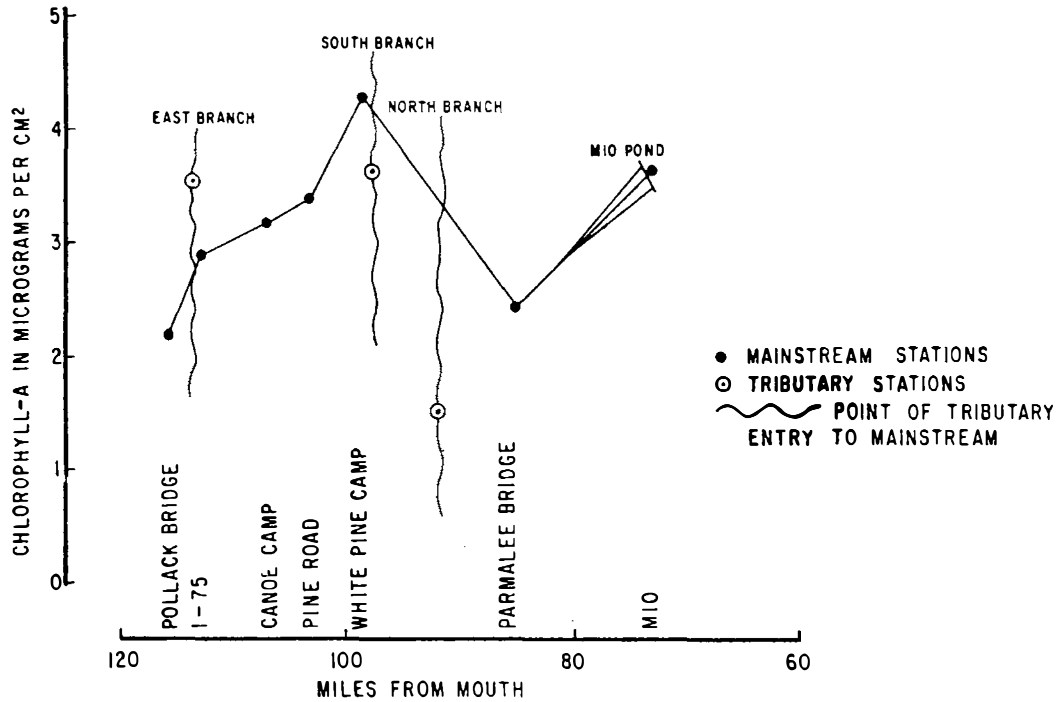

Figure 16. Primary productivity at selected Au Sable River stations expressed in terms of Chlorophyll-A production (represents standing crop measurement).

and September 11, 1972. Results, based on averages for the entire period, show an increase in the level of productivity in a downstream direction between Pollack Bridge above Grayling, and the "still waters" 18 miles downstream. The "still waters" consist of five miles of river which is deep and wide, with low current velocity, and a shifting sand substrate. Growth of rooted aquatic plants is mainly limited to silt beds in slack areas along the margins of the river. Consequently, a lower percentage of the river bottom supports aquatic plant production. The level of productivity in the South Branch and East Branch is nearly the same. Enrichment is mostly from a natural influx of nitrates in the East Branch, and perhaps to some extent from the fish hatchery and private septic systems, although this was not demonstrated by the water samples. The obvious source of nutrients in the South Branch is the sewage treatment plant at Roscommon. Input of nutrient matter from this facility is responsible for increasing plant growth over 12 times when compared with growth upstream (Willson, 1968). The North Branch was the lowest of any station sampled, having less than half of the value measured for the South Branch. The next station on the Mainstream, Parmalee Bridge, below the still waters is also below the confluence with the North Branch. Here the productivity levels are much lower than those found at the "still waters" area. This is at least partially due to the influence of the North Branch. Below Mio, productivity levels are again increased, reflecting nutrients and temperature conditions in the impoundment.

Sediment

Sediment samples were collected on the North Branch and South Branch, in order to estimate the total dissolved solids, and the amount and particle size of sediment in transport. In a system such as the Au Sable, most of this sediment in transport consists of sand-sized particles (> .063 mm) which, being heavy, are termed bed load (particles in continuous contact with the stream bed). Studies conducted on the Pine River by hydrologist Edward Hansen of the U.S. Forest Service at Cadillac (Hansen, 1971) showed that sampling over a natural bottom could produce an error as high as 80% in estimating sand-sized particles by under estimating the bed load. To prevent this error, Hansen constructed sill plates across the stream bed in order to force all of the bed load off the bottom and over the sill where it would be available to the sampler. Limitations on time and manpower on the Au Sable necessitated sampling over natural bottom. To reduce sampling error, the Au Sable samples were collected over rubble substrate where, because of high current velocity, a greater portion of sand-sized particles (>.063 mm) would be in suspension in the sampling "zone." The sampling stations were at: Lovells Bridge on the North Branch; Co. 608 Bridge on Big Creek (tributary to North Branch); and Smith's Bridge on the South Branch.

Samples collected for the Au Sable Study were not intended to give a complete "picture" of sediment movement over a wide range of conditions, but rather to provide a basis of comparison with other watersheds for which information was available. Hansen compared the ratio of maximum flood peak discharge to long-term mean discharge for many streams in the upper part of the Lower Peninsula, having an average of 15-25 years of discharge records available to gain an index. He found that a relationship existed between soil types and stream stability, and consequently between stability and sediment load. Average concentrations in sediment load ranged from 11 to 31 ppm for Hunt Creek and from 16 to 69 for the Pine River. The index for the Pine River (9) was three times higher than for Hunt Creek (3), and accordingly the average sediment load was 40 ppm for the Pine and 20 ppm for Hunt Creek. The Au Sable has a stability index between 3 and 4. The sediment load for samples collected in the North and South branches during the winter of 1973 (Table 9) ranged from 6 to 21 ppm and averaged 15 ppm. This compares favorably with Hunt Creek values, as would be expected from the similar flow-stability indexes.

Table 9. Sediment samples collected in the Au Sable River System during 1973

Station	Date	Dissolved solids	Particles <.063mm	Particles >.063mm	Sediment (<.063mm + >.063mm)
Lovells Bridge	2/1/73	166	3	18	21
	3/1/73	173	3	6	9
South Branch	2/1/73	158	6	10	16
		163	7	10	17
Big Creek	3/1/73	167	7	12	19

In order to assess the effects of sediment load levels on trout biomass, stream channel morphometry, and general effects on insects that serve as trout food, the sediment load is being experimentally increased from 20 ppm to 80 ppm in a 2-mile section of Hunt Creek. The total study will endure for a period of 4 years, 1971-1974 (D-J Project No. F-30-R-7, 1971), under the direction of Gaylord R. Alexander, Biologist-in-Charge of Hunt Creek Fisheries Research Station, Michigan Fisheries Division. Added sand will be trapped at the lower end of study segment and removed. While it is generally accepted that stream bank stabilization to reduce sediment load is beneficial to trout, no studies have been made on effects of sediment increase or reduction on trout or trout habitat. The Hunt Creek study should provide these answers. Meanwhile, the MDNR (Michigan Department of Natural Resources), on the basis that sediment movement can be detrimental to trout in terms of: suffocation or aggravation (stress) to small fish making them more susceptible to disease; scouring or smothering of food organisms; filling pools to reduce shelter; substrate type conversion; smothering of spawning beds; and possibly increasing water temperatures and available nutrients (Mich. DNR and NC Forest Experimental Sta., 1971), is carrying out a large-scale stream bank stabilization trout habitat improvement program on the Au Sable and its major tributaries. This project is under the direction of Regional Habitat Specialist Bill Bullen, and District 7 Fish Supervisor Gary Schnicke. Many of the bank structures are designed to serve as trout cover as well as to correct erosion situations. Hansen has conducted sediment studies on the Pine River System over a period of six years. Although the Pine has a higher gradient (about nine feet per mile in the study area) than the Au Sable (three feet per mile in the upper river), and a higher maximum to minimum discharge ratio (12:1 versus 3.7:1), some comparisons of the two systems are possible. They are both "pool and riffle" type streams with many eroding banks.

Hansen's (1971) study revealed the following:

1. Sediment in transport comes from eroding banks and stream bottom deposits.

2. Sediment concentration and load increases with stream discharge and gradient.

3. About 55% of the sediment load increase through his study area came from eroding banks, less than 10% from tributaries, and the remaining 35% from unobtrusive vegetated stream banks.

4. Eroding banks adjacent to recreational areas and other access points always have high erosion rates.

5. Contribution from bridge crossings and road ends were judged to be insignificant.

Concerning point No. 4, visual observations of bridge crossing and some road ends in the Au Sable Watershed indicate there is a significant input from these areas, and that they should be considered for stabilization. Ribbons of sand can be traced moving downstream from these erosion sites. Since bridge crossings are legally used for access, they should be constructed to withstand foot traffic. Three corners of the bridge could be fenced and stabilized, and the remaining corner designed for access.

Hansen concluded that by stabilizing only large banks in the severe to moderate erosion classes, a 74% reduction in sediment input from this source could be realized from treatment of only 40% of the eroding area. On this basis, the stream bank stabilization program for the Au Sable should effect a 40% reduction in total sediment load.

Fish Populations

Electrofishing Surveys

Electrofishing surveys are an important tool of fish managers, and consequently over 80 such surveys have been made in the upper Au Sable since the early 1960's (Fig. 17). In reviewing these collections, it was found that each survey site could be placed in one of four classifications as follows:

Good trout waters	>50% coldwater species
Fair trout waters	20-50% coldwater species
Marginal trout waters	0-20% coldwater species
Non-trout waters	0% coldwater species

This information is included in Section III, Part B.

It is important to understand that many of these surveys were undertaken to measure the relative abundance of trout present, and while other species were recorded, they were not considered of primary importance. This classification of trout waters by the percentage of coldwater species present, was arbitrarily devised to provide a means of comparing conditions for fish in different areas of the system. It should also be noted that this composition will vary seasonally as well as over a period of years, so that collection from individual sites could be upgraded or downgraded as a result.

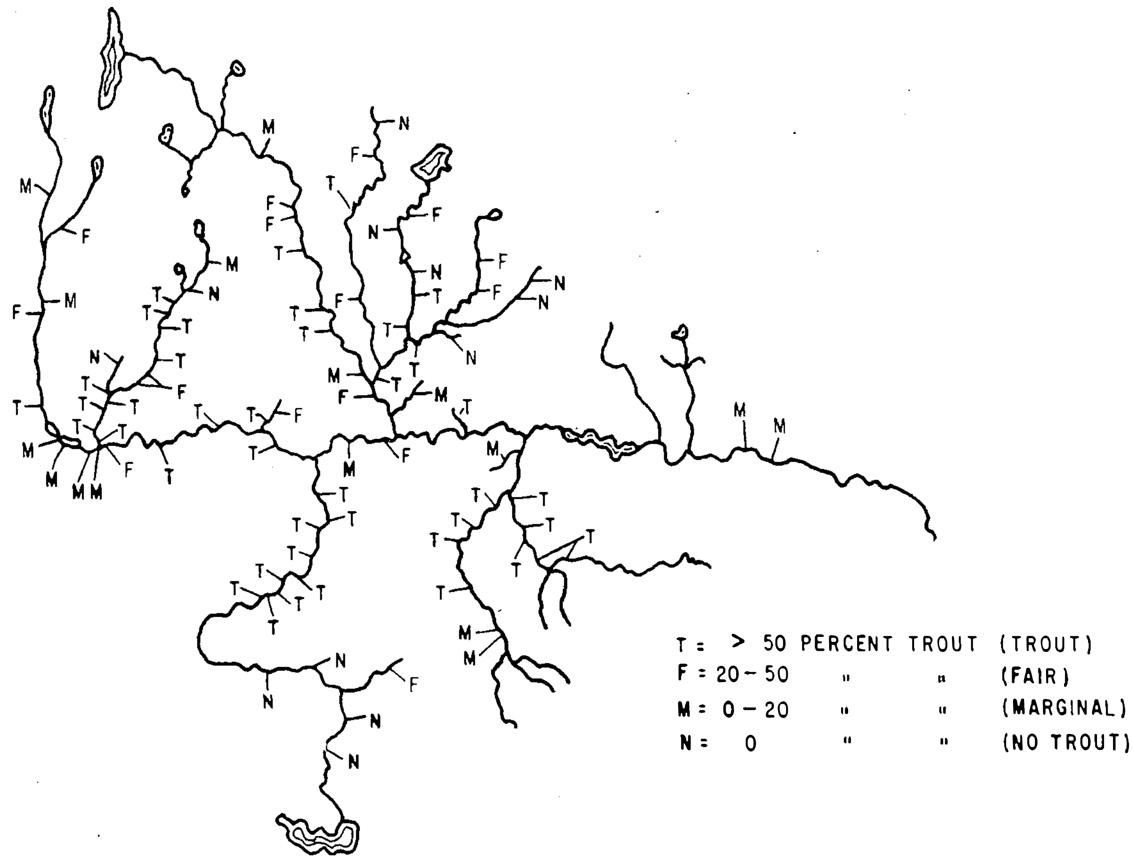

Figure 17. Electrofishing collection sites on the Au Sable River, 1960-1972, and classification according to the number of coldwater species captured.

Other electro-surveys were conducted during 1971 and 1972 for supplemental information in regard to seine collections. Seine collections were made to compare fish populations in areas sampled in the same manner during the 1920's for the purpose of gathering information for trout stocking programs at that time.

The seine collections will be discussed in the next section. Electrofishing collections were made at several stations where there were great differences in species composition between the 1920's and 1970's. Three stations--above the fish hatchery, on the East Branch; Dam Four, on the North Branch; and just below the sewage outfall, on the Mainstream (not operating at that time)--were monitored periodically during the summer season of 1972 to determine whether there were significant changes in population composition due to the migration of species in and out of the area. Results, based on several surveys at two-week intervals, indicated no significant changes in fish population composition.

Trout Population Estimates

In order to effectively manage trout stocks in the Au Sable Basin, it is necessary to understand how trout populations fluctuate from year to year, and what effect angler pressure may have on population structure. Trout population estimates are made at permanent stations of known area. Calculations are made in each inch group for each trout species, so the managers may keep track of year class distribution as well as total populations.

Baseline data were collected for all upper Au Sable branches sampled, except for the East Branch, by Dr. David S. Shetter and Gaylord R. Alexander (Michigan Fisheries Division, Hunt Creek Research Station) during the late 1950's and early 1960's. District 7 fish crews have resampled most of these stations, during the past two years, with the Au Sable Study personnel participation when possible (see map-Fig. 18).

The 1972 estimates at trout population stations in the upper watershed (above Mio) demonstrate higher numbers of brown trout present than mean levels representing the baseline years, 1957-1967 (Table 10). Averages for all 1972 stations show a 23 percent increase in overall brown trout populations, while overall brook trout populations show a 38 percent decline. However, caution must be exercised in interpreting these data as they represent only one year (1972), with the exception of the Stephans Bridge and Wa Wa Sum stations on the Mainstream which represent two years (1971, 1972). The baseline data represent an average based on several years of sampling between the years 1957 and 1967 (Table 11). Baseline data (1960's) appear in Table 10.

Legal-size browns (10 inches and over) were up by 45 percent, while larger brown trout (over 12 inches) were up 18 percent from the baseline average. On the Mainstream "quality waters", where the size limit has been raised to 12 inches for brown trout (1973), larger browns were down by 11 percent from the earlier estimates. Numbers of large brown trout were down from the baseline averages only on the Mainstream quality waters, and at the Chase Bridge station on the South Branch.

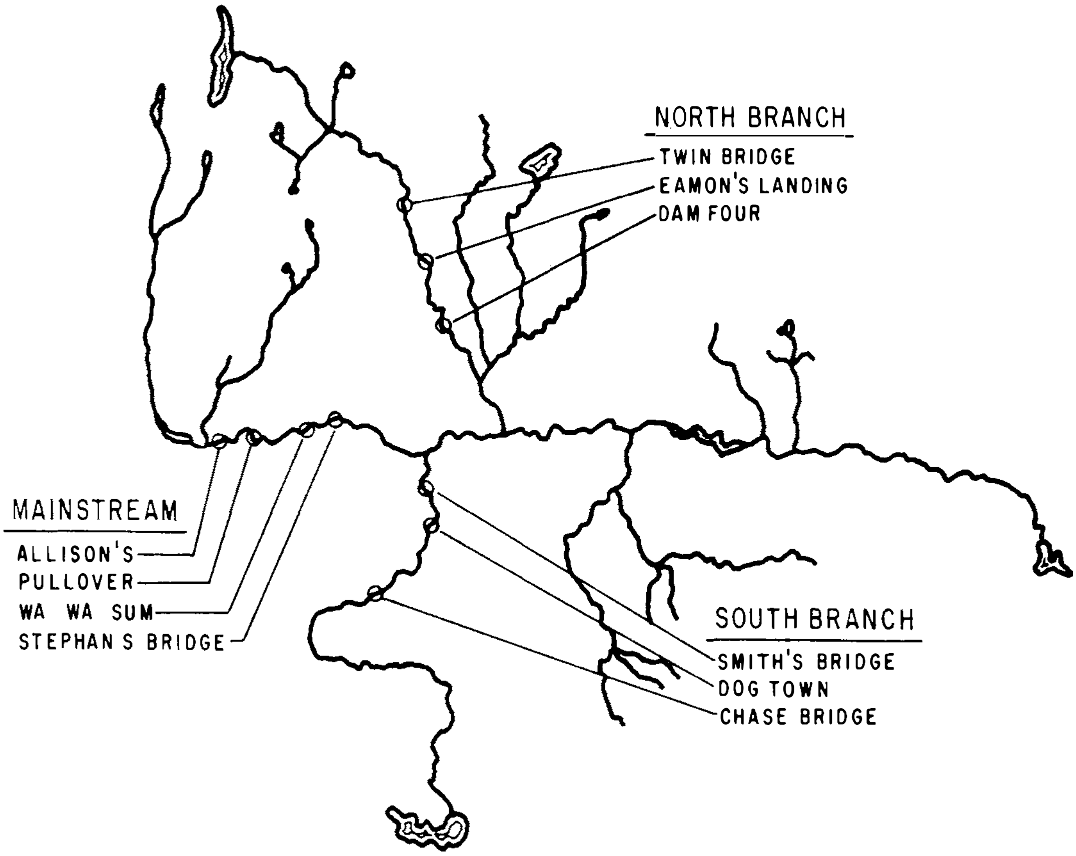

Figure 18. Location of Trout Population Estimate Stations in the Upper Au Sable Basin.

District 7 Fisheries Supervisor Gary Schnicke, is directing a tagging operation on legal-sized trout on the Mainstream quality section between Whirlpool Road and Pine Road over a distance of 3-1/2 miles. Schnicke expects that returns (information) on captures of these tagged trout will furnish an exploitation rate for trout in this river stretch.

It must again be stressed that trout population estimates are quite variable, especially for the larger inch groups where sample size is relatively small. For example, at Stephans Bridge on the Mainstream, surveys conducted in 1971 and 1972 revealed a 31 percent reduction in overall brown trout numbers and a 55 percent decline in legal-sized browns (12 inches and over) between these two years. As much as a 75 percent annual variation in population size was experienced during surveys in the late 1950's and early 1960's.

• As reported by Gary Schnicke in an earlier report[10], overall estimates of brook trout population size show a decline of 38 percent. Brook trout of legal size (over seven inches) were reduced by 68 percent.

10 Schnicke, G. T. 1972. Trout population studies on the Upper Au Sable River System, Crawford Co.

Table 10. Comparison of trout populations in 1972 with populations in the late 1950's and early 1960's (listed as 1960's) at stations on the Mainstream, North Branch and South Branch

BROOK TROUT

Stream	All Sizes 1960's	All Sizes 1972	All Sizes % change	Over 7" 1960's	Over 7" 1972	Over 7" % change
Mainstream						
Wa Wa Sum	495	409	-17	80	33	-59
Stephans	373	129	-65	16	9	-47
Average	434	269	-38	48	21	-57
North Branch						
Twin Bridge	988	256	-74	61	23	-62
Eaman's	672	422	-37	43	11	-76
Dam 4	1,127	627	-44	73	11	-85
Average	929	435	-53	59	15	-75
South Branch						
Chase Bridge	63	219	247	5	3	-39
Dog Town	299	288	- 4	35	6	-82
Smith Bridge	171	235	37	4	5	33
Average	178	247	39	15	5	-67

BROWN TROUT

Stream	All Sizes 1960's	All Sizes 1972	All Sizes %Change	Over 10" 1960's	Over 10" 1972	Over 10" %Change	Over 12" 1960's	Over 12" 1972	Over 12" %Change
Mainstream									
Allisons	78	36	-54	17	17	0	10	8	-17
Pullover	10	47	374	2	31	1291	1	15	1380
Wa Wa Sum	487	375	-23	83	90	7	30	25	-16
Stephans	936	1047	12	143	274	92	72	65	- 9
Average	378	376	0	61	103	68	28	28	0
North Branch									
Twin Bridge	247	428	73	44	50	14	25	32	28
Eaman's	371	477	29	18	19	6	7	12	83
Dam 4	698	1053	51	31	24	-22	11	10	- 6
Average	439	653	49	31	31	0	14	18	29
South Branch									
Chase Bridge	250	427	71	55	34	-37	38	18	-51
Dog Town	153	87	-43	4	1	-85	1	1	0
Smith Bridge	349	424	22	30	80	166	15	59	299
Average	251	313	25	30	38	29	18	26	45

Species	Totals-All Stations 1960's	Totals-All Stations 1972	Totals-All Stations %Change	Species-Size		Totals-All Stations 1960's	Totals-All Stations 1972	Totals-All Stations %Change
Brook	524	323	-38	Brown	10"+	43	62	45
Brown	358	440	23	Brown	12"+	21	24	18
All Sizes	---	---	---	Brook	7"+	40	13	-68

Table 11. Trout population estimate stations in the upper Au Sable River (above Mio) that were established in the late 1950's and early 1960's, and were resampled in 1972

Stream	Station	Length of station in feet	Baseline period	
Mainstream	Allisons	1,053	1959	1963
	Pullover	800	1960	1963
	Wa Wa Sum*	773	1959	1963
	Stephans Bridge*	700	1960	1963
North Branch	Twin Bridges	1,255	1957	1967
	Eaman's Landing	1,000	1962	1967
	Dam Four	1,280	1957	1967
South Branch	Chase Bridge	900	1960	1961
	Dog Town	800	1960	1963
	Smith Bridge	900	1960	1961

* These stations were also sampled in 1971.

The only exception to this pattern is found in the South Branch, where overall brook trout numbers are 39 percent higher than the baseline average. Interestingly enough, even here brook trout of legal size show a decline of 67 percent. The decrease in abundance of larger brook trout is remarkably consistent, as noted by Schnicke, for all stations surveyed on all river branches. This decline is unquestionably due to a reduction, in 1969, in the size limit for brook trout to seven inches, and the vulnerability of the species to angling pressure. At the Twin Bridges station on the North Branch, when the size limit was dropped from nine to seven inches in 1961, the response of brook trout was immediate. The 1959 and 1960 averages were 1,290 brook trout per acre (overall), and 135 per acre over seven inches. The averages for the succeeding years, 1961-1963, were 1,130 and 61 per acre respectively. This represents a 12 percent decline for the overall brook trout population, and a corresponding 55 percent decline for legal-sized brook trout. This station was already under a seven-inch limit for brook trout in 1969, and accordingly the decline in legal brooks was 12 percent lower than the overall population. Other stations with significant brook trout populations experienced reductions in legal brook trout that were on the order of twice as high as the population as a whole.

Of those stations monitored on the Mainstream and North Branch, only Wa Wa Sum showed an overall brook trout population level during any one of the baseline years that was lower than the 1971-1972 averages. However, even at this station, the lowest level of brook trout over seven inches (61 in 1961) was twice as high as the level recorded in 1972 (31).

Several years of data are needed before any meaningful trends could be derived from data comparisons. These studies will be continued in order to accomplish this end.

Impoundment Surveys

There are six major hydroelectric dams on the Au Sable from Mio downstream to Oscoda. The combined area of these impoundments is 6,625 acres. During 1971-72, the four largest basins (Mio, Alcona, Cooke, and Foote) were surveyed; these have a combined acreage of 5,585 acres or 84 percent of the total area involved (Fig. 19).

Mio Pond. Mio Basin was constructed in 1916. It is over 6 miles long and covers 860 surface acres. There are two access sites and a new campground near Camp 10 Bridge. The fish population was surveyed in July, 1971 over a 2-week period by District 7 fish personnel.

Over 50 percent of the fish captured were rough fish (i.e., suckers, brown bullheads, carp, bowfin), and 75% of these were suckers. Game fish populations were generally poor, and just under 30 percent were of catchable size. Perch were 62 percent catchable, but reportedly did not furnish a good fishery. The pond was drawn down in the fall of 1969, which resulted in some reduction in numbers of fish. Large 1970 year classes of suckers, perch, largemouth bass, and crappies were observed, along with some walleyes. A follow-up survey in 1972 revealed that suckers and carp had increased at the expense of game fish and forage species.[11] Only two trout were captured in this survey.

Alcona Basin. Alcona Pond is three miles long, and covers 1,075 acres. The dam was built in 1924, the last of the major dams to be constructed in the watershed. There are two large campgrounds on the backwater and three access sites.

Here rough fish were also dominant, composing 43% of the total population. A larger proportion (36%) of game fish are of catchable size than in Mio Pond, and accordingly fishermen reported good catches of walleyes, smallmouth bass, northern pike, and yellow perch. Walleyes were slow-growing during the first few years (Appendix Table IX). This could be an indication of impending troubles for walleyes in this basin, according to Fisheries Supervisor Gary Schnicke. Even more important, no trout were captured during the survey. Growth analysis suggests that the abundant numbers of rough fish have not affected growth rates of most game fish species, although they could have an effect on recruitment in these species. Attendant weather was cold and windy, which could have affected capture success. Netting and electrofishing conditions, in regard to physical characteristics, were the best of the lower three basins surveyed.

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[11] Schnicke, G. T., District Fisheries Biologist, mid 1972. Letter of information to G. F. Coopes.

Cooke Basin. Cooke backwater covers 1,800 surface acres. It is the oldest of these impoundments, having been built in 1911. There are boat liveries and rental cottages near the dam, and an access site and several cottages at the upper end. A paddle-wheel river boat is in operation for summer tours.

Only 21% of the fish captured were classified as rough fish; these were mostly bullheads and bowfin. Game fish were 42% catchable (mostly panfish). Panfish were fair in number and most were of catchable size. However, smallmouth bass and walleyes were scarce, and the northern pike which we captured were mostly sublegal. Fishermen whom we interviewed complained of disappearance of walleyes, and of too many undersized northern pike. Survey efforts were concentrated in the upper end of the basin (after the poor results experienced in Foote Basin) and netting was spread over most of the basin with the exception of the upper 2 miles. More shoal area was available for trap nets and for electrofishing, and accordingly more fish were captured. One brook trout was taken during the survey.

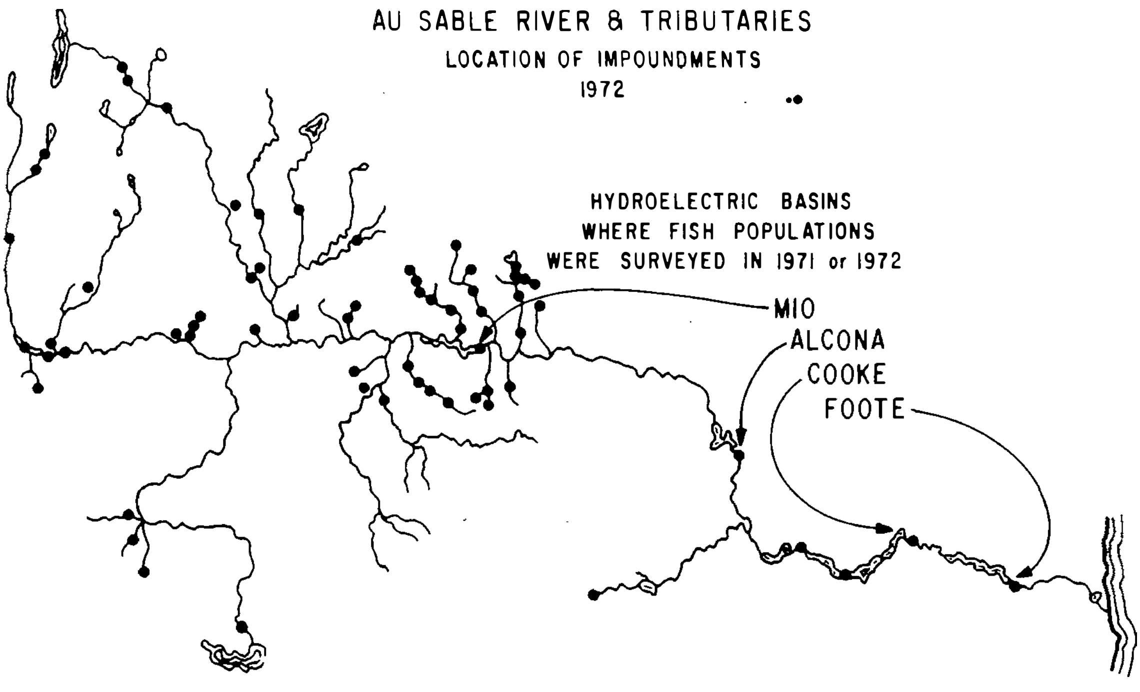

Figure 19. Au Sable River and tributaries showing locations of dams (dots), with special reference to the hydroelectric basins surveyed during 1971 and 1972.

Foote Basin. Foote Basin is over seven miles long and covers 1,850 surface acres. It is the largest of the impoundments and was built in 1918. There is a county park and campground located on the south side of the major basin, and additional access sites just above Foote Dam and just below Cooke Dam.

Of the fish captured, only 14% were of the rough fish variety. About 37% of the game fish captured were of catchable size. Walleyes were again scarce, but smallmouth bass and northern pike were present and mostly of catchable size. Panfish were also scarce, while rock bass were present in good numbers. Suitable shoal for netting was limited, and the presence of many logs and stumps hampered electrofishing at night, which greatly reduced capture success. Coldwater temperatures likely had an effect as well, because fish were not moving in the shallows. During the time of the survey, fishermen were having excellent success on northern pike.

Productivity in Impoundments

This is dependent upon nutrient inflow and drainage (Cooper, 1967). In the Au Sable basins nutrient inflow is likely matched by nutrient outflow, and some nutrient matter may be lost to bottom sediments in the larger basins of Foote and Cooke impoundments. Productivity is related to nutrient fertility and species composition. Large impoundments characteristically exhibit good production for a period of years, but eventually become less productive than natural lakes due to nutrient loss, and the nature of sedimentation (Cooper and Hubbell, 1967; and Neel, 1963).

In new impoundments there is initially good growth of game fish species as a result of low population density and nutrient release from the flooded area. However, impoundments favor introduced species (warmwater) which, at best, results in residual populations of indigent species (trout). Over a period of many years there is usually a shift in dominance from predators (trout, pike, walleyes, bass) to comparatively worthless species (suckers, carp bullheads, bowfin). Other associated problems include fluctuating water levels, drawdown after fish have spawned, build-up of carbon dioxide, and competition with rough fish for food supply, for spawning areas, and for living space. Not only are physical conditions for trout altered (rate of water exchange, warmer temperatures, lower oxygen levels), but favored food organisms are eliminated because of changes in habitat and water quality.

The Au Sable hydroelectric basins are presently undergoing many changes, as indicated by the almost total disappearance of trout, by the changes in distribution and growth patterns of warmwater game fish, and by the increasing dominance by rough fish species.

The Fish Fauna, Judged from Seine Collections,

1972 Compared with the 1920's

By J. Scott Richards

Background and Objectives

Prior to 1923, it was the policy of the Michigan Department of Conservation to send hatchery fish to anyone who requested them. The value of this policy became increasingly suspect, and in 1923, it was decided that the state should begin to oversee the planting of fish. This required knowledge of water quality and natural fish populations in all systems that were to be planted. The State of Michigan therefore initiated a state-wide survey of all lakes and streams. One of the first rivers to be studied was the Au Sable, which even at that time was the state's best-known trout stream. However, then as now, there was concern that trout fishing in the Au Sable was on the decline. The grayling had been gone from the river for years, and the brook trout that were originally planted in 1884 and had provided excellent fishing, were believed to be on the decline. So serious was the apparent decline that an article in the Times News (now The Ann Arbor News) on July 4, 1924 described the Au Sable as "...once the greatest trout stream in Michigan, but now one of the worst, because it has been fished to death." Whether fishing was the cause, and whether the decline in brook trout abundance was real, will remain open for debate. The problem was real enough in the minds of fishermen, and so it was that five investigators--Dr. C. L. Hubbs, University of Michigan; Professor T. L. Hankinson, Zoology Department, Eastern Michigan University; Dr. J. Metzelaar, Fish Culturist, Michigan Department of Conservation; Professor C. W. Creaser, University of Kansas; and Professor T. H. Langlois, University of Michigan, during the years 1924-1927, made extensive fish collections over the entire Au Sable Watershed (Fig. 20). These collections were made in order to identify existing fish populations and to make recommendations for future trout stocking programs, with the goal of restoring the Au Sable to its rightful place as Michigan's premier trout stream. These fish collections, now on record at the Institute for Fisheries Research, provided a basis for comparison with collections taken in the same sites today, nearly 50 years later (see map, Fig. 21). It was hoped that these comparisons would provide some insight into the nature of changes in the watershed over that period, specifically:

1. What is the overall effect on the distribution of fish species resulting from the increased use and development in the watershed since the 1920's?

2. Do changes in fish distribution and abundance indicate substantial habitat change?

3. In particular, have conditions for trout changed, and if so, in what way?

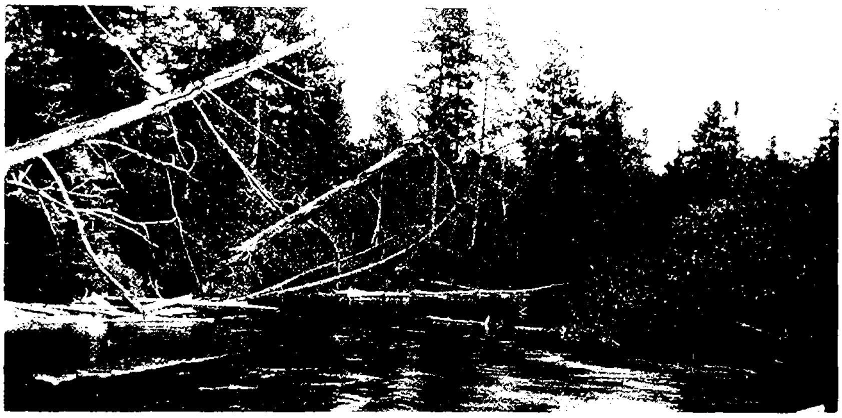

Figure 20. Upper: Dr. Carl L. Hubbs during a fish collection expedition with Professor T. H. Langlois in 1924.

Lower: Mainstream, Au Sable River, below Grayling in 1924. Note the number of "sweepers" along the bank on left.

Procedures

To validate comparisons, an attempt was made to duplicate, as closely as possible, everything that Hubbs et al. did in making their collections. Dr. Hubbs, still scientifically active, was generous enough to write several lengthy letters describing the methods that were used to seine fish and how much time was generally spent at a particular collecting site. In addition, the original field notes, on file in the University of Michigan Natural Science Museum, indicated precise locations of collections and the particular mesh and net sizes of seines used. Seines, ranging in size from 4-foot common sense minnow seines to 50-foot bag seines, were used. One final precaution was taken. The 1972 collections were all made within two weeks of the dates of corresponding collections from the 1920's in order to minimize seasonal differences in fish populations.

A map (Fig. 21) is included which shows the locations of fish collection sites. Percentages of fish species by major habitat types are listed in Appendix Table III. A list of fish species, and the numerical abundances of each, is also included for both collection periods (Appendix Tables IV and V).

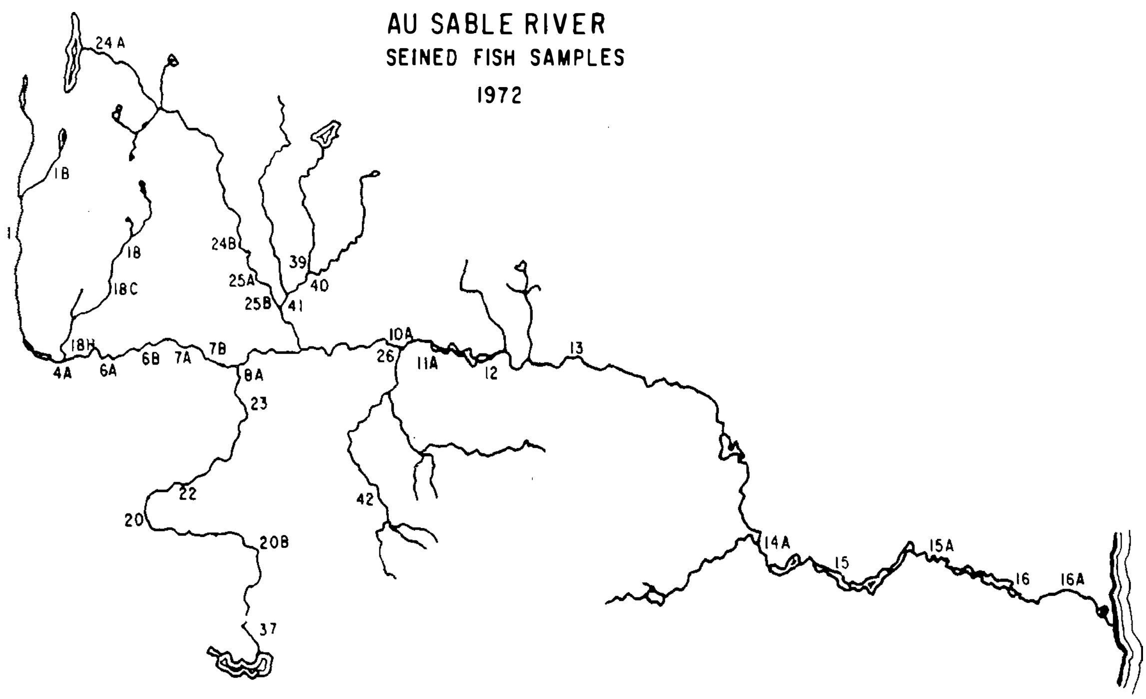

Figure 21. Au Sable River System, showing locations of 1972 seined fish collections (numbered), for comparison with similar collections made during the 1920's.

Discussion of Findings

General

Dr. Hubbs and his associates found 45 fish species in the Au Sable Watershed in the 1920's (Table 12), one more than the number which we found in 1972. Of the 44 species found in 1972, 7 were not found in the 1920's, and 8 of the species found then were not found in 1972. In other words, during the last 50 years in the areas sampled, 8 species have disappeared, and 7 new ones have replaced them. Since some of these are introductions and others were found only occasionally, discussion of the significance of these species shifts will be reserved until later.

Until recently, it has been difficult to talk about groups or communities of fish other than by simply listing the species found, and their relative abundance. It would be useful if one could abstract a number or index from a collection, do the same for any number of other collections, and then compare the numbers to see how similar those collections were. This is made possible to a great extent by a mathematical concept called species diversity (Fig's. 22 and 23). The type of index used in this study consists of two major components: the number of species in the collection, and the way numbers of individuals are apportioned within those species. It behaves in this way: the more species, the greater the diversity; and the more even the distribution of individuals within those species, the greater the diversity as well. This type of index has one major drawback: it does not differentiate between the species involved. Thus it would be possible to compare two fish collections and find they both had the same species diversity index, yet

Table 12. 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

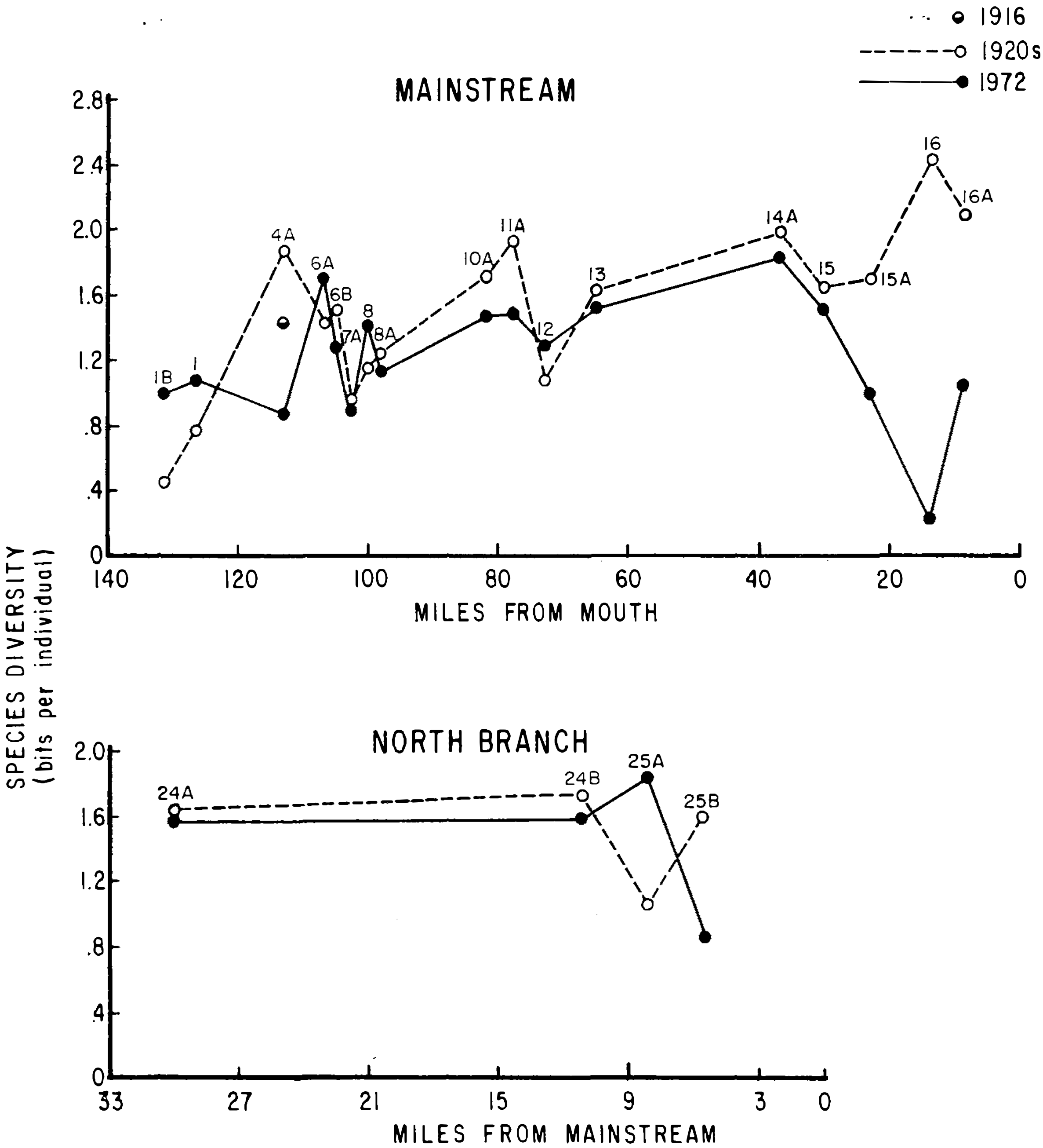

Figure 22. Comparison of species diversity for fish collections (seine) from the Mainstream and North Branch in 1920's and 1972. Refer to Watershed Map, page 51, for the location of collection stations.

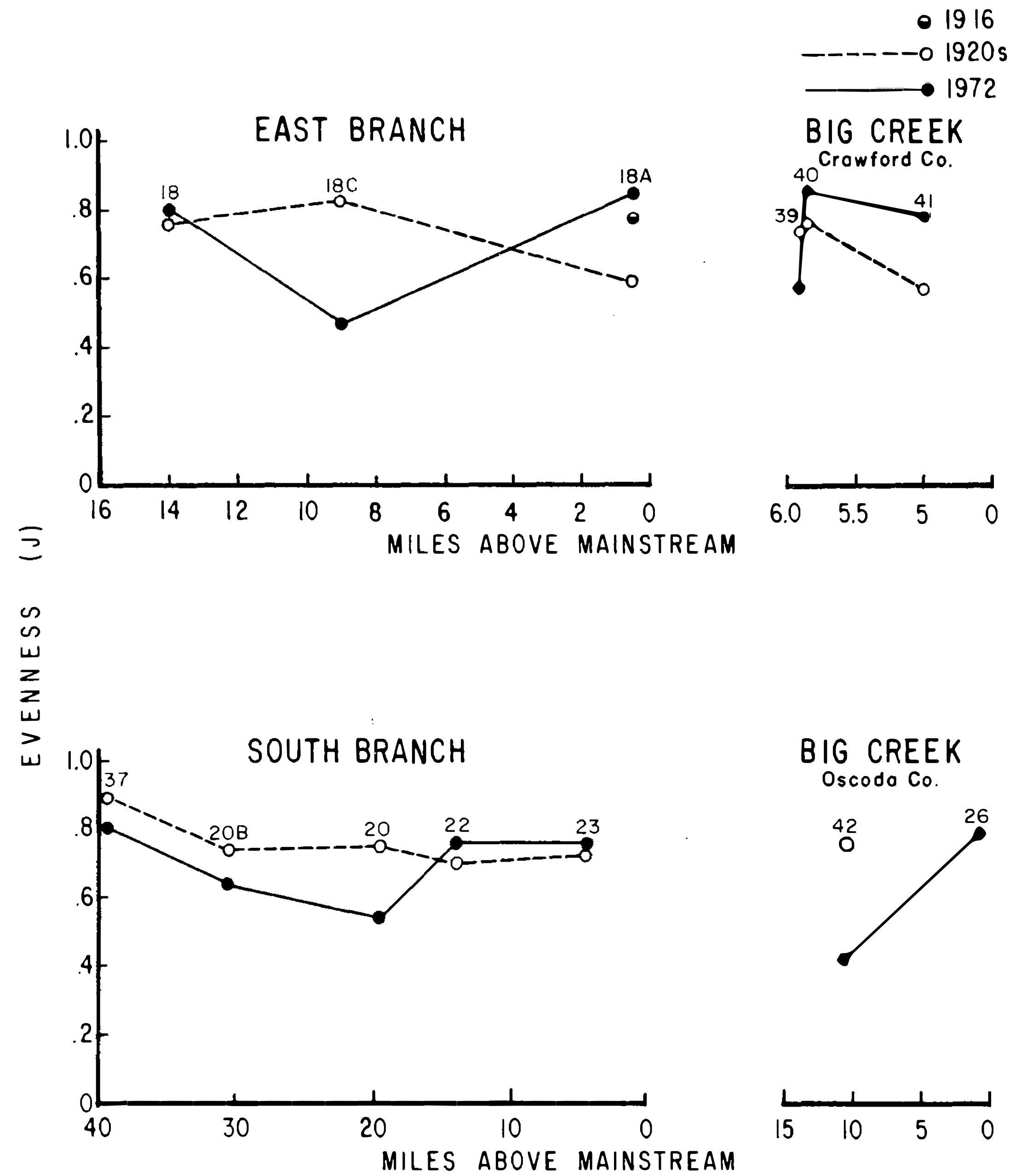

Figure 23. Comparison of species diversity for fish collections (seine) from Au Sable tributaries in the 1920's and in 1972. Refer to Watershed Map, page 51, for the location of collection stations.

they could contain entirely different species. In making comparisons, this fact has been kept in mind. Species diversity is a tool, but its usefulness depends on the wise use of other analytic devices. In summary, when species diversity is referred to in this paper it is simply a number that represents the complexity of a given fish collection, a summary of the number of species in a collection, and their relative distribution. Persons interested in the theoretical derivations and practical applications of such an index are referred in the Literature Cited section to papers by Pielou (1966, 1967, 1969), Margalef (1968), Tramer (1969), and Wilhm and Dorris (1966).

In one of the papers mentioned above, Tramer plotted species diversity against the Log_n of the number of species. The theoretical reasons for doing so are not important here, but the implications are. He postulated that in rigorous, non-predictable, unstable environments, one would expect a poor correlation between diversity and the log of the number of species. In stable, predictable environments, one would expect a good correlation. Using this procedure for the fish collection data (Fig. 24), it is clear that for the collections in the 1920's there is a good correlation ($R^2 = 0.80$), and for the 1972 collections there is not ($R^2 = 0.26$). Using Tramer's hypothesis, this could mean that the Au Sable River as a whole is a more rigorous, less predictable, less stable environment for fish now, than it was in the 1920's.

Analysis by Habitat

Categories

The easiest way to discover where change has occurred, without looking at each of the 34 collecting sites individually (as in Section III), is to group the data in some fashion. Grouping the data by habitat was the most logical approach. Anyone familiar with the Au Sable knows that not all of the habitat is suitable for trout. Several of the branches originate in warmwater lakes, and thus the headwaters of these branches, in most situations, are warmwater fish habitat. The collection sites were accordingly divided into four different habitat types as follows:

1. Warmwater stations (see Fig. 21) - having low to moderate flow (<100 cfs) and normal maximum temperatures >70°F: station numbers 18, 37, 20B, 20, and 24A.

2. Coldwater stations - having a flow of <300 cfs and normal maximum temperatures <70°F: 1B, 1, 4A, 6A, 6B, 7A, 8, 18A, 18H, 22, 23, 24B, 25A, 25B, 39, 40, 41, 42, 26.

3. Large-river stations - having a flow of >300 cfs: 8A, 10A, 11A, 13, 14A, 16A.

4. Large-river stations (tailwaters of impoundments): 12, 15, 15A, 16.

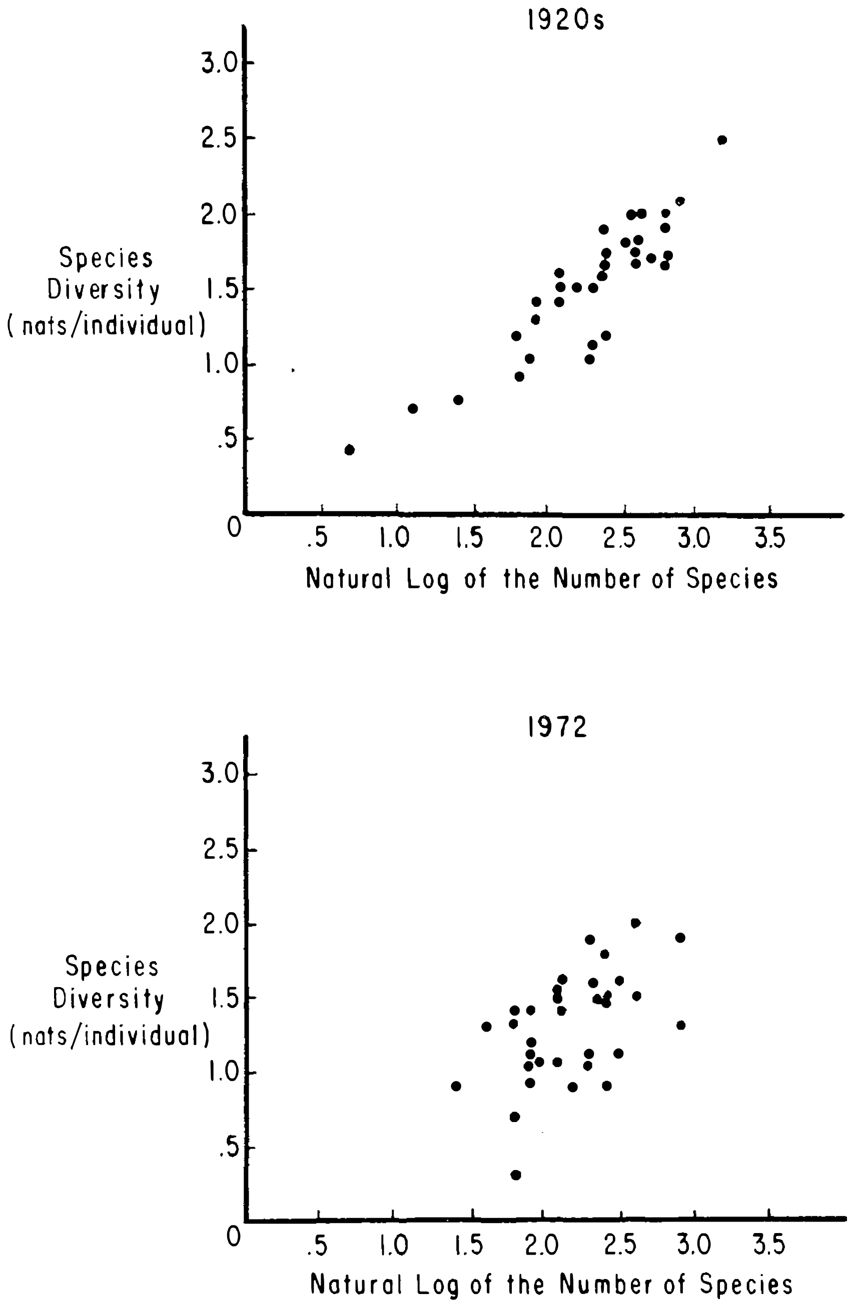

Figure 24. Fish species diversity vs $\log_n$ of the number of species. The 1920's collections demonstrate good correlation (R^2 = 0.80) and 1972 collections do not (R^2 = 0.26).

Diversity and Habitat Types

By looking at the mean species diversity for each of these habitats (Fig. 25), changes that have occurred in fish community structure can be more accurately determined. Using the student's t test (at the 90% level of significance--P = 0.10), the diversity in the warm- and coldwater habitats has not changed in that time span, whereas, diversity was significantly lower now than it was in the 1920's in both the large river sections and below impoundments. It is impossible to state categorically that a decrease in species diversity is bad, but generally, as Wilhm and Dorris (1966, 1968) have demonstrated, pollution or ecological stress of any sort will tend to decrease the diversity value in a given area. In short, if diversity goes down, it probably means that the particular area under consideration is under some sort of ecological stress. Such seems to be the case with the large-river sections, and below impoundments. It is of interest that all of the stations in these two habitat types are on the Mainstream of the Au Sable between the mouth of the South Branch and Oscoda.

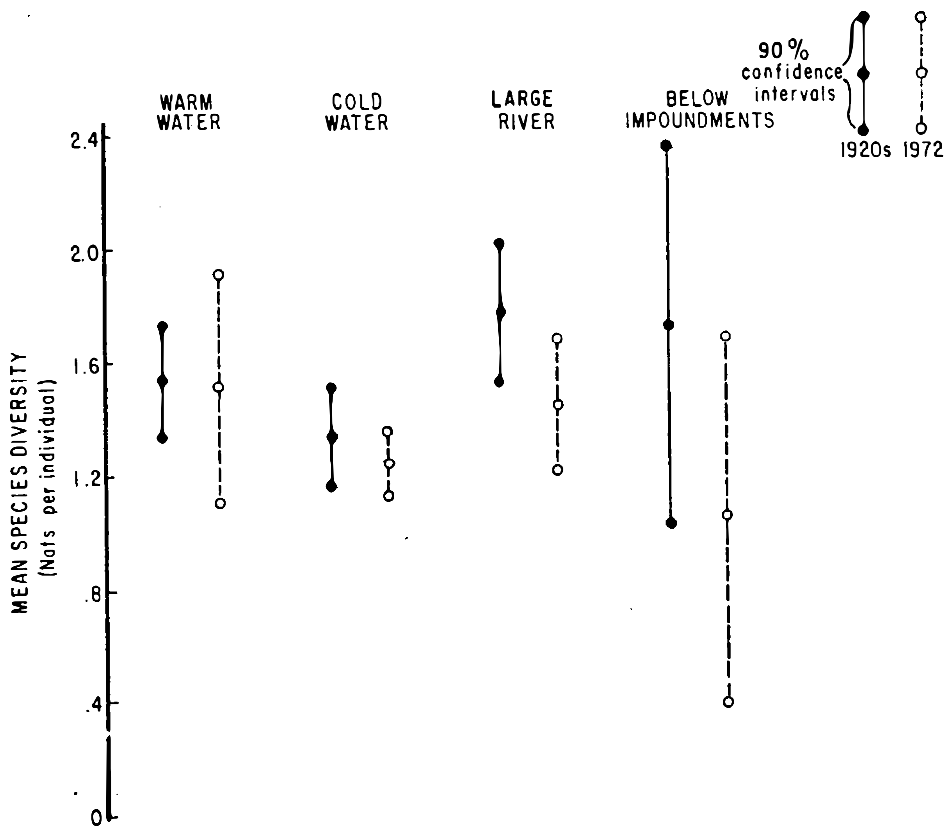

Figure 25. Changes in fish community structure as indicated by mean species diversity of the major habitat types.

Looking at the two major components of species diversity--the number of species (Fig. 26), and their relative distribution as expressed by the term evenness (Fig. 27)--the same trend is evident in the latter. The mean number of species has decreased in all but the warm headwater areas, although none of these decreases was statistically significant. In the case of evenness, however, the large-river and impoundment habitats evidenced a statistically significant decrease (0.10 level), whereas the other two habitat types showed no significant change. It has been shown (Wilhm and Dorris, 1966) that a stream receiving a pollutional input is characterized by few species, and by a superabundance of individuals in one or two of those species. This type of situation would be reflected by a low evenness. Relating this to the Au Sable River, it appears that the lower part of the Mainstream (with a decrease in evenness) has become more degraded than it was in the 1920's, while the warm- and coldwater habitats have remained unchanged.

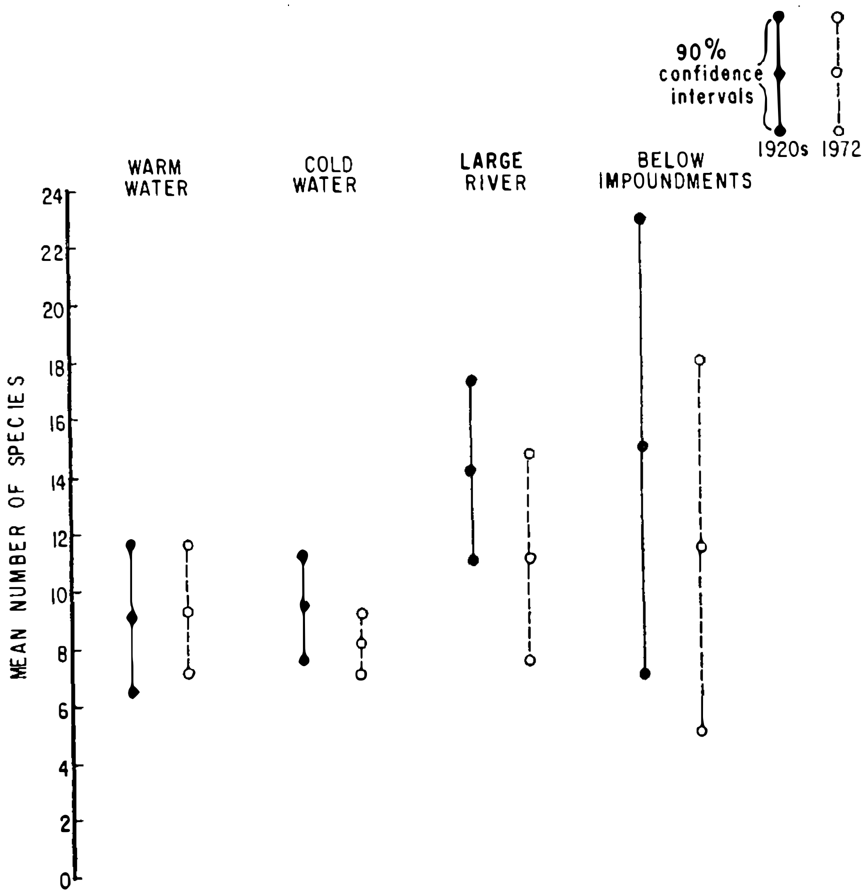

Figure 26. Changes in fish community structure for the major habitat types, as indicated by the mean number of species collected in the 1920's and in 1972.

Jaccard Index

In an attempt to clarify species diversity analysis, I used a device known as the Jaccard Index (Simpson, 1960). It is a simpler, and much more sensitive tool than species diversity. This index allows the user to take two species lists, compare the number of species in common, and calculate a percentage similarity.

Jaccard formula:

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

where: C = species in common

N_1, N_2 = number of species in first and second samples respectively

This index is useful and fits very well into present needs as it reflects on a scale of 0 to 100 just how similar or dissimilar two collections are.

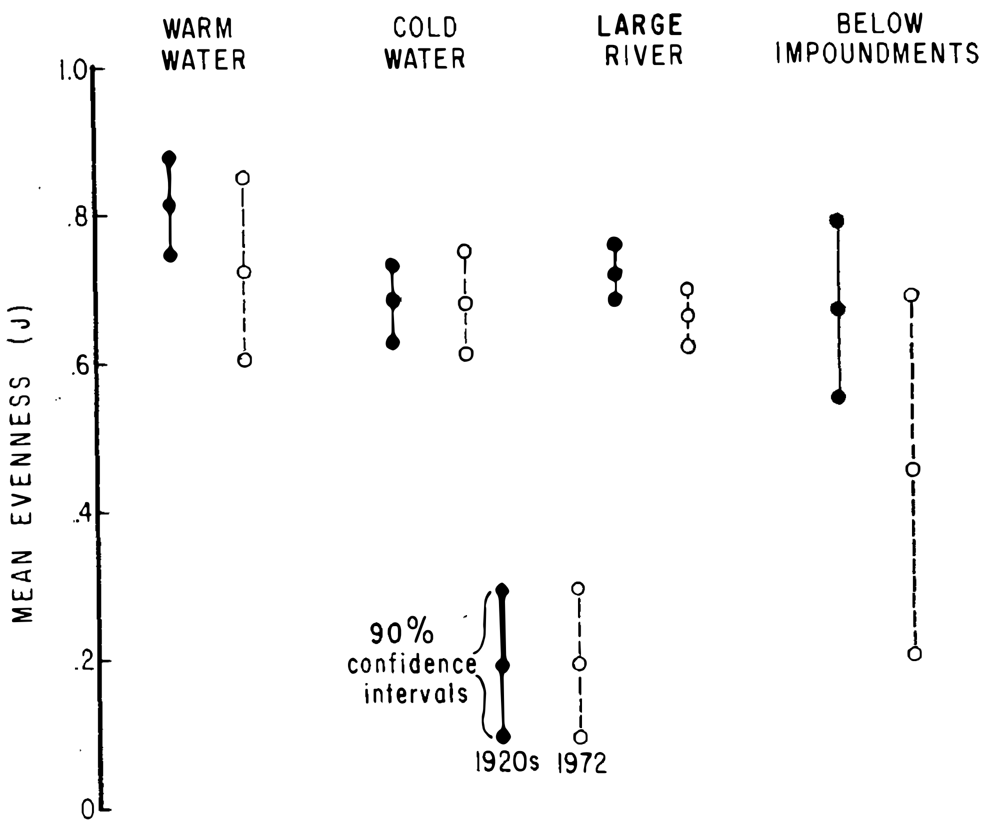

Figure 27. Changes in fish community structure for the major habitat types, as indicated by the mean evenness (similarity in the numbers of fish within each species) found in collections from the 1920's and 1972.

The collections of the 1920's were compared with those made in 1972 in this pair-wise manner, so that at each sampling station the percentage change in number of species over the 50-year period could be determined (Fig's. 28 and 29). The Jaccard value for each station was then placed in the appropriate habitat category, and the mean Jaccard Index was calculated for each habitat (Fig. 30). Brown (1969) calculated a cut-off value for the Jaccard Index which simply allows one to determine, with some degree of quantitative validity, whether two collections can be considered the same, similar, or dissimilar. A cut-off point for the 1972 fish collections was calculated on the basis of the normal amount of variability found in the sampling procedures. It was determined that if the Jaccard Index exceeded roughly the 74% level, the two collections being compared for the 50-year period could be considered similar or unchanged. In no case did the Jaccard Index for any of the habitat types approach the similarity level. Again, as was the case with diversity, the warm- and coldwater habitats showed the greatest similarity (least change), and the large-river and impoundment habitats showed the least similarity, or the greatest change. In general, this analysis shows that there has been a substantial species shift in all areas of the watershed, with the lower part of the Mainstream showing the greatest shift. It should be pointed out that this index is perhaps too sensitive, because it weights the loss of a rare species the same as the loss of a very abundant one. This is unfortunate, but the Jaccard Index remains the most useful index of its kind that could be found. In summary, it indicates the following: that a substantial shift of fish species took place in the watershed over the last 50 years in all habitats; that the good quality cold trout waters had the least change; and that the lower part of the Mainstream had the greatest change.

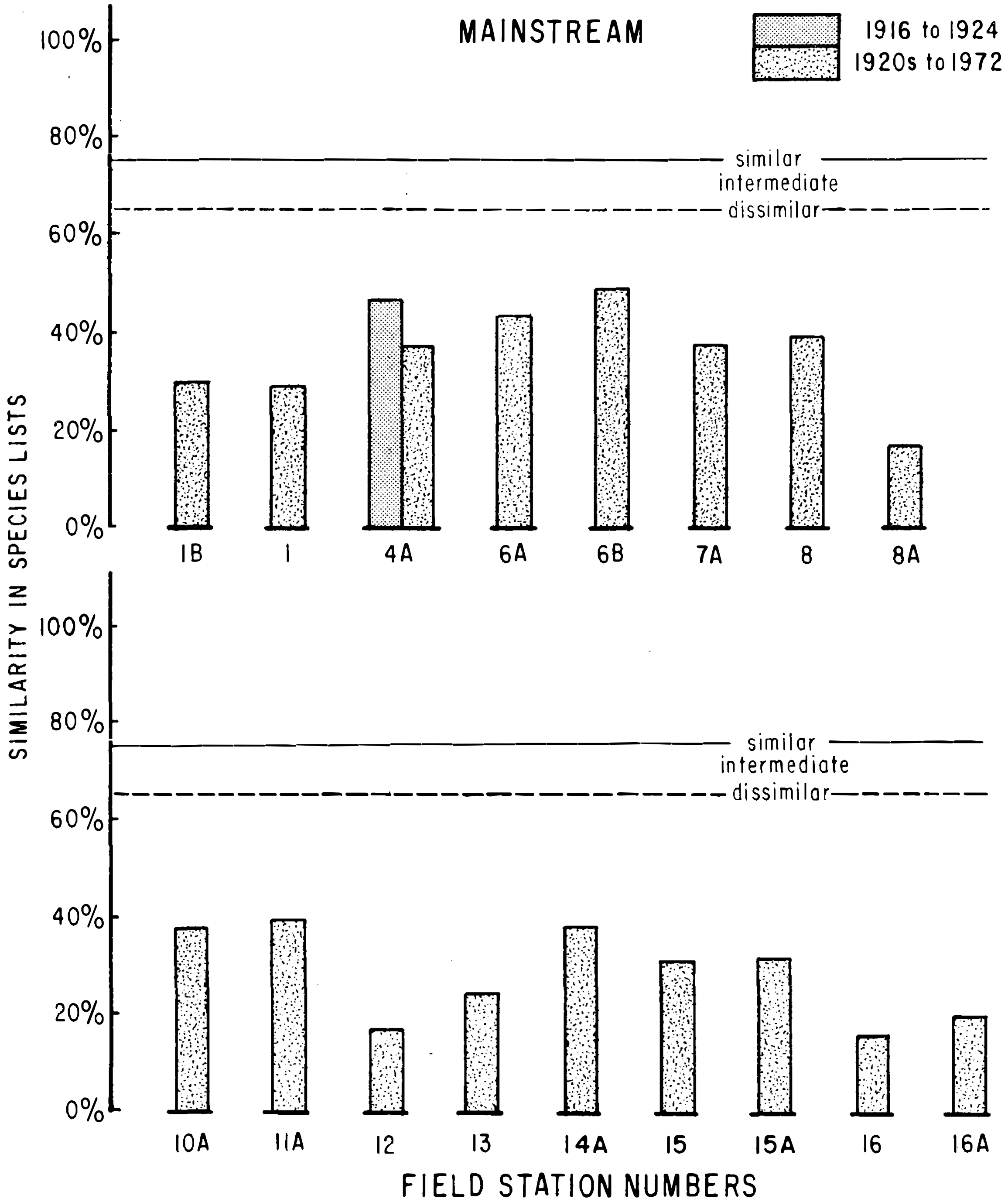

Figure 28. Comparison of the similarity in lists of fish species in 1920 and 1972, Mainstream of the Au Sable.

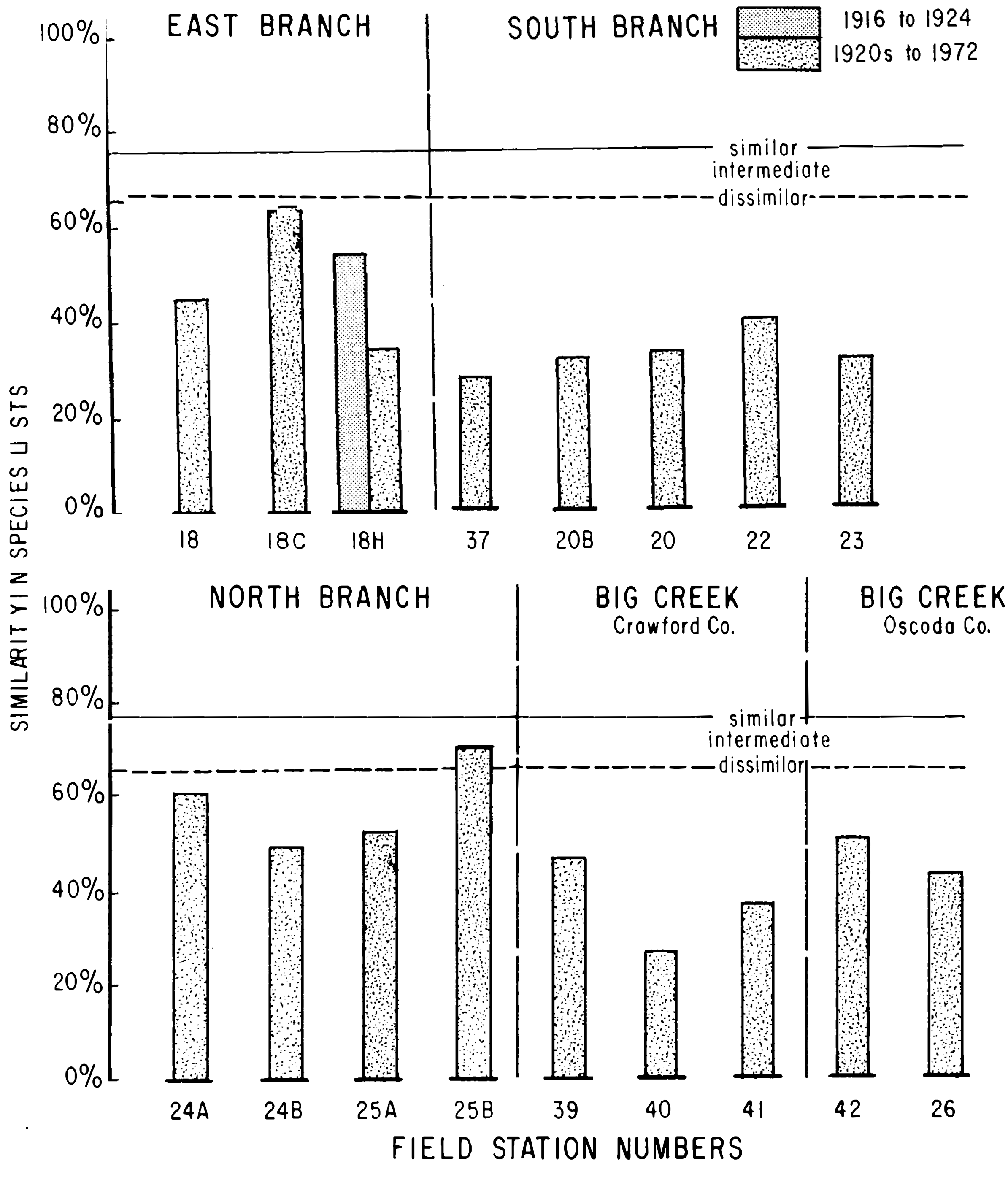

Figure 29. Comparison of the similarity in species lists in 1920 and 1972 - tributaries.

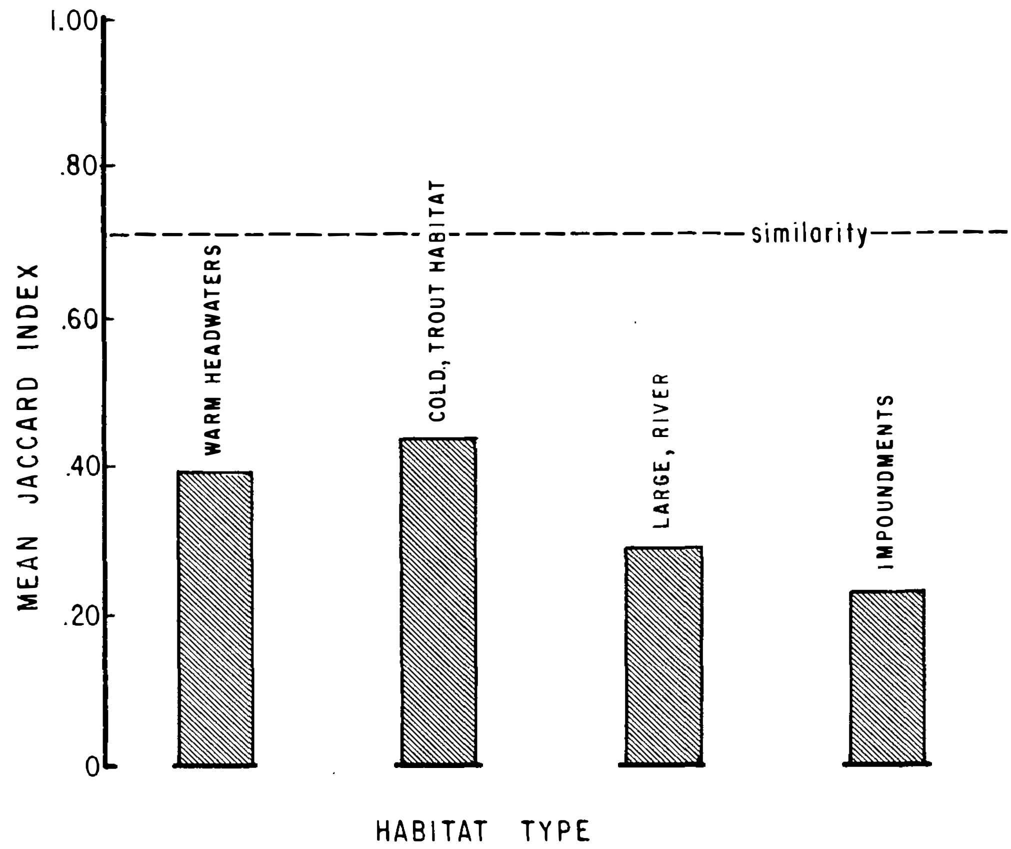

Figure 30. Comparison of the mean Jaccard Index for the major habitat types.

Species Changes in Relation to Habitat

What species of fish have been affected by habitat change, and how have their distributions been altered? The number of times each species occurred in a collection was determined for each habitat, and the percentage occurrence was calculated (Appendix Table III). Those changes that have been the most significant have been summarized in Tables 13 and 14. Only 16, of the 52 species of fish taken, showed what were considered to be large changes in frequency of occurrence over the entire watershed. In other words, 37 of the 53 species occurred as often in collections in the 1920's as they did in 1972 collections. This tempers earlier conclusions about species shifts based on the use of the Jaccard Index, and implies that although there have been large species shifts locally in response to changes in microhabitat, the species distribution in the watershed as a whole has stayed fairly constant.

Of particular interest is the fact that slimy sculpin, brown trout, and round whitefish all showed an overall increase. These are all cold-, clean-water species indicative of good trout habitat

Table 13. 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%

(Trautman, 1957). The rainbow trout has experienced a general decline throughout the watershed, due in part to a decrease in stocking, but due primarily to competition from the more successful brown trout. It is interesting that the pearl dace, longnose dace, river chub, rosyface shiner, and to some extent, the redfin shiner and common shiner, all of which have become less widely distributed throughout the watershed, are intolerant of turbid waters and of silt- and sand-covered bottoms (Trautman, 1957). Their decline, along with the increase in the mimic shiner and fathead minnow which prefer low gradient and a sandy-silt bottom type, therefore may reflect a change in the quality of the water and bottom conditions in the system over the last 50 years.

Warmwater Habitat

There are so few stations in each of the warmwater, large-river, and impoundment areas that it is difficult to say with certainty whether changes which have occurred are significant. It does not appear as though much change has taken place in the warm headwater areas, although the decline in frequency of occurrence of brook trout and river chubs (Table 14) could be the result of a change in water quality as well as increased competition from other species.

Large-river Habitat

The large-river habitat seems to show evidence of a change in water quality. The decline of rainbow trout and slimy sculpin, both cold-water species (Hubbs and Lagler, 1970), and of longnose dace and river chub (Table 14), both intolerant to turbidity and silty conditions (Trautman, 1957), indicates a decline in water quality. The increase in brook trout in those same areas is not real--in one case, individuals captured were recently planted hatchery fish; and in the other they were

Table 14. 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
			Warmwater Habitat (Five stations)		
			Pumpkinseed	40%	0%
			Brook trout	40%	0%
			River chub	60%	0%
			Coldwater 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 (six 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 (four 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%

really captured at the mouth of Big Creek, a cold trout stream, and were therefore responsive to the water quality of that stream rather than the main Au Sable itself. The greatest change in fish species has occurred in the large-river habitat (Figs. 31 and 32) along with impounded waters.

Impounded-water Habitats

Effects of the hydroelectric impoundments (built 1913-1924) on water quality were relatively recent at the time Dr. Hubbs made his collections. Typically, in the successional stages of impoundments, there is an initial surge in growth of fish populations, with characteristically good fishing for several years, after which fishing success and fish populations decline (Hynes, 1970; Bennett, 1962). It seems likely that when Dr. Hubbs et al. collected in the 1920's, these basins were newly impounded and fish populations were thriving. Today (50 years later) these fish populations are being adversely affected by the subsequent deterioration of water and habitat quality. Also, the instability of the habitat below the impoundments, because of day-to-day fluctuations in water level (for hydroelectric production), has no doubt had a very detrimental effect on fish populations. These two factors--the age of the impoundments, and the constant fluctuations in flow below them--are probably the principal causes for the general decline which has occurred in fish populations. The decrease, or complete loss of species intolerant to silt and turbidity, and the increase in the frequency of occurrence of the more tolerant mimic shiner (Trautman, 1957) lend support to this supposition.

Coldwater Habitat

The waters of greatest concern in the Au Sable System are the coldwater trout habitat. The increase in frequency of occurrence of brown trout, and the decrease in rainbow trout, have been trends well known to trout fishermen for years. The supplanting of rainbows by browns was evident even at the time Hubbs made his collections.[12] Given the habitat requirements of the two species (Trautman, 1957), it seems likely that the Au Sable, in most of its reaches, has always been more suited to the brown than the rainbow. Coupled with the fact that when Dr. Hubbs made his collections, rainbows were being stocked much more heavily than browns, the decline in rainbow trout in recent years should not be viewed with alarm, but with the understanding that it is less well suited to this particular watershed than is the brown trout. The brook trout was reportedly on the decline, as mentioned previously, even before Hubbs et al. made their collections, in spite of the fact that this species was being stocked at the time far more heavily than either the brown or rainbow. The general decline of brook trout in recent years is probably due in part to its lower tolerance to the temperature regime throughout much of the system, coupled with continuing competition with brown trout (Trautman, 1957). There are areas within practically all of the good quality trout habitat where even today brook trout have remained abundant, due to locally cooler water temperatures resulting from good groundwater inputs. The existence of such areas

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[12] Ruthven, A. G. 1924. Letter to P. G. Zalsman.

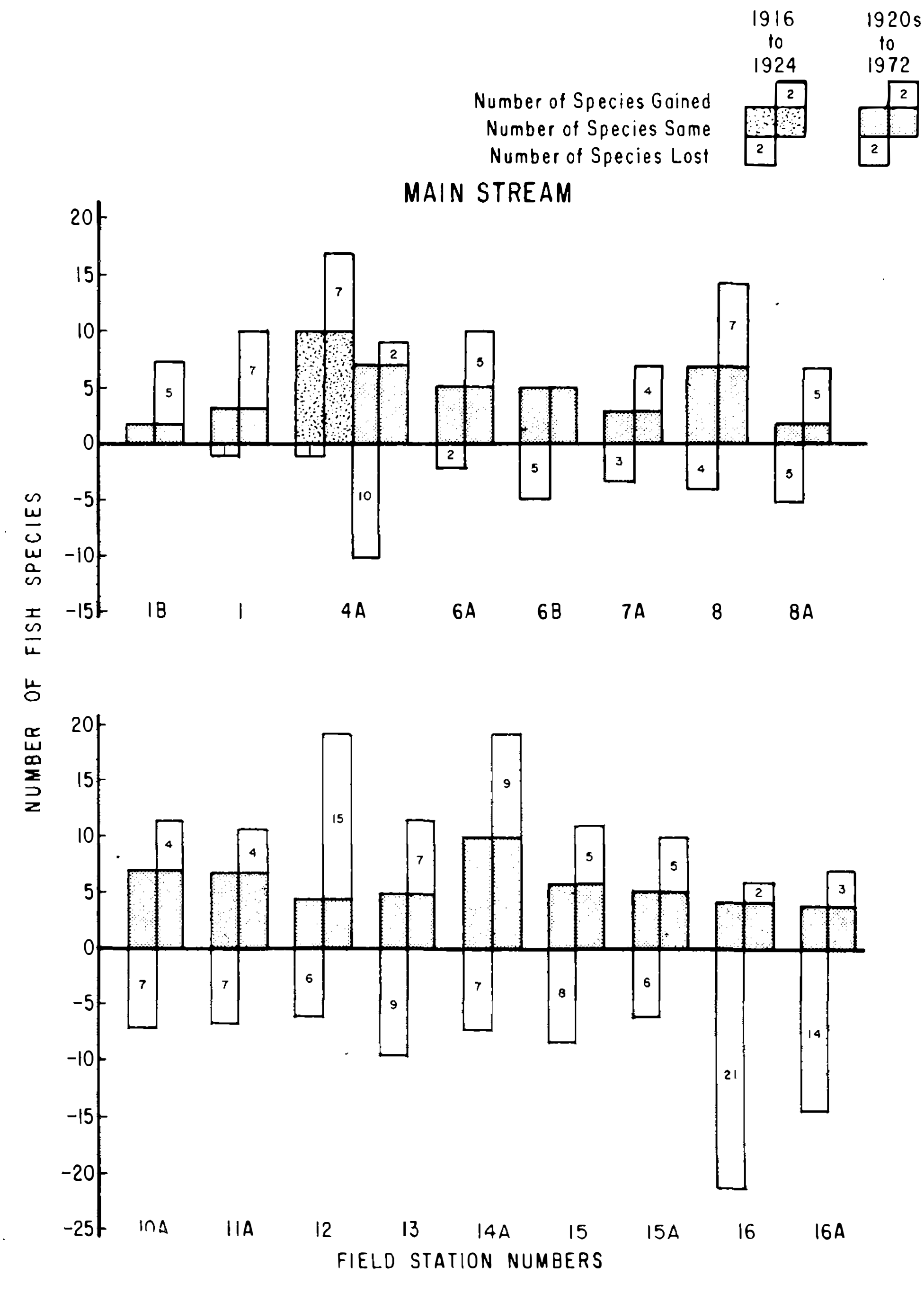

Figure 31. Changes in the numbers of species gained or lost at each Au Sable River Mainstream station during the periods indicated.

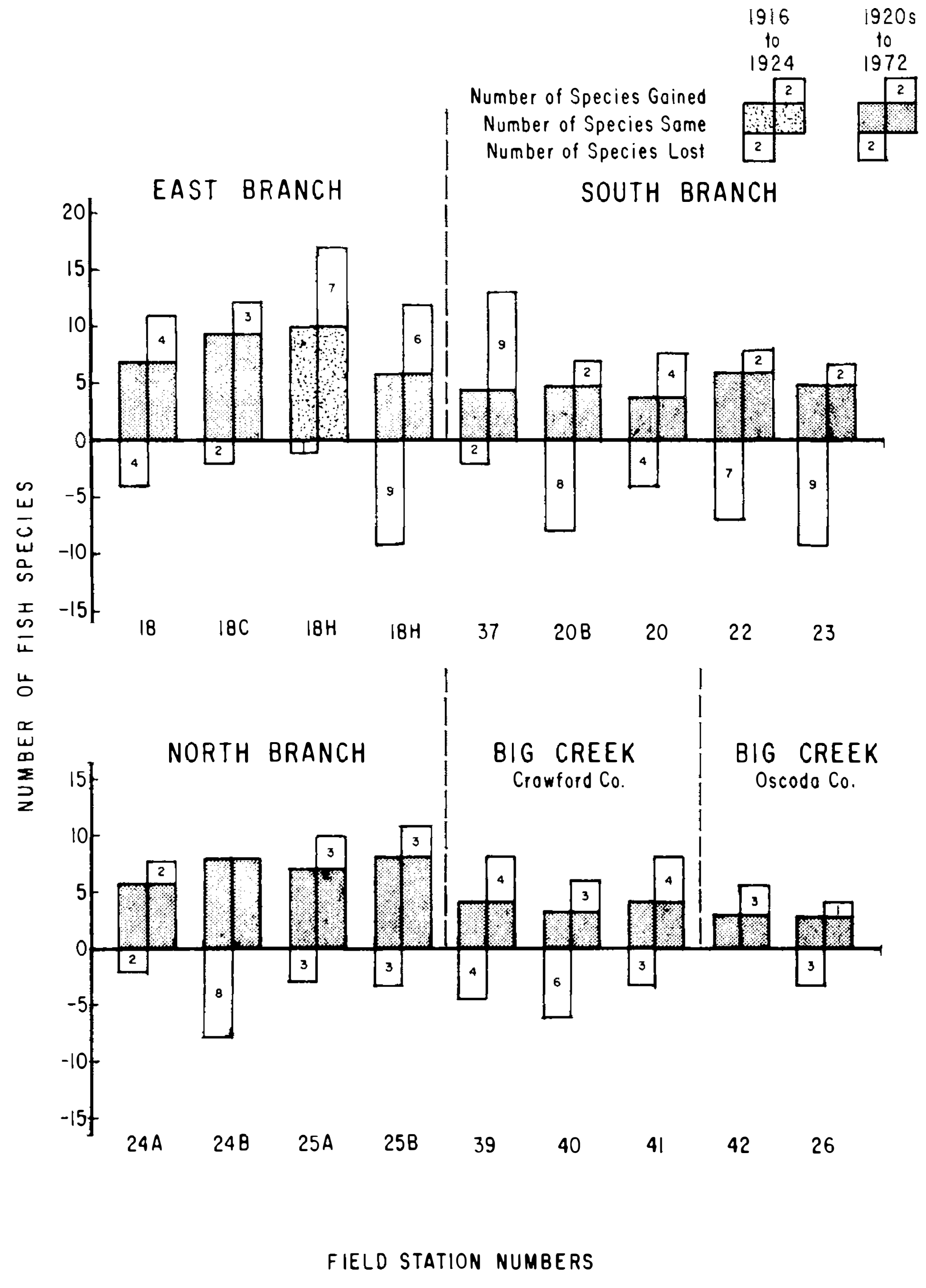

Figure 32. Changes in the numbers of species gained or lost at each tributary collection site during the periods indicated.

was recognized by Dr. Hubbs and formed the basis for his planting recommendations for the system.[13] He recommended increased planting of browns and rainbows generally, but suggested that the headwaters of the Mainstream, and much of the East and North Branches be maintained for brook trout. These areas today still contain some of the best brook trout populations left in the system. Because of its cooler temperature requirements and greater susceptibility to fishing pressure, it seems unlikely that the brook trout will ever again be as important a game fish in the Au Sable as it was at the turn of the century.

Examination of changes in all species of fish in the coldwater habitat indicates that brown trout, slimy sculpin, and round whitefish have all increased in frequency of occurrence (Table 14). This implies a general improvement in water quality. The decrease in frequency of occurrence of blacknose shiners, common shiners, pearl dace and river chubs could indicate an increase in sand and silt accumulation since the 1920's (Trautman, 1957), or simply a response to a lower temperature regime which would be more suitable to coldwater species than to minnows (Spence and Hynes, 1971B).

Coldwater Fish as Indicators of Conditions

The three species of trout, slimy sculpin, and round whitefish were lumped together as coldwater types (Trautman, 1957). By doing this and noting changes in the frequency of occurrence of this group, it was possible to make inferences concerning changes in water quality. This sort of approach to data analysis is admittedly outdated and has been supplemented in modern times by methods such as species diversity analysis. But it does indicate qualitative changes which, together with the other approaches we have used, give a more complete picture of the nature of the ecological changes that have taken place in the watershed.

The percentage of the total number of individuals that the five coldwater species represented in each collection was calculated (Fig's. 33 and 34). If one examines just the coldwater habitat stations, it is clear that more stations have experienced a marked increase in percentage of coldwater species than a decrease (Table 15). In other words, it appears that in a number of what are considered good trout areas, conditions have actually improved for coldwater species. Changes at particular stations, and possible reasons for them, are discussed by stream section (Section III). The average percentage of coldwater species found at the 19 coldwater trout habitat 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 notion that the overall trend of change in trout habitat in the Au Sable since the 1920's has been for the better.

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[13] Hubbs, C. L. 1924. Unpublished "Preliminary Report on Au Sable Fish Investigations." In files of Museum of Zoology, University of Michigan.

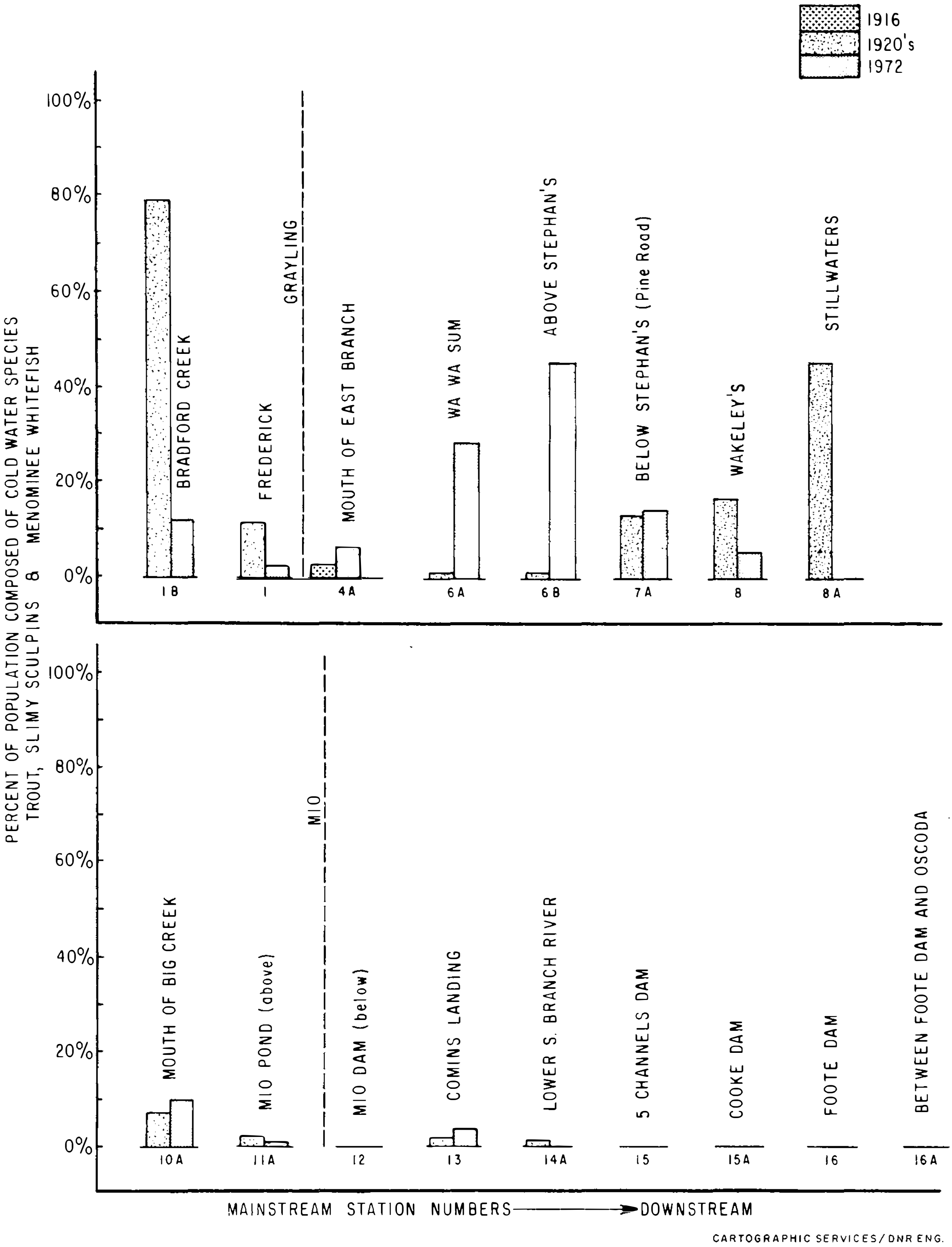

Figure 33. Comparison of the percent of coldwater fish species present in seine collections made in the 1920's and in 1972 on the Au Sable Mainstream.

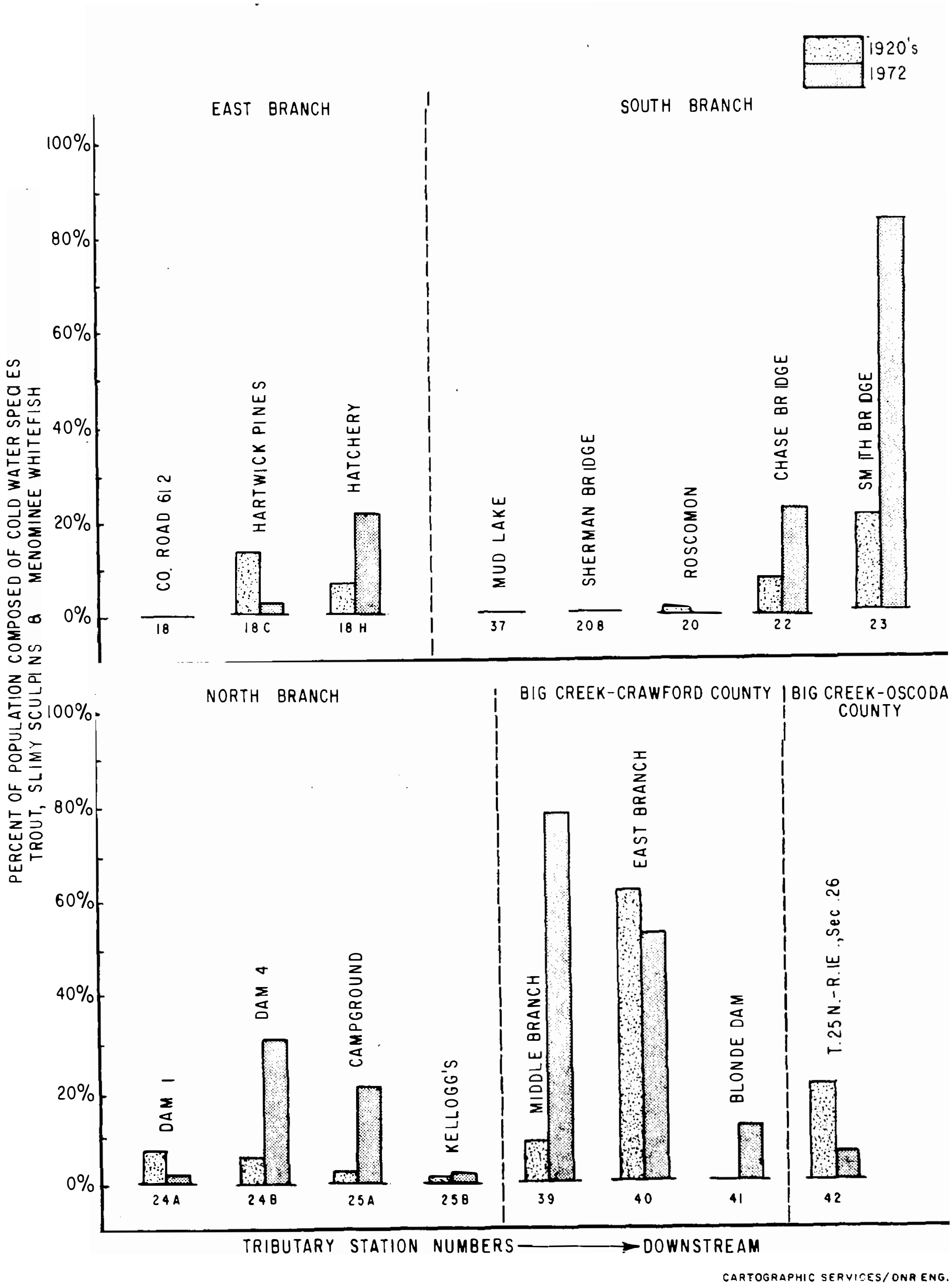

Figure 34. Comparison of the percent of coldwater fish species present in seine collections made in the 1920's and in 1972 on the Au Sable tributaries.

Table 15. Coldwater stations showing a marked change in percentage of coldwater fish species present (brook, brown, and rainbow trout, slimy sculpin, and round whitefish), Au Sable River, 1920's and 1972

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

Summary

It would be misleading to make sweeping generalizations about changes in the fish populations and water quality of the Au Sable System as a whole over the last 50 years. Ideally, each station should be examined separately as a discrete unit. That being a laborious task, some order of generalization is necessary, and that was provided by grouping our sampling stations into four habitat types: warmwater areas, coldwater areas, large-river areas, and below impoundments.

The last two habitat types, which include only stations on the Mainstream below the mouth of the South Branch, have shown a general decline in water quality over the 50-year period in question. They show the greatest shift in fish species, the greatest loss of species, the greatest decrease in evenness, and the greatest loss in species diversity of the four habitat types. These facts, along with the qualitative analysis of the types of species that have increased or become reduced in frequency, tend to suggest both a decline in water quality and a change in bottom conditions. The major factor contributing to this decline in water quality has been the presence and operation of the six hydroelectric dams. Reference to the high- and low-water fluctuations in flow below Alcona Dam, even in the 1920's, shows that the fluctuations were drastic. Photos showing conditions over six river miles below Alcona Dam, underscore the fact that this instability of flow was not (and is not) simply confined to areas immediately below the impoundments. Nutrient-rich, warmed waters, drawn from the top of the impoundments, result in conditions that are unfavorable for trout. Dramatic proof of the detrimental effects of impoundments is found by examination of changes at Blonde and Mio Dams. The former dam has been removed and where Hubbs described that area as containing "no trout; fish typical for fairly warm creeks," it now has one of the best populations of trout in the system.[14] Mio Dam, the flow through which has not been continually regulated in the last 10 years (except to maintain minimum flow requirements), is the only major impoundment station to evidence an increase in numbers of fish species since Dr. Hubbs made his collections. In short, dams can have a detrimental effect on trout streams, but their removal can be followed by complete or nearly complete recovery over a period of years to the quality of water formerly present.

The decrease, in the lower part of the Mainstream, of fish species intolerant to silt, sand and turbidity, indicates a possible shift in bottom type in some parts of the system over the last 50 years. The decline in species of minnows throughout the watershed, and particularly in the coldwater habitats, might also reflect a general decrease in average water temperature in the system (Spence and Hynes, 1971B). This seems particularly likely as all indications are that conditions for the coldwater species--trout, slimy sculpin, and round whitefish--have improved. It seems likely that average water temperatures have dropped since the 1920's. A look at some of the areas of the North Branch (photos) shows the complete lack of shade present in parts of the system at that time. Heavy cutting and post-logging fires in Michigan at the turn of the century apparently resulted in a clear-cut landscape over much of the Au Sable Watershed. The growth of shade cover and the subsequent stabilization of banks would have begun before Hubbs et al. made their collections, but by no means was it as complete as it is today. In addition, several of the water-warming impoundments (Dams 3 and 4 on the North Branch, and Blonde Dam on Big Creek) have been removed. This adds further credence to the idea that conditions for trout, in the areas that have always been considered good trout waters, have improved since the 1920's. While water temperature and quality may have improved due to increased shade and bank stabilization, and to decreased nutrient input, these changes apparently have not been sufficient to save the brook trout in its decline in competition with the brown trout in many parts of the system.

Conclusions

The coldwater trout habitat has, if anything, improved over the last 50 years. This conclusion is substantiated by the following reported findings:

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

b. A significant change in species lists (Jaccard Index), but the least change in trout habitat as compared to the other three habitat types.

c. An increased mean percentage of trout, round whitefish, and slimy sculpin.

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[14] M.D.N.R. electrofishing survey report. 1972. Big Creek above Co. Road 608, on file at I.F.R., Ann Arbor.

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

The disappearance of certain species of minnows may be a joint function of decreased water temperatures and secondarily of changes in bottom type. Where the average water temperature has seemingly increased (Bradford Creek), the (coldwater) trend has reversed, with an increase in minnow species and a decrease in percentage of trout. Changes in bottom conditions might be generally related to increased erosional input and to enrichment from human use. Decreases in average water temperature could be attributed to increased growth of shade, and to the removal of impoundments in trout habitat since the 1920's.

Water quality in the lower part of the Mainstream, including the impounded and the large-river habitats, has deteriorated, with corresponding changes in the fish populations. 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 general loss or lesser abundance of species of minnows intolerant to silt and turbidity, 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 old impoundments contain warmer, more turbid, enriched waters, and an unstable environment. Increased human disturbance might be playing a part in bottom changes here as well.

The warm headwater reaches of the system seem to have remained about the same over the past 50 years. The following data support this conclusion:

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

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

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

These warm headwater reaches were at best very marginal, or were non-trout waters, when Dr. Hubbs et al. made their collections; and they remain so today. As they are fed by warmwater impoundments and lakes, for the most part, that are not likely to be removed, it is doubtful that these areas will ever be able to sustain substantial trout populations.

Insect Communities of the Au Sable River

By Michael Quigley

Review of Existing Data

Although the Au Sable Watershed has historically received a great deal of scientific attention in areas concerned with the management of its valuable sport fishery, little quantitative information exists regarding the disposition of other aquatic fauna of the river (see Fig. 35 for collection sites). A survey of the literature revealed that only four quantitative collections of bottom fauna had been conducted prior to the Au Sable River Study collections in the summer of 1972. Previous investigations are listed chronologically in Table 16. In order to supplement the meager amount of usable quantitative data, an effort was made to compile a list of qualitative observations pertaining to changes in the bottom fauna community within the past 35-40 years. Early food habit studies of fishes provided the bulk of such data. Sources of qualitative data are given in Table 17.

Other information regarding changes in the Au Sable's aquatic insect community was extracted from informal interviews with long-time residents and/or users of the river. Because observations and impressions

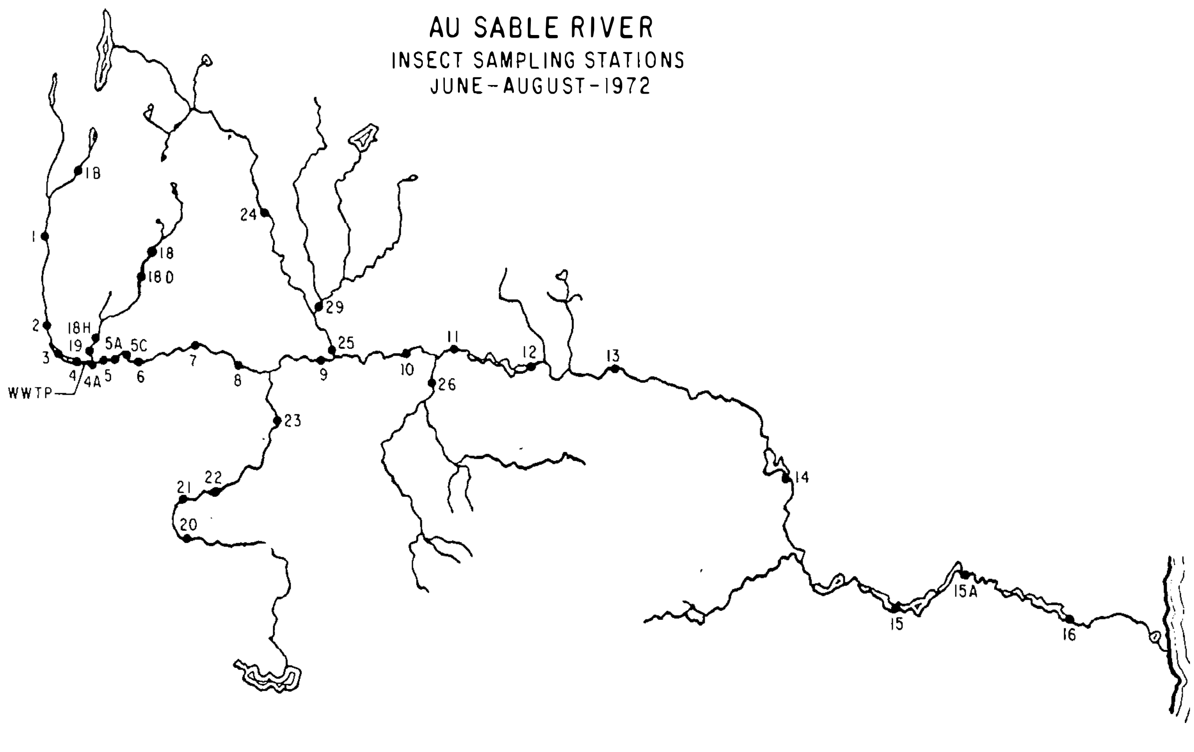

Figure 35. Location of Au Sable River bottom sampling stations, June to August, 1972.

Table 16. Quantitative insect data compiled from previous investigations in the Au Sable Watershed

Collection Date	Collection Site	Investigator(s)
1931	North Branch	C. M. Tarzwell (1936)
June 14-16, 1966	(8)* Mainstream (2) East Branch	Institute for Fisheries Research
1954-1957	North Branch	Lavern Curry, MDNR Fish. Division, 1957, unpublished
Sept. 20-22, 1966	(5) South Branch	Mich. Water Resources Commission, 1966
Sept. 27-28, 1968	(11) Mainstream	Dorence C. Brege, 1968, MSU, Masters thesis
May 5, 1970 thru Feb. 15, 1971**	(1) Mainstream	Institute of Water Research, MSU

* Figures in parentheses are numbers of sampling sites.
** Study is still in progress

Table 17. Qualitative insect data compiled from previous investigations in the Au Sable Watershed.

Collection Dates	Information	Collection Sites	Investigator(s)
June, 1924	Trout food habits	North Branch East Branch of Big Creek (North) East Branch Bradford Creek Middle Branch of Big Creek (North)	Dr. Carl L. Hubbs, Univ. of Mich. Dr. Jan Metzelaar, Mich. Dept. Cons.
July-Sept., 1924	Trout food habits	Mainstream (Stephans Bridge)	Prof. T.L.Hankinson, East. Mich. Univ. Prof. T.H.Langlois, Univ. of Mich.
March, 1931	Trout food habits	North Branch (Lovells Bridge)	Prof. J.W.Leonard, Univ. of Mich.

pertaining to insect fauna varied greatly among individuals, reliability of such data is only marginal. However, certain individuals contributed much in the area of supplementary data. The observations and impressions of Dr. Justin W. Leonard were particularly valuable. Dr. Leonard, a prominent entomologist, and his wife, Fannie A. Leonard, with a seasonal residence on the Au Sable River, spent eight years identifying its insect fauna. Their book Mayflies of Michigan Trout Streams is a valuable contribution to the understanding of mayfly taxonomy. Much of the book is the product of extensive taxonomic study which the Leonards directed toward the Au Sable's diverse mayfly fauna. Among all Au Sable residents and users, the Leonards undoubtedly possess the greatest knowledge of its benthic fauna.

Discussion of Analytical Procedures

Analysis of all insect data and its comparison with previously existing data followed two traditional approaches.

Diversity Analysis

Diversity indices derived from information theory (Wilhm and Dorris, 1968; and Brillouin, 1960) provide a useful means of simultaneously expressing both numbers of insect taxa present in a square-foot area of stream bottom, as well as the relative distribution of individual insects among such taxa.

Two equations were used to evaluate components of insect diversity. The first equation composes the actual measure of diveristy and is taken from a formula of Shannon and Weaver (1949), using Stirling's approximation:

$$\text{Diversity } (H) = -\sum_{i=1}^{n} (N_i/N) \log_2 (N_i/N)$$

where, N_i = number of insects in *i*th taxa
N = total numbers of insects of all taxa
n = total number of taxa

A second equation complements the above diversity measure by providing a measure of the distribution of insects among each taxa. Such a measure is referred to as "evenness." Thus, for an individual square-foot bottom sample with n number of taxa present:

$$\text{Evenness} = \frac{H}{H_{max}}$$

where, H = actual diversity of sample
H_{max} = maximum diversity possible with n taxa and N equal to toal number of organisms present in the sample. Since n is constant, H/H_{max} is essentially a measure of percent maximum possible diversity. Field samples seldom reach maximum diversity values, and thus evenness composes a useful index of the relative proportions of insects present in each insect taxa.

In general, high diversity values (many taxa and/or an even distribution of individuals among taxa) indicate the existence of a diverse and well balanced insect community, while low diversity values (few taxa and/or uneven distribution of individuals among the taxa) imply, in most cases, a degradation of the insect community which has oftentimes been induced by the introduction of a natural or man-made environmental stress (Wilhm and Dorris, 1968).

Tolerance Analysis

A variety of insect taxa have been found to have differing capacities for tolerating pollutional stress (Gaufin and Tarzwell, 1952). Such differences permit the investigator to evaluate impact of stress (pollution) upon the stream bottom community by comparing the relative abundance of insect groups having similar tolerance capacities. Traditionally, benthic organisms have been assigned to one of three tolerance categories according to relative abilities to tolerate organic wastes and depressed levels of dissolved oxygen. The three categories are commonly defined as follows (WRC, 1966):

> Tolerant - Organisms that can withstand a variety of adverse environmental conditions and often respond by becoming more abundant, while less tolerant animals respond by becoming less abundant.
>
> Intolerant - Organisms found only within a narrow range of optimum environmental condition, rarely found in waters of low quality.
>
> Facultative - Organisms with the ability to survive over a wide range of conditions. They possess "medium" tolerance and often respond positively to moderate organic enrichment.

Criteria for classification of insect taxa according to tolerance status were derived from several past reports of the Michigan Water Resources Commission.

Tolerance vs Diversity

Experience with tolerance status and diversity indices indicate that one can expect the two parameters to vary in similar ways. A statistical analysis of the data revealed that a significant linear correlation ($\alpha = .05$) existed between insect diversity values and values for percent intolerant and percent facultative insects contained in a square-foot bottom sample. The diversity vs percent intolerant insects relationship was positively correlated, and significant--$\alpha = .05$ (R=.65)--whereas, the relationship between diversity and percent facultative insects was negative. Thus, an increase in diversity is accompanied by an increase in percent intolerant organisms found in a sample.

Response of Insects to Water Quality

A comparison of insect tolerance and diversity with computed water quality indices (WQI) was made for 39 bottom samples taken at 23 different water sampling sites. Though insect communities are commonly held to be sensitive indicators of water quality, the analysis found no significant correlation (α = .05, R = -.4) between change in values of the water quality index (WQI) and values of either insect diversity or percentages of intolerant and facultative insects. The most likely source of such a contradiction rests in the composition of the water quality index which integrates only physical and chemical data and does not include variables which may be of crucial biological importance. The nature and composition of bottom substrate, for example, are enormously important factors in determining a stream's capacity to sustain a diverse insect community (Hynes, 1970). It is exceedingly difficult however, to integrate such a factor into present-day water quality indices. In addition, changes in water chemistry might exert a "lag" or delayed effect in which no notable change is exerted upon resident fauna, while insect populations further downstream may be dramatically affected. Such a relationship might hold in the case of a nutrient influx into a stream. In small concentrations, the substances would tend to show little effect on the immediate insect community while many miles downstream, delayed results of enrichment caused by the original input, could exert a sizable effect on insect community structure.

Discussion of Results

Mainstream

Changes in insect populations sampled along the Mainstream are summarized below.

Diversity (Fig. 36)

Insect diversity experienced a gradual decline beginning at Bradford Creek in the headwaters and continuing to the I-75 Bridge below Grayling. Diversity increases markedly below I-75, and continues increasing to Wakeley Bridge 12 miles downstream. Diversity then remains constant on downstream to the public access site at Co. Road 606, the last station sampled above the Mio Dam backwater. Below this access site, samples from five successive impoundments indicate a sharp reduction in diversity. In fact, the five lowest diversity values on the Mainstream all occurred below impoundments. Trends similar to those mentioned above were also present in samples taken by WRC during August, 1972 and June, 1966 from the portion of the Mainstream between Pollack Bridge and Burtons Landing.

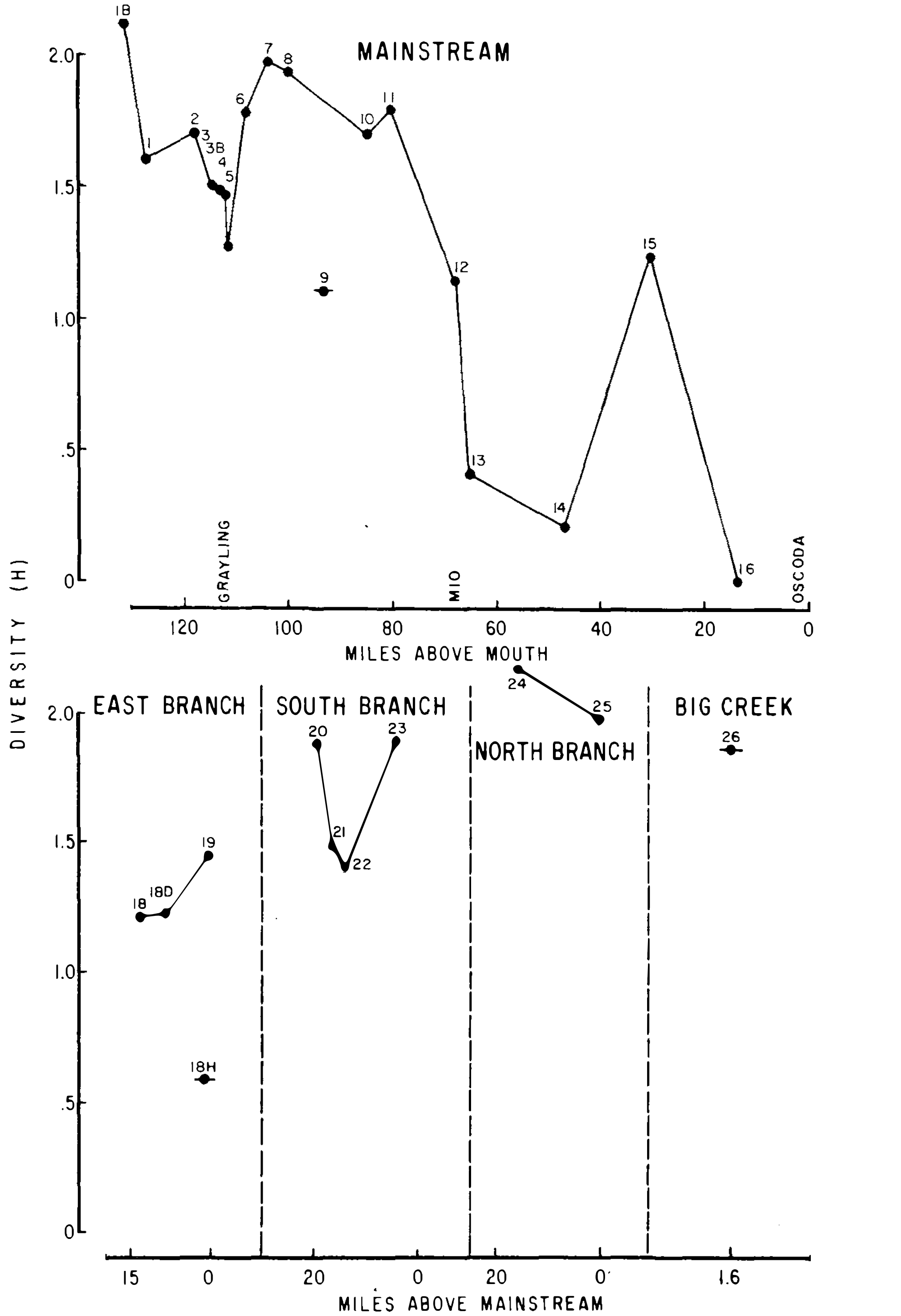

Figure 36. Diversity of insect populations at sampling stations in the Au Sable River Watershed.

Tolerance

Statistical analyses demonstrated that a significant correlation (α = .05) existed between insect diversity and percent intolerant or facultative insects in square-foot samples. There was direct correlation between diversity and the percent of intolerant insects present, whereas diversity and percent facultative insects varied inversely. Since no tolerant insects appeared in samples, we need only consider relative changes in proportions of intolerant and facultative insects. Therefore, percent facultative insects in all cases equals 100% less the percent of intolerant insects. For the sake of simplicity, all discussion which follows will focus upon changes in percent intolerant insects.

Tolerance data (Fig's. 37 and 38) from Mainstream collections during June and July, 1972 agreed closely with major trends in diversity. Percentages of intolerant insects declined slightly between Bradford Creek and the mouth of the East Branch. Further downstream, intolerant insects remained between 35 and 60% as far down as the public access site at Co. 606. Thereafter, effects of impoundments are again evident, as four out of five impoundments had an unusually low percentage of intolerant insects, namely: 15, 7, 4, and 0%.

Tributaries

Diversity

I determined the downstream trend of insect diversity during the summer of 1972 (Fig. 36) on the East, North and South branches. The insect community in the South Branch has a diversity which decreases below Roscommon; it reaches a minimum value at Chase Bridge, and returns to a value comparable to Roscommon at Smith Bridge which is at the downstream limit of the Mason Tract. Diversity values for September, 1966 (WRC, 1966) increased from the highest upstream site (150 yards above Roscommon Sewage Treatment Plant) to Steckert Bridge.

Results from the North and East branches were dissimilar from those of the South Branch, as diversity remained relatively unchanged over the lengths of both streams. This difference is due to the impact of sewage effluent on the South Branch below Roscommon. Diversity values for Big Creek (North), a tributary to the North Branch, were also relatively consistent in the East, Middle, and Main branches of this system.

Tolerance

Tolerance data (June-July, 1972) for the South Branch were inconsistent with its diversity values (Fig's. 36 and 38). Results indicated that the insect community at M-144 Roscommon, above the waste water treatment plant (WWTP), has a high diversity; yet it is composed largely of facultative insects (87%). Two and one-half miles downstream, at Steckert Bridge (below the WWTP), proportions of facultative and intolerant insects are essentially the opposite of the M-144 sample, with

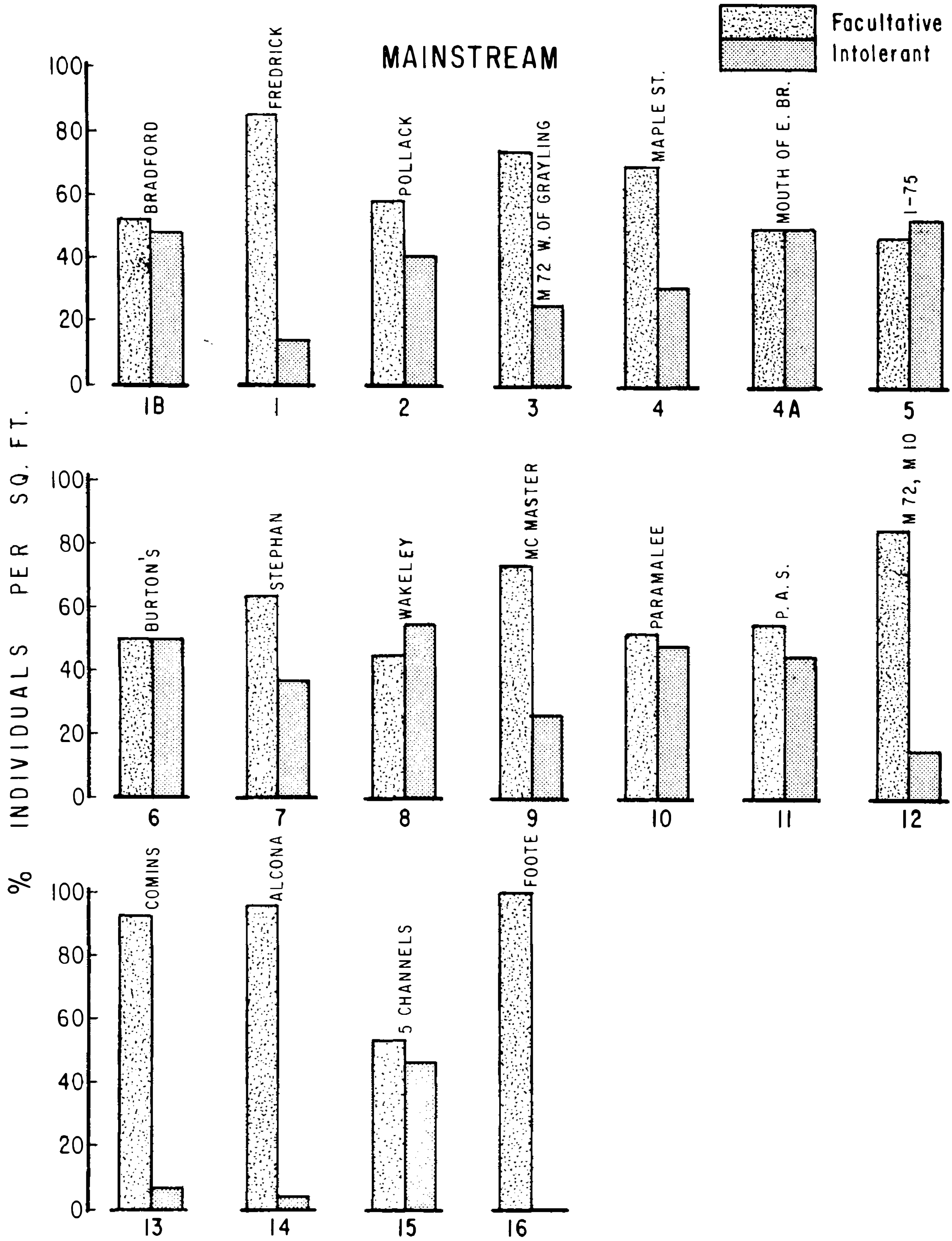

Figure 37. Percentages of Intolerant and Facultative insects present in Au Sable River (Mainstream) bottom samples taken in June and July 1972.

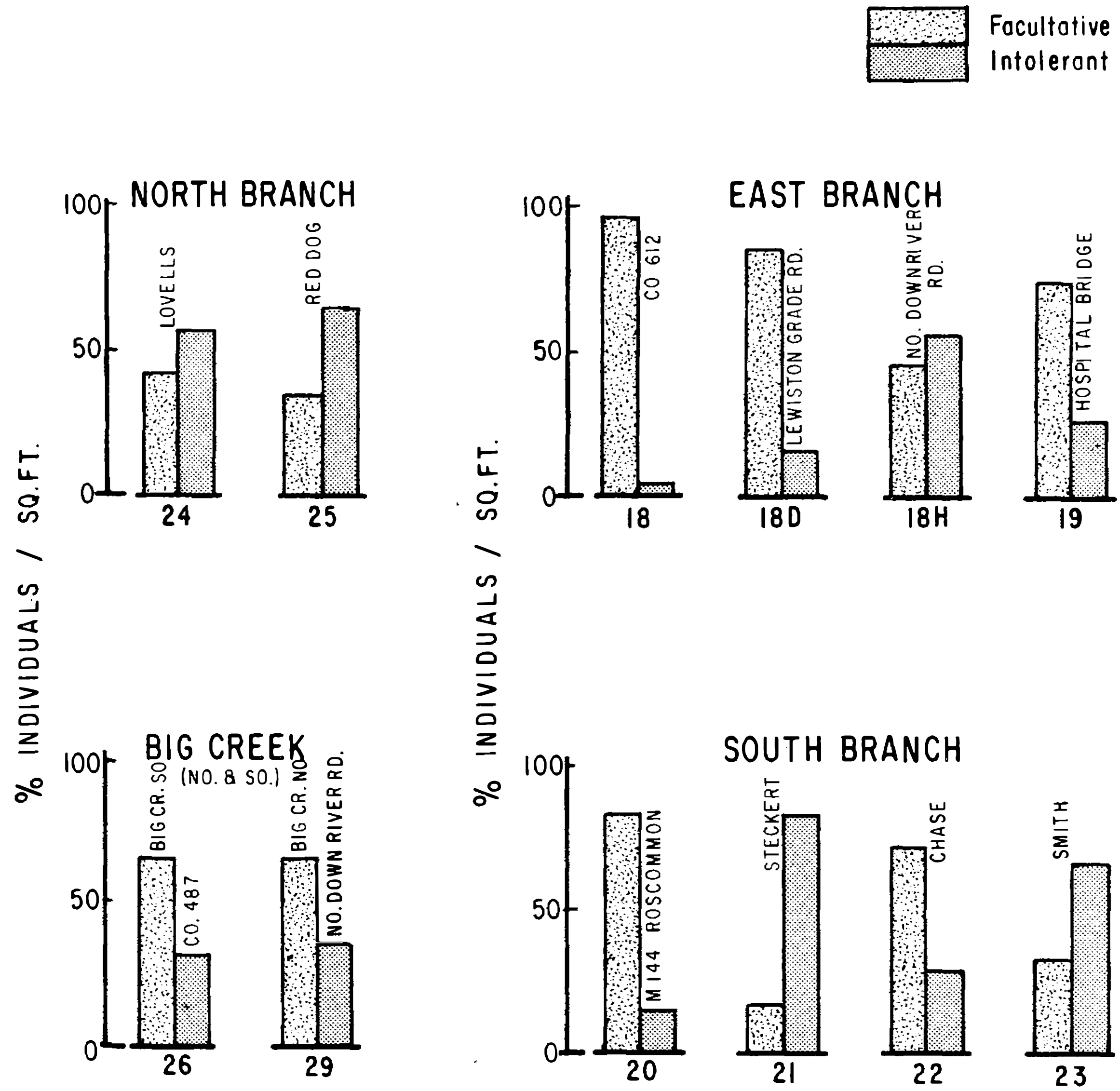

Figure 38. Percentages of Intolerant and Facultative insects present in Au Sable River (tributaries) bottom samples taken in June and July 1972.

88% intolerant insects present, indicating at least partial recovery from the sewage effluent input at Roscommon. Despite this radical shift, diversity at Steckert was reduced relative to the M-144 site. Further downstream, at Chase Bridge, intolerant insects composed less than one-fourth of all insects sampled. Finally, at Smith Bridge, intolerant insects once again dominated, and the stream community returned to a diversity which was slightly higher than that recorded at M-144. These results were obviously influenced by the bottom type at sampling locations.

Two samples on the North Branch (June and July, 1972) showed little change in percentage of intolerant insects which composed 57 percent of the Lovells sample and 65% of all insects in the Red Dog sample.

The sample furthest upstream on the East Branch (Co. 612) contained only 4% intolerant insects, but proportions of intolerant insects gradually increased with downstream distance until they composed 55% of a sample at North Down River Road. Further downstream, intolerant insects composed only 20% of the sample at the Hospital Bridge below the Fish Hatchery.

Two stations, one on each of the Big Creek tributaries (North and South), contained 30-35% intolerant insects.

Temporal Changes

During June 14-16, 1966, investigators of the Michigan Water Resources Commission collected square-foot bottom samples at seven sites along stretches of the upper Mainstream (Pollack Bridge-Burtons Landing). The prime objective of the study was to evaluate the impact of Grayling's sewage effluent upon the Au Sable's bottom fauna. The Grayling sewage treatment plant continued operation until November, 1971 when it was finally shut down.

During the summer of 1972, the WRC sampling program was repeated by the Au Sable study team, at each of the seven 1966 sampling sites of the upper Mainstream. Comparison of data from 1966 and 1972 provided a useful means of following changes in the insect community through time. Shutdown of the Grayling sewage treatment plant (STP) undoubtedly was the most significant event during the 6-year period from the standpoint of changes in water quality. Thus, the overall changes identified by comparison of 1966 and 1972 data can be largely attributed to the removal of the effects of the Grayling sewage effluent. Major results are discussed below.

Diversity

Among diversity values for the seven WRC sampling sites for June 1966, June 1972, and August 1972 (Fig. 39), four of the seven sampling sites (Pollack,WWTP, Allison and Burtons Landing) appear to have had higher diversity values in 1966 than they did in either June or August, 1972. The remaining three stations (mouth of East Branch, I-75, and canoe campground) had samples with substantially higher diversity in 1972 than in 1966.

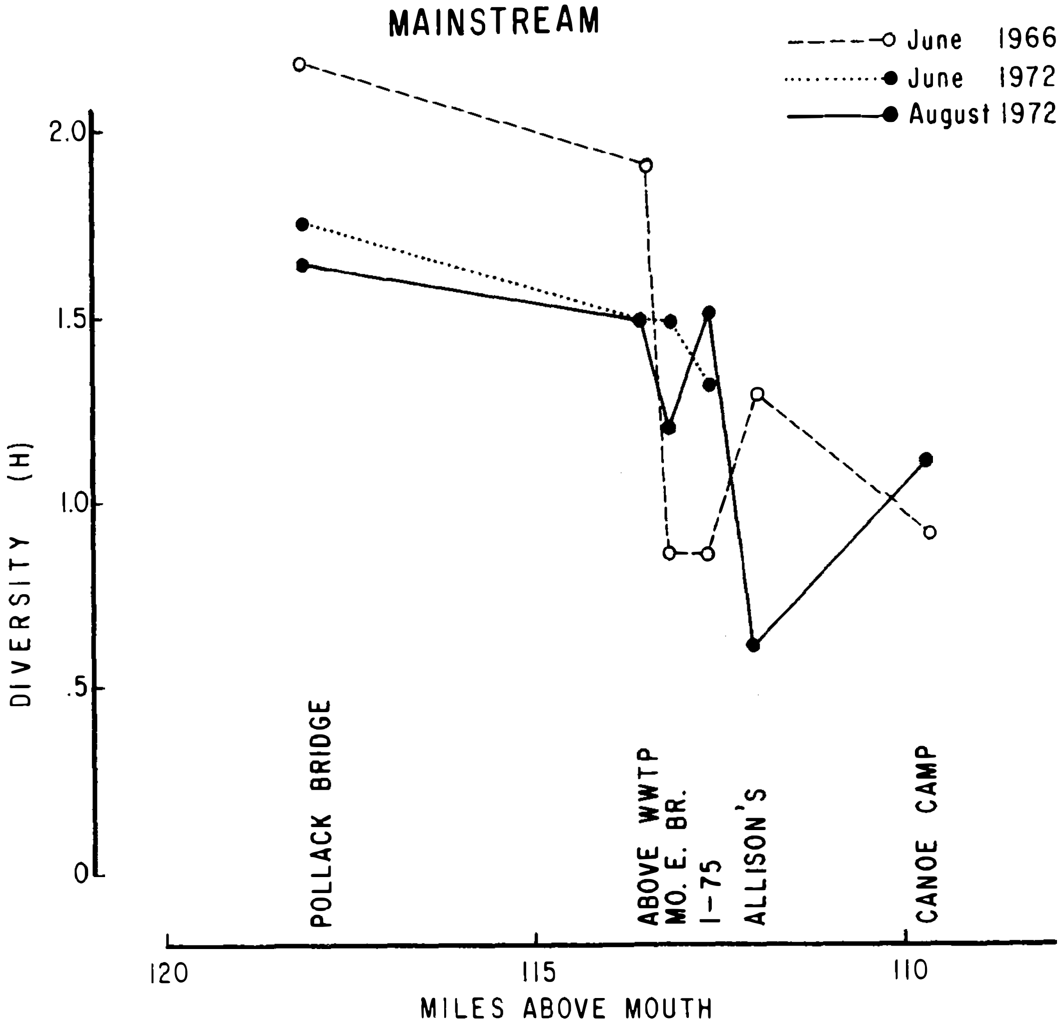

Figure 39. Comparison of bottom fauna diversity changes from 1966 (WRC collections) to 1972. The Grayling sewage treatment facility was shut down in favor of a lagoon system in November, 1971.

Comparison of average diversity values for all stations showed that diversity in June, 1972 (1.527) was greater than in June, 1966 (1.413). Diversity values for stations located immediately below the sewage outflow (mouth of East Branch, I-75) showed dramatic drops in diversity compared to upstream stations (WWTP,Pollack) for both years. However, reductions in diversity were less dramatic in 1972 than in 1966, which indicates that elimination of the sewage effluent has allowed the insect community to recover to some degree.

Though collections of Brege (1968) overlapped somewhat with WRC sampling sites, the data were not suitable for diversity comparison due to differences in the degree to which insects were identified.

Tolerance

Averages for all stations for both years showed only a small decrease in percent intolerant insects from 1966 (29.3%) to 1972 (22.6%). Figure 40 shows changes in percent intolerant insects for both years. Overall trends for both years are quite similar, as percent intolerant insects declined gradually with downstream distance.

Tolerance data for 1972 samples from the mouth of the East Branch and I-75 (below former Grayling sewage treatment plant) indicate that some recovery of the intolerant insect community has occurred. Tolerance data from the 1968 data of Brege (Fig. 41) showed reduction in percent intolerant insects as the Au Sable passed through Grayling. Samples below the town had greater percentages of intolerant insects, from I-75 to the canoe campground. Dorance Brege's September, 1968 samples at Burtons Landing, however, contained only 4% intolerant insects. Again seasonal differences in sampling may have been the cause of such an anomaly, as the samples from Burtons Landing in both 1966 and 1972 contained more than 50% intolerant insect forms.

Comparison of the mean percentage of intolerant insects suggested proportions of these forms have increased moderately since 1966. Data of June, 1966 possessed a mean percent intolerant value of 32.3%, while the June, 1972 mean was 37.6%.

Seasonal differences in proportions of intolerant and facultative organisms are evident between samples of June and August, 1972. August, 1972 samples contained an average of 16.5% intolerant insects (Brege, 1968), while June samples had an average of 37.6%; the average for September, 1968 (18.2% intolerant insects) may also be a depressed value similar to the June-August, 1972 situation.

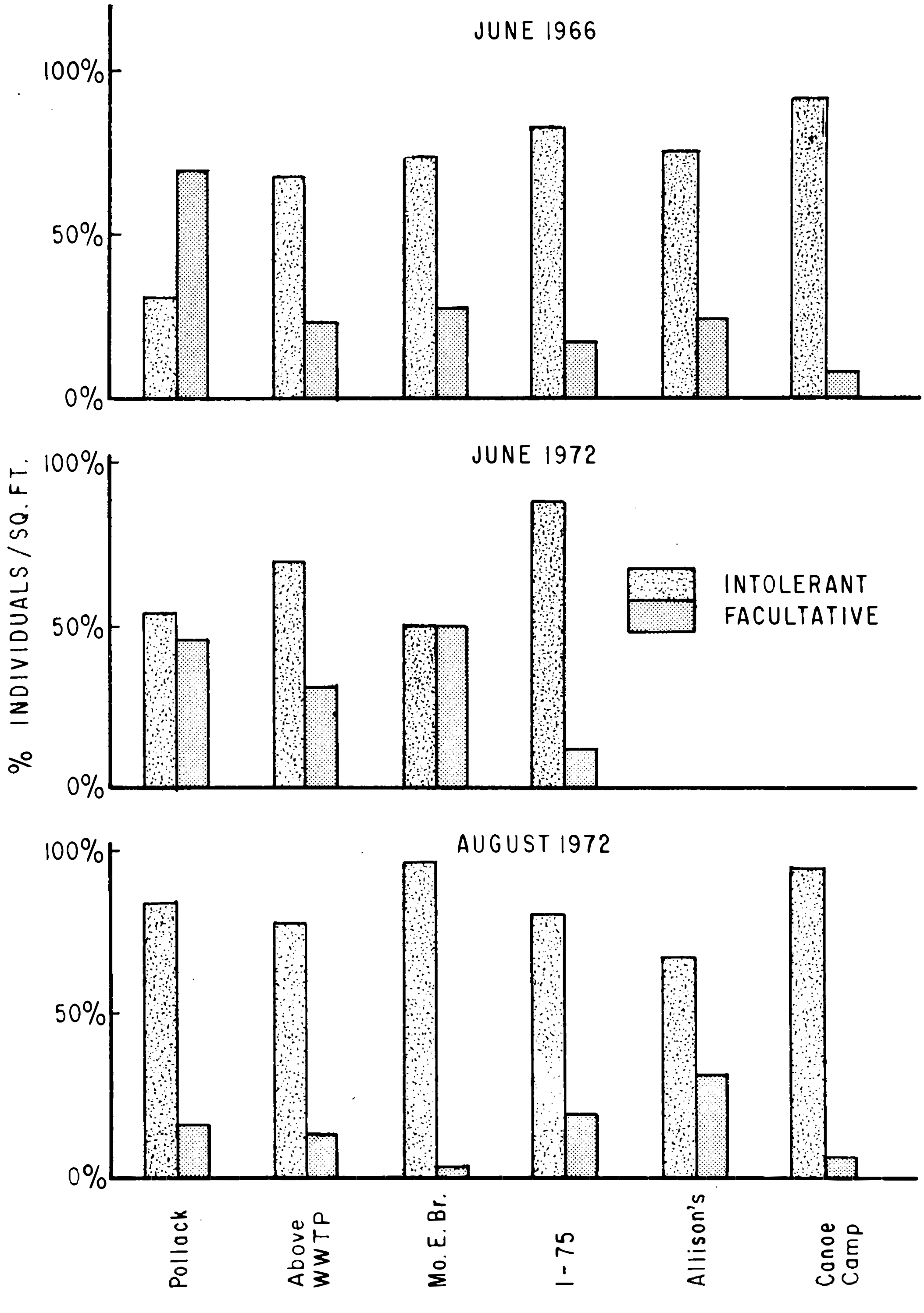

Figure 40. Bottom samples above and below the Grayling sewage treatment plant.

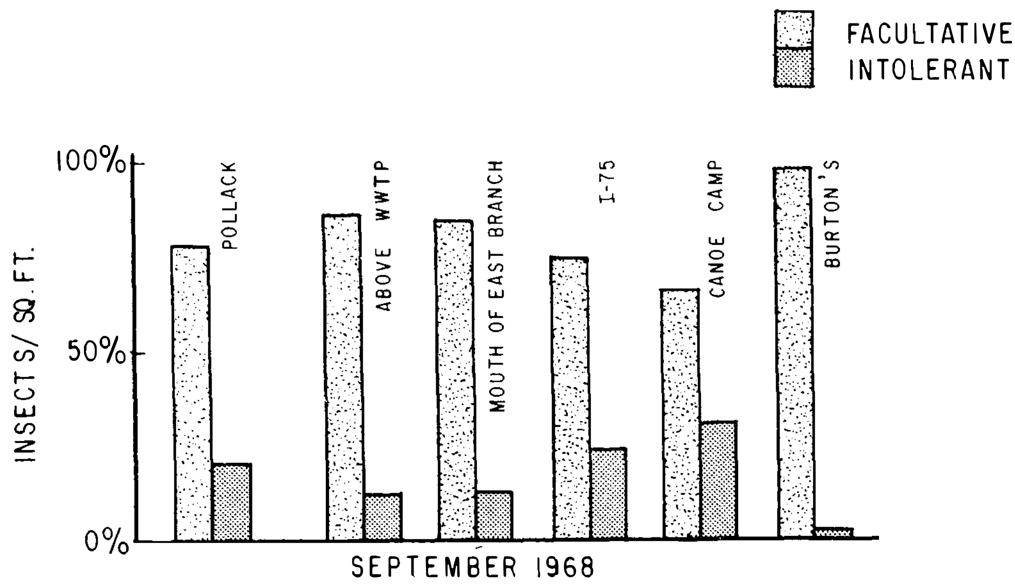

Figure 41. Insect tolerance percentages above and below Grayling, from data (bottom samples) collected by Dorance Brege in 1968 (Brege, 1969).

Overall Comparisons

The means for diversity and percent intolerant and facultative insects for data of June-July, 1972, from all branches of the Au Sable, are given in Table 18. Segments of the river system are ranked from top to bottom in order of descending diversity. Although water quality showed no significant correlation with diversity or tolerance data, ranking of river segments by diversity on a relative basis does compare favorably with trends in water quality (i.e., streams with high WQI tended to have higher rankings in diversity).

However, certain inconsistencies did exist in the ranking of diversity and water quality, particularly for the East Branch where water quality was comparable to that of the North and South branches. Insect diversity on the East Branch was next to the lowest in the entire watershed. The probable cause of such a discrepancy might be the prevalence of heavy sand deposits over most of the stream's bottom which precluded the maintenance of a large and diverse insect community.

Table 18. Mean diversity and tolerance data for samples of benthic insects in the Au Sable River System, June and July, 1972

Stream	Mean diversity	Mean percentage intolerant insects
North Branch	2.08	51.90
Big Creek (North)	1.86	35.12
Mainstream (upper) Bradford to M-72	1.78	33.19
Mainstream (middle) Maple St. to PAS[1]	1.69	42.90
South Branch	1.68	48.61
Big Creek (South)	1.64	31.82
East Branch	1.13	25.43
Mainstream (lower) Mio to Foote	0.62	6.59

[1]PAS = Public Access Site

Recreational Impact of the Au Sable Insect Community

At first glance, one might doubt that the condition of the Au Sable insect community has any direct relationship to the river's potential for recreational use. However, a frequent user of the river would dispute such doubts if he were to recall harassment he may have received from various pest insects along the river (e.g., blackflies, non-biting midges, deerflies, horseflies, "no-see-ums," and mosquitoes). Conversely, the insect fauna of the river offers valuable recreational assets in the form of large and timely "hatches," which are so highly sought after by the fly fisherman.

Poor management of the Au Sable watershed could conceivably lead to deterioration in water quality and subsequent increases in populations of pest insect forms which tend to be more tolerant of reduced water quality than other insects found in clean waters. Reductions in water quality could also depress populations of "beneficial" insects (mayflies, stoneflies, caddisflies) which cannot tolerate such degradations. In general, reduction of water quality and a resulting modification of the Au Sable insect community would severely detract from the overall value of the region as a recreational resource.

Although most of the Au Sable presently enjoys conditions of high water quality and normal proportions of both pest and beneficial insects, the investigations did expose a few areas concerning pest insects. Following are some insect families of interest to the recreational user.

Deerflies and Horseflies

Deerflies and horseflies (Tabanidae) appear to be quite common throughout the watershed. In most areas they posed little more than a mild annoyance, but canoe trips (surveys) through two areas (South Branch above Roscommon, and Frederic to Pollack Bridge on the Mainstream) proved to be particularly unpleasant due to the unusual abundance of deerflies. The bites of these insects are quite severe. Within the above two areas a long-sleeved shirt and a headnet were necessary, for commercially available insect repellents provided no deterrent.

Although no historical data exist regarding the Tabanidae in the watershed, Dr. Justin W. Leonard (University of Michigan entomologist) believes that populations of these insects have become more abundant in recent years. Extent, or direct cause of such increase is unknown at present.

Blackflies

Blackflies (Simuliidae) at certain times of the year do pose a nuisance to users and residents of the Au Sable. Bottom samples, however, failed to show any elevated populations of blackfly larvae, and thus it is questionable whether man's activities have intensified the blackfly problem.

Stream alteration could lead to explosive increases in blackfly numbers. Hynes (1970) cites examples in which construction of shallow stream channels, having a laminar flow, led to massive increases in blackflies. Increases in blackfly numbers are also often created by impoundments (Keup, 1973), although little evidence of such conditions at any of the Au Sable impoundments could be found. However, large numbers of blackfly larvae have been observed below the Luzerne Dam on Big Creek (South), by electrofishing crews.[15] Many dams exist on small feeder streams in the Au Sable Drainage, which poses a potential problem. Dams provide laminar flow over spillway devices, and the impounded waters produce more particulate and organic matter as a food supply for blackfly larvae than would the normal streamflow conditions.

Midges

Midges (Chironomidae) are something in the way of a mixed blessing to the river user. Although they provide an important food source for trout fry, they can frequently produce much discomfort by flying in the face and eyes of the recreationist.

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[15] Electrofishing Survey Report, 1972. On file at IFR in Ann Arbor.

Populations of midges are normally restrained by the high quality of water and by the maintenance of a diverse insect community. Many genera of this insect family can tolerate a great deal of pollution, and may establish large populations, given such conditions where competition or predation from less tolerant insects is eliminated.

Insects and the Sport Fishery

A diverse and healthy insect community is essential for the continued existence of natural trout populations. Invariably, the most diverse insect communities of the Au Sable also supported the most dense trout populations.

The Au Sable has been long endowed with outstanding mayfly, stonefly, and caddisfly (Trichoptera) populations. Informal conversations with long-time anglers on the river gave the impression that hatches have declined to some degree. However, bottom samples did not show any appreciable wide-scale decline in any of the above three insect orders. It was also Dr. Leonard's opinion that no such decline has occurred. Dr. Leonard also pointed out (in private conversation) that precise measurement of size of an insect hatch would prove to be extremely difficult. It should also be noted that insect hatches are highly variable from year to year and respond to a multitude of environmental variables.

Effects of Stream Improvement on the Insect Community

One of the earliest demonstrations of the beneficial effects of stream improvement upon bottom fauna communities was conducted by C. M. Tarzwell (1936) on the North Branch of the Au Sable, and on several other Michigan streams. Overall results of the study indicated that construction of stream improvement structures effected a three- to nine-fold increase in volume of bottom-dwelling organisms per unit area. Increases in fish food organisms were attributed to removal of sand by deflectors, uncovering of gravel, and production of silt and plant beds. Such dramatic increases in production of food organisms may promise secondary increases in fish production.

A stream improvement program oriented toward alteration of stream bottom (i.e., deflectors) might prove beneficial for particularly the lower reaches of the East Branch. The ubiquitous sand bottom of the lower East Branch leads to a highly variable and sometimes marginal insect community. A similar program might also be suitable for several miles of the Mainstream immediately below I-75 where again a sand bottom is prevalent.

Insects of the Au Sable River Compared to Other Michigan Rivers

Data on insect diversity and tolerance are summarized in Table 19 for portions of the Au Sable River (June and July, 1972 samples), and for other Michigan Rivers (derived from other Michigan watershed studies between 1951 and 1972). Comparison of this information reveals that the Au Sable insect community, in general, is characteristic of a mildly perturbed system. The North Branch, which has a high water quality index (89.36) and a generally excellent substrate type, accordingly has the greatest insect diversity in the Au Sable Watershed. The diversity here is comparable to that found in the Pigeon River System. The lower Au Sable Mainstream (below Mio) possessed the lowest diversity of the watershed, and took on an intermediate rank in the diversity list of other Michigan rivers. Such a ranking indicates that the stress upon the lower Au Sable insect communities is only moderately less than levels of stress induced upon a stream by heavy exposure to pollutants.

Thus, while most of the Au Sable insect communities enjoy high levels of diversity, certain stream reaches (the lower Mainstream, and East Branch) possess diversity and tolerance values similar to values of other disturbed Michigan streams. Although diversity in benthic communities normally tends to decrease in a downstream direction (in the lower watershed of large river systems), the low insect diversity situation in the lower Au Sable is very pronounced and is likely related to the adverse effects of the impoundments. This hypothesis gains support from similar changes that have taken place in fish populations at the same sampling locations. In the East Branch, while diversity is fairly low compared to the rest of the Au Sable System, the percentage of intolerant forms present indicates that substrate type is a more important causative factor than is water quality. Overall, the Chocolay River in the Upper Peninsula had the highest insect diversity and percentage of intolerant forms. The Saline River and the South Branch of the Paw Paw River, below domestic and industrial waste outfalls, and below sewage and fruit processing wastes respectively, had insect diversities of 0.07, the lowest recorded.

Conclusions on Aquatic Insects

Upper Mainstream (Bradford-Mio Pond)

For the upper Mainstream, comparisons between 1966 and 1972 gave us the most significant results. Insect communities below the Grayling waste water treatment plant are clearly becoming more diverse, with greater proportions of intolerant insects. This recovery took place within six months after elimination of the sewage effluent. Not all changes on the upper Mainstream were favorable, as insect communities at Pollack Bridge and Burtons Landing showed a lower diversity and had lower proportions of intolerant insects. However, any significant physical or chemical stress which might be responsible for such a decline could not be identified, and it is hoped that the detected changes were simply the result of "natural" fluctuations in insect populations through time.

Table 19. Mean diversity and tolerance data for insects in the Au Sable and several other Michigan streams

Stream, date, and location	Diversity	Intolerant insects-%	Stress	Investigator(s)
Au Sable R. (6-7/72)				
North Branch	2.08	51.90	None	Au Sable Study (1973)
Upper Mainstream (Bradford-M-72)	1.78	33.19	None	Au Sable Study (1973)
Mainstream (State St.-PAS)	1.69	42.90	Storm drain (Grayling)*	Au Sable Study (1973)
South Branch	1.68	48.61	Domestic sewage	Au Sable Study (1973)
Big Creek (North)	1.65	57.59	None	Au Sable Study (1973)
Big Creek (South)	1.64	31.82	None	Au Sable Study (1973)
East Branch	1.13	25.43	Sediment	Au Sable Study (1973)
Lower Mainstream (below Mio)	0.62	6.59	Impoundment effects	Au Sable Study (1973)
Chocolay R. (Fall,1965)				
Marquette Co.	2.32	70.50	None	R.C.Haas (1970)
Davis Cr. (10/16/68)				
Livingston Co.	1.26	14.06	None	W.P.Kovalak (1968)
Kalamazoo R. (11/20/51)				
Above Battle Creek	--	57.69	None	E.W.Surber (1951)
Below Battle Creek	--	0.0	Municipal sewage	E.W.Surber (1951)
Paw Paw R. (7/9/58)				
Berrien Co.				
East Branch	1.60	10.06	None	Mich. WRC
South Branch	0.07	1.0	Sewage,fruit proc. waste	Mich. WRC
Pigeon R. (7/8/72)				
Otsego Co.	2.05	38.34	None	S.G.Hildebrand (1972)
Platte R. (5/67)				
Benzie Co.	--	44.14	None	S.G.Hildebrand (1969)
Saline R. (6/10/69)				
Washtenaw Co.				
Above Saline WWTP	0.93	4.17	Unknown	U.of Mich. (1969)
Below Saline WWTP	0.07	0.0	Domestic sewage, Ind. waste	

* Had received primary treated sewage prior to November, 1971.

While earlier data (i.e., prior to 1972) were not available for other stations on the upper Mainstream, conditions of the insect community at Frederic caused some concern because of a depressed value in diversity and in proportion of intolerant insects. As with the Pollack Bridge and Burtons Landing communities, no source of stress could be located, and it is assumed that the condition of the community again has a "natural" origin.

Lower Mainstream (Mio-Foote Dam)

A mere glance at insect data for the lower Mainstream will reveal the large impact of impoundments upon communities of stream insects. Diversity was severely depressed and proportions of intolerant insects were minimal. Additionally, water quality parameters were demonstrated to be similarly degraded. Although it was not feasible to monitor and subsequently identify all factors responsible for the degradation of insect communities below the impoundments, changes in several water quality parameters are suspect. These include:

1. Elevated water temperatures.
2. Greater variability (instability) in discharge (with the possible exception of the Mio Dam--since 1964).
3. Increase in loads of organic matter (zooplankton and phytoplankton). Increases in production of phytoplankton were also detected.

Detected changes in the benthic communities below impoundments were similar to changes described in the Literature (Neel, 1963), (Spence and Hynes, 1971).

East Branch

High variability in diversity and percentages of intolerant insects in both 1966 and 1972, plus absence of adverse water quality conditions, indicate that composition of the stream bottom is the primary factor influencing the disposition of insect communities in the East Branch. Sand and silt bottom prevails over much of the East Branch. However, proportions of the bedload attributable to the activities of man are not known. Construction of a bridge (I-75) during the period 1963-1965 may be responsible for at least some input of sediment.

North Branch

Both water quality and insect communities characterize the North Branch as being perhaps the least disturbed segment of the Au Sable. Insect communities of the North Branch were not only the most diverse of all communities sampled, but also supported the largest percentages of intolerant insects.

Big Creek(s)

Three samples from Big Creek (North) indicated that the stream had the fifth highest mean of insect diversity, while possessing the second highest value for proportion of intolerant insects.

One sample from Big Creek (South), at Co. 487 near Luzerne, showed that this section of the tributary possessed only moderate values for both insect diversity and percent intolerant insects. Such results are surprising, as this station had the highest water quality index in the watershed. As with the East Branch, however, quality of insect habitat was only marginal because of a high proportion of sand in the substrate.

South Branch

Relationships between water quality, habitat, and the resulting insect community structure proved to be exceedingly complex for the South Branch. Although, the 1966 and 1972 samples were separated seasonally by two months, they suggest that diversity in the stream has declined. There was not sufficient information to evaluate the long-term effect of the continued input of primary treated sewage at Roscommon, but it seems highly unlikely that the insect community could sustain such a stress for some 15 years without undergoing at least some change.

SECTION III, PART B. ANALYSES SUMMARIZED BY STREAM SEGMENT

Part A of this section contains the basic biological investigations of the Au Sable River Study in a watershed approach. This was done so that the data collected for each investigation (i.e., water quality, fish, benthos) could be compiled and analyzed in the most cohesive manner possible. It is important to evaluate the status of the watershed in its entirety, in order to understand where the Au Sable River fits into the scheme of watershed management on a state-wide basis. Based on the findings in Part A, it is obvious that the Au Sable is uniquely suited to be maintained as a coldwater recreational river system, and is worthy of all our efforts to preserve its natural characteristics.

Part B offers a description of conditions and uses of the watershed by stream segment, to facilitate the use of the report by planners and managers.

Habitat features, water quality, the impact of human development, and the use of the segment, are discussed for each of eight river segments as follows:

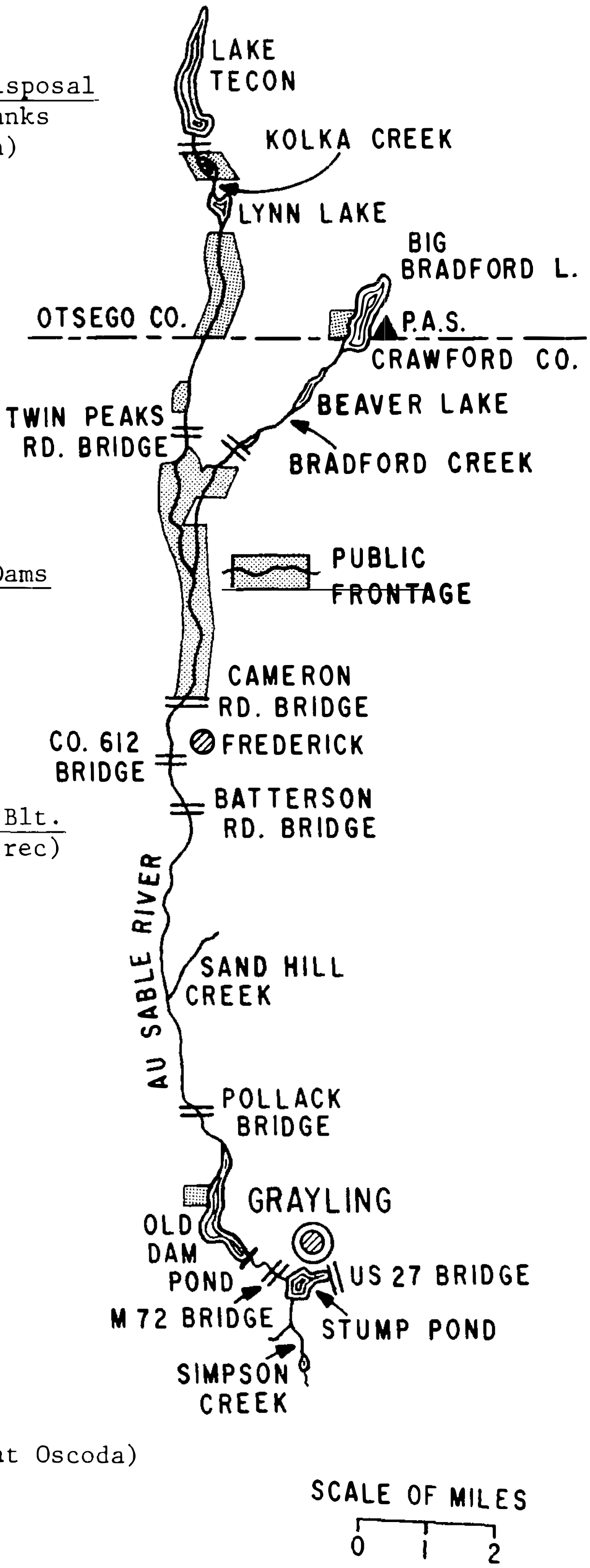
The Upper Mainstream	-	Headwaters to Grayling
The Middle Mainstream	-	Grayling to Mio
The Lower Mainstream	-	Mio to Oscoda
The East Branch		
The South Branch	-	Headwaters to Roscommon, and Roscommon to Mainstream
The North Branch	-	Headwaters to Lovells, and Lovells to Mainstream
The Big Creek System (North)	-	tributary to the North Branch
The Big Creek System (South)	-	tributary to the Mainstream

Each treatment of a river segment is preceded by a map of the segment showing main tributaries, road crossings, villages, ponds, and public frontage. Certain key information is presented in capsule form.

In this type of format, the duplication of some information discussed in Part A is unavoidable, but was felt to be justified in promoting clarity and completeness of Part B.

SECTION III
PART B – I MAINSTREAM – HEADWATERS TO GRAYLING

CAPSULE INFORMATION



Villages	Population	Method of Sewage Disposal
Frederic	275(est)	Private septic tanks
Grayling	2,143	Off-river (lagoon) (effective 11/71)

Miles of Stream in Section

	Public	Private
Mainstream	2.5	12.0
Tributary	8.5	12.0
Total	11.0	24.0

Main Tributaries

Stream	Class	Mile Pt.	No. Dams
Kolka Creek	coldwater	129.2	1
Bradford Cr.	coldwater	129.2	1
Sand Hill Cr.	warmwater	120.8	1
Simpson Cr.	coldwater	114.7	1

Mainstream Dams	Mile Pt.	Head	Pond A.	Year Blt.
Old Frederic lumber dam	126.8	2.5'	2	1930(rec)
Old power dam	115.7	20'	81	1900
Grayling	114.2	4'	45	1933
Bradford Lk.	133.2	6'*	265	--

*Lake Level

Drainage area - 110 sq. miles

Average discharge at Grayling - 73.5 cfs

Maximum to mean discharge ratio (stability index) - 3.7:1 (at Grayling)

Percent of total discharge - 4 percent (at Oscoda)

Gradient feet per mile - 4.0

Capsule Information, continued

Streamflow Measurement (February 8, 1973)

Location	Mile Point	Discharge (cfs)	Increase In cfs Per Mile	Increase In Percent Per Mile
Kolka Cr.	Mouth	18.84	--	--
Bradford Cr.	Mouth	16.97	--	--
Frederic Co. 612	127.1	54.31	5.52	13.8
Batterson Rd,	125.2	60.50	3.26	6.0
Pollack Br.	118.1	73.77	1.87	3.0
Grayling (US-27)	114.2	86.00	3.14	4.3

Occurrence of permanent and seasonal dwellings along the riverfront, by section(s), where the density exceeds 20 units per section or linear mile:

None in this segment. Cottage development is the most dense near Frederic, near Pollack Bridge, at the lower end of the old power dam, and above M-72 west of Grayling

KOLKA CREEK

Habitat Features

General. The Mainstream is formed by two tributaries, Kolka and Bradford Creeks, 2.9 miles above Frederic. Kolka Creek originates in Tecon Lake, 2.3 miles above Otsego County line. Tecon Lake is a natural lake of 270 acres, maximum depth of 3 feet, panfish type, mineral shore, and little development. Below the Tecon Lake (0.3 mile downstream) the stream enters No Name Lake. This lake is natural, 12 acres, organic shore, and has no development. One-half mile further downstream Kolka Creek flows through Lynn Lake. Lynn Lake is a natural lake, 52 surface acres, panfish type, organic shore, and little development. From the outlet of Lynn Lake, Kolka Creek picks up cooling groundwater; it has an average flow of 15 cfs at Twin Peaks Road in Crawford County. The headwaters are very warm in summer, but temperatures cool to normal maximums of about 70°F at Twin Peaks Road (marginal for brook trout). Beaver dams and modest groundwater inputs, from here down to the confluence with Bradford Creek, cause temperatures to rise to 74°F (Fig. 42) discouraging brook trout.

Bottom type. Mostly sand and silt, with limited gravel patches in lower reaches.

Trout cover. The cover is good to excellent with many log jams and dense bank cover over most of the lower half.

Water Quality

General. As reported in Section II, nitrate-nitrogen is relatively high in the upper Mainstream. Supplemental samples collected in January 1973 demonstrate how nitrate levels markedly increased in areas of marshy surface cover with little or no human activity in evidence. Nitrates and phosphates are at significantly lower concentrates in summer samples indicating the sensitivity of this headwater area to biological production. All other parameters tested were characteristic of undeveloped streams.

The diurnal monitoring of dissolved oxygen levels in August 1972, at the Twin Peaks Road crossing, showed a variation of 2 ppm during the 24-hour period, and a maximum value of 1.8 ppm below saturation. These values are also in the normal range.

Quality index (WQI). This index is a product of the physical and chemical nature of the water sampled at a given point. While it is sensitive to factors that influence D.O. (and temperature) it does not reflect other conditions such as substrate type, suspended solids, and stream channel characteristics. The index calculation for Kolka Creek at Twin Peaks Road was 91.56, the highest recorded above Grayling on the Mainstream. In order to gain an index to stream metabolism, diurnal oxygen values were periodically recorded over a 24-hour period in August. The

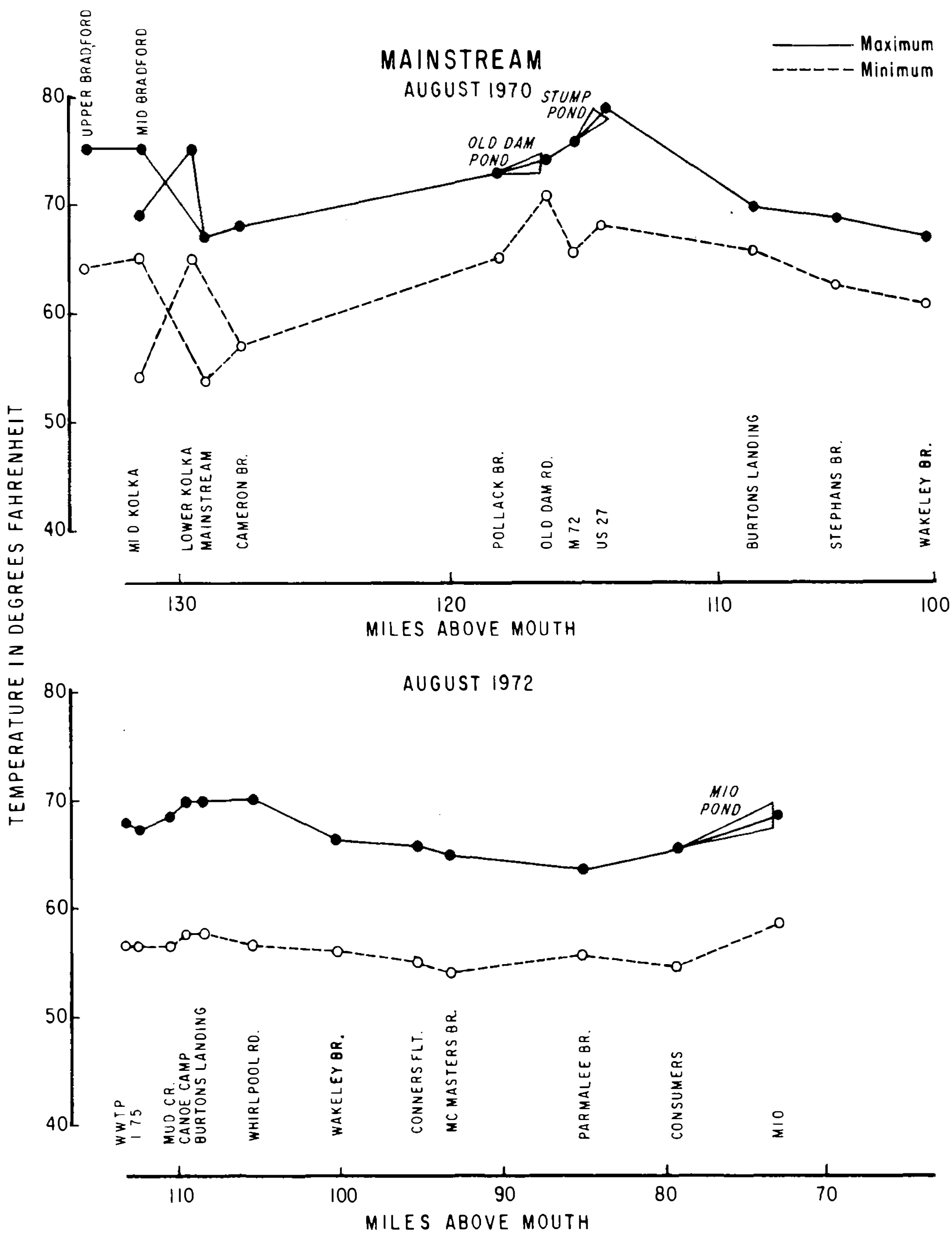


Figure 42. Maximum-minimum temperature data from Upper and Middle Mainstream. These 1970 data were recorded by District 7 personnel.

Kolka Creek station demonstrated a fluctuation (difference in ppm between the lowest and highest recordings during the 24-hour period) of 2 ppm (Fig. 43). This reading is normal for unstressed streams of this type. The maximum departure below the saturation level (difference in ppm between the amount of dissolved oxygen the water is capable of holding at a given temperature, and that which it actually holds) was 1.8 ppm, which is also a normal reading. The major effects on water temperature from beaver dams is below the monitoring point, accounting in some part for the high rating at this station.

Quality reflected by biota. An electrofishing collection just above Twin Peaks Road produced 14% coldwater species and indicates fair trout water. This area is a marginal zone for trout, with groundwater input overcoming natural temperature effects upstream.

Human Impact

Problems. There is very little evidence of human activity. Beaver dams in lower part of creek increase summer temperatures and organic matter.

Outlook. Fair to good brook trout waters can be maintained if beaver dams are removed, and if recreational activity associated with Twin Peaks Lodge does not disturb the habitat.

Use

There is a brook trout fishery of some importance, but this area gets very little use otherwise (due to its small size) including riparian use.

BRADFORD CREEK

Habitat Features

General. Bradford Creek originates in Bradford Lake whose boundaries extend into Otsego County. Bradford Lake is a natural lake that has a lake level dam, covering 265 surface acres (including Little Bradford Lake), maximum depth of 40 feet, warmwater fish type, mineral shore and moderate development. Downstream (0.8 mile) Bradford passes through Beaver Lake. Beaver Lake is a natural lake of 7 acres, very shallow, panfish type, organic shore, and no development. There is a little groundwater contribution above Twin Peaks Road and summer water temperatures reach 75°F. The streamflow increases three-fold between Twin Peaks Road and the confluence with Kolka Creek. A small tributary enters below this road which adds to the flow but most of the increase is due to groundwater. Consequently, temperatures in lower Bradford (above Kolka) are moderated, and normal maximums are 68°F (quite suitable for brook trout).

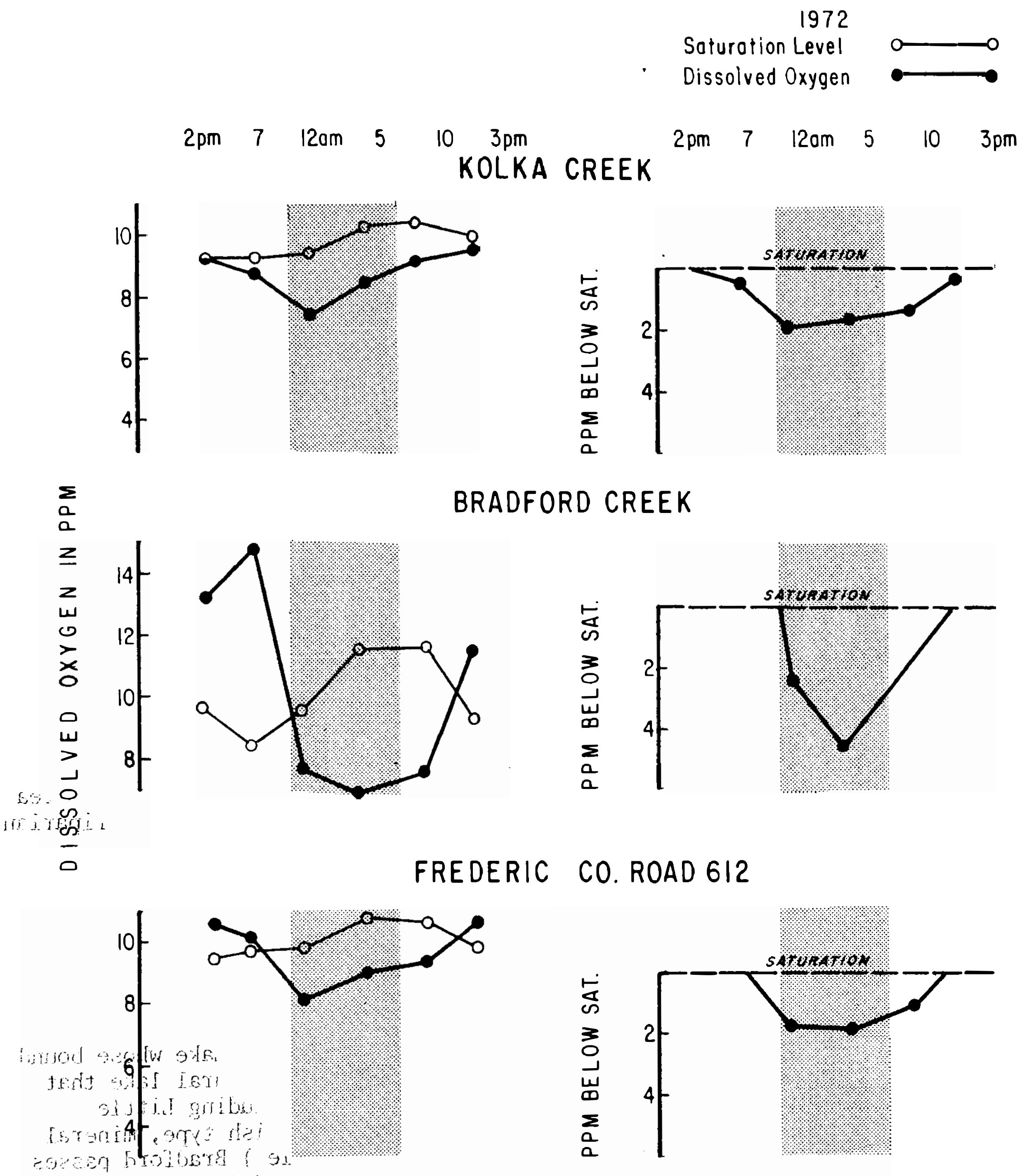


Figure 43. Dissolved oxygen concentrations observed for three stations in the Upper Mainstream headwaters of the Au Sable River, August 3-4, 1972.

Bottom type. Mostly sand, no gravel observed.

Trout cover. Good in lower reaches, log jams, undercut banks, and dense bank cover.

Water Quality

General. The temperature regime in this tributary reflects the presence of lakes, beaver dams, and ponds in the upper part. Then responds favorably to good groundwater input and bank cover in the lower part as noted above (Fig. 42). Water samples from the Twin Peaks Road crossing demonstrated higher conductivity and alkalinity readings than samples from the same road crossing on Kolka Creek. However, this may be due to effects of a small pond upstream.

Quality index. The WQI at Twin Peaks Road is 86.34, the lowest index in the Upper Mainstream, which is chiefly due to high normal maximum water temperatures and low diurnal D.O. values. A very wide range of 24-hour D.O. readings was recorded at this station (7 ppm) while the maximum departure below saturation was 4.6 ppm D.O. These were the most extreme values recorded in the watershed and would adversely affect animal communities downstream.

Quality reflected by biota. Bottom-dwelling organisms indicate good conditions for aquatic insects in lower Bradford Creek, both in terms of community diversity and presence of intolerant individuals. Analysis of fish collections (taken in this same area by seine) indicates a change in conditions favoring the invasion of intermediate species (Fig. 21, page 51). This situation is most likely related to the rise in water temperatures and an increase in nutrient matter that occurs upstream from the collection site. These conditions are caused by beaver dams and a road crossing. However, these factors have not disturbed the insects to any great degree. Effects of temperature and nutrient inputs have typically extended further downstream in favoring intermediate fish species competing with trout, rather than in favoring facultative species competing with intolerant insect species (based on the Au Sable Study results). The WQI reading was taken further upstream and was accordingly more directly associated with the aforementioned adverse effects.

Human Impact

Problems. Development is increasing on the east side of Bradford Lake at the headwaters of Bradford Creek. Presently no measurable effects can be directly attributed to human activity around the lake. However, fecal coliform counts have been higher in Bradford Creek than in Kolka Creek where no such human activity is in evidence. These small, clear, headwater streams are very sensitive to even moderate enrichment. That is why Greenbelt zoning is necessary for lakes, as well as stream frontage, in order to prevent development in low-lying sensitive areas. Inspection of tile field placement, relative to soil types and to the location of the water table, is also necessary.

The Twin Peaks road crossing (1963) has effectively created a back-water situation on Bradford Creek. Wide fluctuations in temperature and dissolved oxygen values are a result of low discharge (<5 cfs) and aquatic plant productivity here. Elevated summer temperatures and low diurnal dissolved oxygen levels have an adverse effect on the success of brook trout downstream. Five new intermediate fish species (intermediate in tolerance between cold- and warmwater species) have appeared since 1924. The culvert should be redesigned to prevent the impounding of the creek.

Outlook. If trout habitat is to be maintained in lower Bradford Creek, beaver dams need to be removed, and the Twin Peaks Road crossing redesigned so that streamflow is no longer restricted. Bradford Lake has over 40 cottages along the east shore now, and cottage development is increasing. Existing septic systems should be inspected and tested in order to retard nutrient input.

Use

Bradford Lake has public access, and receives moderate fishing pressure the year around. Cottage development is not heavy at this time and is presently occurring only on the east side of the lake. A new marina and new homes are now being built on the southeast corner of the lake. There is some brook trout fishing available below Twin Peaks Road but access is limited.

HEADWATERS TO BATTERSON ROAD

Habitat Features

General. The Au Sable Mainstream is formed by the union of Kolka and Bradford creeks. This upper stretch, downstream to a mile below Batterson Road (3-1/2 miles below Frederic), has good groundwater contribution, and fair to good brook trout populations. Normal maximum temperatures remain in the mid-sixties, and the current velocity is moderate to fast.

Bottom type. Mostly sand bottom in the upper part, with gravel type bottom predominating below Frederic.

Trout cover. The cover is poor to fair, having some log devices, and having pools up to 3 feet deep downstream from Frederic.

Water Quality

General. Water samples taken at Co. 612, near Frederic, show high nitrate-nitrogen levels compared to the rest of the river system (see Fig. 7, page 21). Since there is little human use upstream, these inputs are unquestionably of natural origin. Supplemental water samples (January 1973) show a three-fold increase in the concentration of nitrates over the concentration in samples taken in the uppermost limits of Kolka and Bradford creeks. All other parameters measured were in ranges considered normal for undeveloped streams.

Quality index (WQI). The WQI for Frederic (at Co. 612) was 89.54, which represents a compromise between the index values for Kolka and Bradford creeks upstream. A 24-hour diurnal oxygen test revealed a 2.5 ppm fluctuation in D.O. values, and a maximum departure of 1.8 ppm below the saturation level. These values reflect a normal, unstressed situation as found in Kolka Creek.

Quality reflected by biota. Intolerant insect species are markedly reduced, and the diversity of insect species is somewhat reduced. There is also a slightly lower percentage of coldwater fish species in evidence here compared to a 1920's collection at this site. This station differs from those upstream in having: less trout cover; a broader width; less bank cover; and a poorer substrate type. There are no known, significant, man-made inputs. Electrofishing collections at Batterson Road indicate fair brook trout waters with 30% of the species present being coldwater.

Human Impact

Problems. There are two erosion sites, one at Co. 612, and the other at the Batterson Road Bridge. Remnants of the old lumber dam were found just below Co. 612, but not enough water is held back to create much of a problem, and the dam may serve to provide cover. Beaver dams upstream elevate water temperatures to levels that are marginal for brook trout.

Outlook. The habitat could be improved by removing beaver dams, and repairing the erosion sites. The temperature range is quite suitable for brook trout, although a fish collection station at Co. 612 (seine collection) indicates that there is trend toward intermediate fish species since the 1920's.

Use

There are at least a dozen cottages near the stream between Cameron and Batterson roads, but there is no development above Cameron Bridge. The frontage is all public above this point, but downstream the access is limited to bridges. Brook trout fishing is spotty along this reach, but is reported to be fairly good near the old lumber dam.

BATTERSON ROAD TO POLLACK BRIDGE

Habitat Features

General. There is no public access between Batterson Road and Pollack Bridge some 7.1 miles downstream. The upper mile of this segment has a predominantly gravel bottom with only 15% of the bottom covered by aquatic vegetation. Current velocity is moderate to fast, and water temperatures are cool because of good groundwater input. From this point on downstream the bottom is mostly sand, and there is very little groundwater contribution. The current velocity is slow to moderate and the channel is braided in places resulting in warmer water temperatures.

There is little development in evidence. About a mile above Pollack Bridge, the bottom changes abruptly to gravel, shallow riffles predominate, the current is swift, resulting in favorable conditions for brook trout.

Bottom type. Nearly all sand except for the predominantly gravel bottom above Pollack Bridge.

Trout cover. Mostly poor, some shallow pools and undercut banks are in evidence in upper and lower ends.

Water Quality

General. All chemical parameters observed were in the expected normal ranges (at Pollack Bridge), and nitrate-nitrogen values were considerably reduced (by nearly 50% in summer averages due to uptake by aquatic plants) from the higher levels measured upstream.

Quality index (WQI). The index at Pollack Bridge was 89.46, about the same as the value for Frederic, indicating good water quality. Although the normal ~~maximum~~ temperature is about 70°F, the numerous riffle areas just upstream keep the water oxygenated. The range in diurnal D.O. fluctuations was 2.6 ppm, and the maximum departure below the saturation level was 1.7 ppm. A similar test by the WRC in 1971 resulted in a range in D.O. fluctuation of 2.2 ppm, and a departure of 2.7 ppm below the saturation level (Fig. 44). These tests (WRC) were conducted under conditions of lower stream discharge and higher water temperature (see Appendix Table X) that should result in a wider range of D.O. values.

Quality reflected by biota. A higher percentage of intolerant insects were present in this segment, and the insect community was more diverse, than at Frederic. This was probably due to an improvement in substrate type. Electrofishing collections revealed good quality trout water below Batterson Road, and in the vicinity of Pollack Bridge. The results of periphyton analysis showed a low level of primary productivity at Pollack Bridge, which was the lowest of the seven stations sampled on the Mainstream.

Human Impact

Problems. The weedy areas of this segment, where the channel is braided and the current is slow, have elevated water temperatures. A low head dam at the Sand Hill Lake outlet, provides a warming effect (temperature in outlet channel measured at 77°F during float trip in July) in this stream segment. However, the effects are minor due to the low volume of flow (<5 cfs). Some beaver dams were encountered along with several stream improvement devices, and cottage development (Au Sable Estates) is increasing along the east bank near Pollack Bridge.

Outlook. In the 7 miles of river between Batterson Bridge and Pollack Bridge, maximum water temperatures are elevated 5-10 F° (Fig. 42).

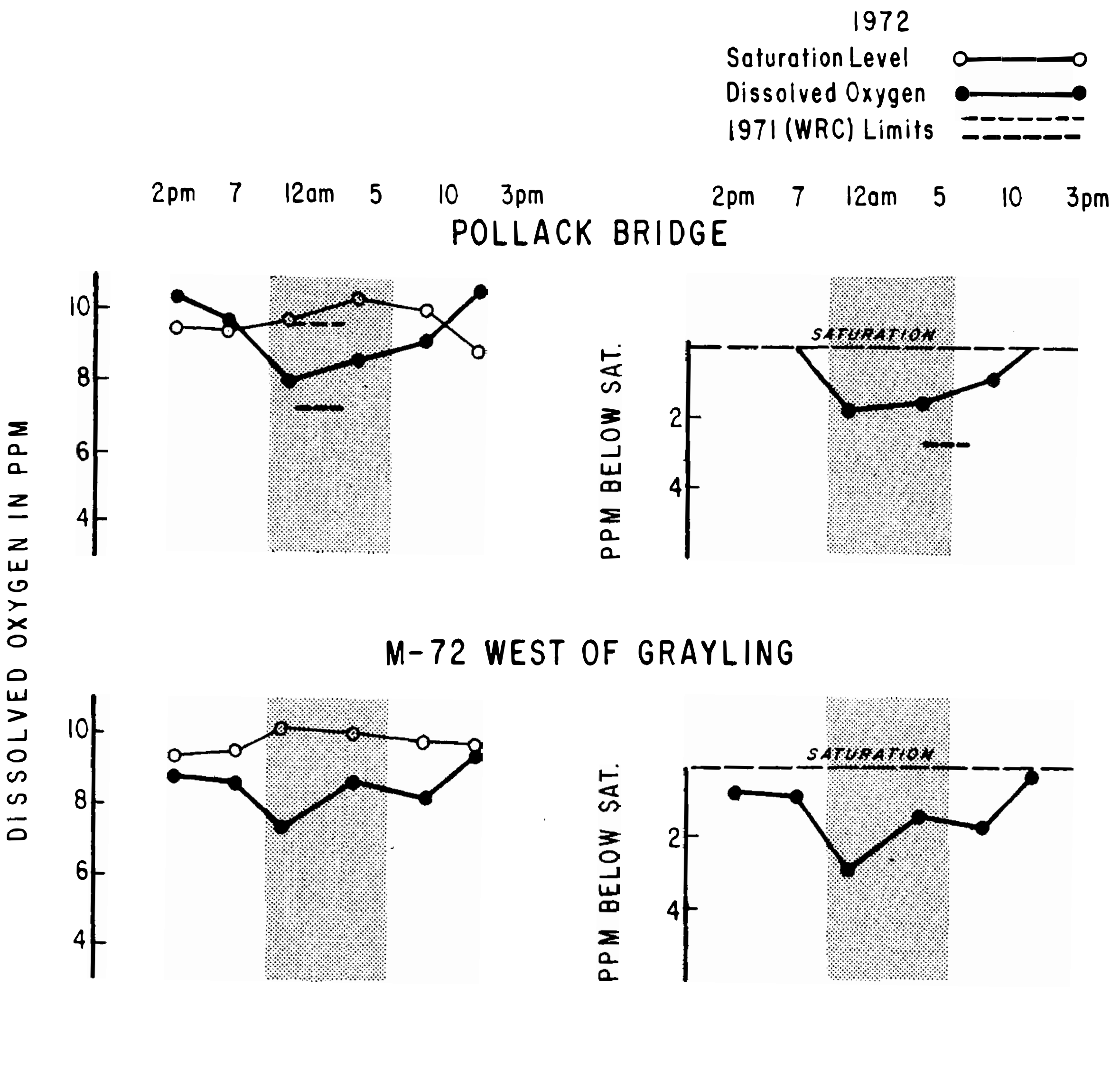


Figure 44. Dissolved oxygen concentrations observed at two stations above Grayling on August 3 and 4, 1972.

This situation could possibly be relieved by restricting the river channel in places and removing the beaver dams up river. It is questionable whether a meaningful improvement could be realized here, because of the natural characteristics which preclude maintenance of a significant trout population. Emphasis on improvement should first be directed on removal of the impoundments above Grayling.

Use

As mentioned previously, the only access along this stream segment is at Batterson Road Bridge and at Pollack Bridge. Cottage living is the major use of this area (especially near the two bridges), although some fishing and canoeing do take place. The float trip from Frederic to Pollack is enjoyable even though there are numerous carryovers.

POLLACK BRIDGE TO US-27 AT GRAYLING

Habitat Description

General. The 3.9 miles of river from Pollack Bridge to US-27 at Grayling, contain 126 acres of impounded waters. The old power dam backwater begins just below Pollack Bridge. This basin is 2 miles long, and is nearly 700 feet wide near the dam. The average depth is about 3 feet and the maximum depth is 10 feet at the dam. The stump pond above US-27 is very shallow over most of its area (average depth <3 feet) and is heavily laden with silt. Because of the large surface area (45 acres) exposed to solar radiation, temperatures at the gaging station just above US-27 often exceed 80°F in July and August (Fig. 42). Simpson Creek, a small coldwater feeder stream, enters the Mainstream in the backwaters of the stump pond.

Bottom type. The bottom is nearly all sand and silt, with considerable aquatic plant production (covering upwards of 70% of the bottom).

Trout cover. Some good cover is in evidence between the ponds, in the form of pools and undercut banks and brush, but warmwater fish species dominate because of the high summer temperatures.

Water Quality

General. All chemical parameters tested at the M-72 Bridge west of Grayling, and between the two impoundments, were within normal ranges for river systems not having major disturbances. No significant changes in chemical concentrations were noted below the impounded waters.

Quality index (WQI). The WQI at M-72 was 89.28, essentially the same as the index measured at Pollack Bridge. The 24-hour fluctuation of dissolved oxygen was 2 ppm, and the maximum departure below saturation was 2.8 ppm. These values are considered normal, although the D.O. never reached the saturation level during the 24-hour period suggesting a loading of organic materials in the stream. The spill over the dam, about 1/2 mile upstream, provides for the physical reaeration of the water.

Quality reflected by biota. Insect populations were again reduced in diversity and in the percentage of intolerant individuals present. Two electrofishing collections indicated that the waters were marginal for trout. Animal communities are consistently depressed below impoundments in the Au Sable Basin. The most recent fish survey conducted in the stump pond (Grayling Pond) on May 26, 1971, produced only 12 trout (7 brooks, 5 browns) in a total of 290 captures.

Human Impact

Problems. The two impoundments completely change the character of the stream just above Grayling. Neither of the ponds supports significant populations of coldwater species, while both raise normal maximum temperatures and increase productivity. This results in accelerated eutrophication and depressed quality of downstream waters. Low groundwater input (2.7 cfs per mile of stream), low velocities, increased sedimentation, and higher temperatures have rendered these waters less suitable for trout. The old power dam was sold to Mr. John Bruun in 1942 after it was no longer needed to produce power. The stump pond, formed by the low-head dam just above US-27, was originally used as a storage pond for logs to supply a lumber mill. The pond underwent periodic flushing before a permanent concrete structure was built by the Highway Department in 1933 as part of the new bridge. The pond was used as a water supply for fire protection until a water tower was built in 1938.[16] The pond presently has little utility, and the Wildlife Division of the DNR has reported it to be of minimal value for waterfowl.[17] Most of the backwater of the stump pond is covered by yellow pond lilies, stumps, and heavy silt deposition. Temperature surveys taken in 1953 and 1970 showed that the pond raised maximum temperatures by six or seven degrees even during higher than normal streamflow. Refer to Section IV for model predictions of temperature increases under more adverse weather conditions, and predicted temperature ranges if these ponds were removed.

Housing units are increasing along the river above Grayling. The Karen Woods subdivision is in a low-lying area adjacent to the riverbed, and therefore must be suspect in providing a seepage of nutrients and bacteria to the river. The Bear Mountain Lodge lagoon, originally designed to serve only the lodge, now also handles a 45-unit trailer park and horse stables. The lagoon presently has no test well to monitor groundwater quality. Although it is too late for baseline information, such a monitoring program is needed to insure that the river is not receiving contaminating seepage.

Outlook. In order to restore this stretch of river for trout, the two dams should be removed and the original river channel properly stabilized. This would entail construction of a coffer dam and settling

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[16] Allison, Dr. Leonard. 1953. Institute for Fisheries Report No. 1391.

[17] Anderson, Ralph, DNR Wildlife Biologist. Mio, July 5, 1971. Letter to Philip Baumgras, DNR Wildlife Division, Lansing.

basin to prevent destruction of downstream habitat from possible escapement of stored silt and sand deposits.

A collection system for sewering the area just west of Grayling, including the Karen Woods subdivision, the airport, and the Lake Margrethe shore, has been discussed although no final action is planned at present.[18] The Rich Svendory Engineering firm of Traverse City (the same firm that engineered the Grayling lagoon system), has recommended a 20-acre lake as part of a sewage treatment complex for Lake Margrethe, and a 30-acre lake, for the Karen Woods-airport areas. The projected cost of these waste disposal systems was two million dollars, and two and one-half million dollars, respectively.[19]

Use

The lower end of the stump pond in Grayling is fished for warmwater species, but fishing is reportedly quite poor. A higher degree of fishing success is claimed for the old power dam pond. The removal of these ponds should eventually restore suitable conditions for trout. Simpson Creek (the lower end is now flooded by the stump pond) provides cooling waters to the Mainstream and there is significant groundwater input below US-27.

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[18] Larson, R. W. USGS Hydrologist, Grayling, 1973. (Personal communication.)

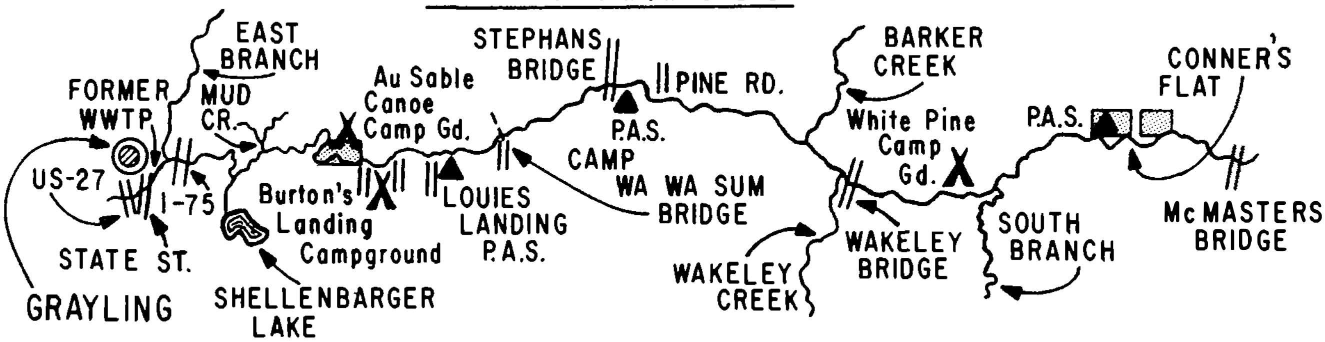
[19] Byelich, G. H. Au Sable River Watershed Project coordinator. N.E. Mich. Regional Planning and Development Commission. 1973. (Personal communication.)

SECTION III PART B-2 MAINSTREAM – GRAYLING TO MIO

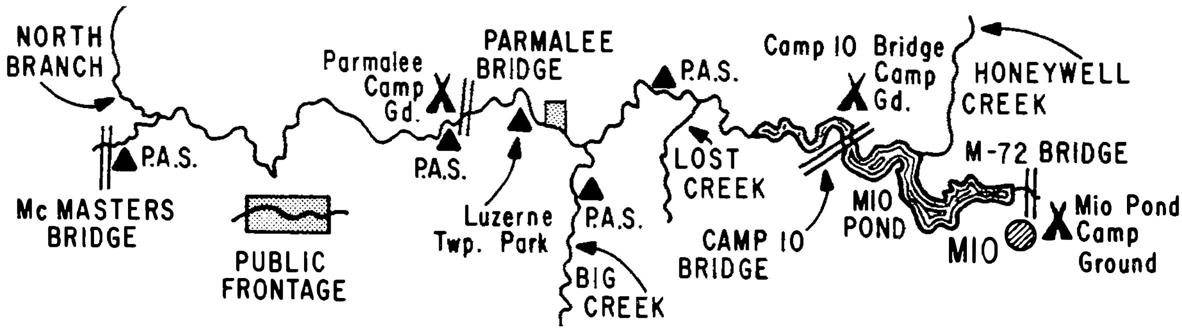
SCALE OF MILES

0 1 2

– GRAYLING TO McMASTERS –



– McMASTERS TO MIO –



CAPSULE INFORMATION

Villages	Population	Method of Sewage Disposal
Mio	1,150(est)	Private Septic Tanks

Miles of Stream in Section

	Public	Private
Mainstream	2.4	40.0
Tributaries	11.8	39.0
Total	14.2	79.0

Main Tributaries

Stream	Class	Mile Point	No. Dams
East Branch	coldwater	113.2	2
Shellenbarger	warmwater	111.0	0
Mud Cr.	warmwater	110.6	0
Barker Cr.	coldwater	101.2	3
Wakeley Cr.	warmwater	100.5	0
South Branch	coldwater	98.1	4
Conner's Cr.	warmwater	95.3	1
North Branch	coldwater	91.6	8
Big Cr.	coldwater	83.2	4
Lost Cr.	coldwater	80.8	4
Honeywell Cr.	warmwater	75.7	6

Capsule Information, continued

Mainstream Dams	Head	Pond Acres	Year Built	Mile Point
Mio (Consumers)	28.5'	860	1916	73.1

Drainage area - 1,100 sq. miles

Average discharge at Mio - 957 cfs

Maximum to mean discharge ratio (stability index) - 4.3:1

Percent of Total Discharge
Below E. Branch - 7
Below S. Branch - 26
Below N. Branch - 44
Below Big Creek - 48
At Mio - 50

Gradient feet per mile - 4.71

Streamflow Measurement (July 20, 1972)

Location	Mile Point	Discharge (cfs)	Increase In cfs Per Mile	Increase In Percent Per Mile
Grayling (US-27)	114.2	76.00	--	--
(Old) WWTP	113.4	92.87	20.0	26.3
I-75	112.7	141.44	1.4	1.6
Above Burtons Ldg.	109.2	163.50	0.6	0.4
Wa Wa Sum	106.2	213.62	16.7	10.2
Stephans Br.	104.6	230.68	10.6	5.0
Wakeley Br.	100.3	278.45	11.2	4.6
Beaver Bend	93.5	511.36	9.0	1.8
Mio	73.0	862.00	1.3	0.3

Occurrence of permanent and seasonal dwellings along the riverfront, by section(s), where the density exceeds 20 units per section or linear mile:

T 26N,	R 3W	Sections 7, 8 (near Grayling)
T 26N,	R 2W	Sections 5, 4, 3, 11, 12, 13 (Stephans to Wakeley Bridge area)
T 26N,	R 1W	Sections 11, 12, 1 (McMasters Bridge area to the mouth of the North Branch)

US-27 TO BURTONS LANDING

Habitat Description

General. The first half mile (from US-27 to Maple Street) is lined with dwellings, and the banks are almost solid seawalls and sheet piling. From Maple Street to the mouth of the East Branch, the river frontage is more sparsely populated. About 1/4 mile downstream from the East Branch, river-front cottages increase in occurrence and remain fairly dense until the river bends south past Beaver Island toward Shellenbarger Swamp some 1.2 miles below I-75. There are only a few dwellings from Beaver Island downstream to Burtons Landing (4 miles below I-75).

There is good groundwater contribution between the Grayling "stump" pond and the East Branch confluence 8/10 of a mile downstream. This groundwater, coupled with the cooler waters of the East Branch, reduces summer water temperatures that often reach the 80's F at US-27 upstream. The flow of the East Branch (averages 43 cfs) is slightly more than half the flow of the Mainstream at US-27. Two small tributaries enter the Mainstream between I-75 and the canoe camp, carrying 15 and <10 cfs, and are considered warmwater feeders. The current velocity is rather swift where the river passes through Grayling, slows to about 1/3 of a mile per hour in the braided channels near Shellenbarger swamp, and reaches a mile per hour below the canoe campground.

Bottom type. The bottom is mostly gravel to the mouth of the East Branch, then sand and gravel to about 1/4 mile below I-75. There is a distinct broad ribbon of sand extending from the East Branch into the Mainstream and continuing about 200 feet downstream where it is incorporated into sand bottom of the main channel. There is normally heavy sand and silt movement in the East Branch below the "meadows," although the I-75 bridge crossing project (East Branch) in 1960 reportedly contributed a large amount of sand to the stream. From I-75 (Mainstream) to a point about 1/2 mile downstream from the Au Sable River canoe camp, the bottom type is nearly all sand. The current velocity slows considerably (0.5 foot per second) in the vicinity of Shellenbarger swamp. Halfway between the canoe camp and Burtons Landing the bottom changes abruptly to gravel and current velocity increases to 1.5 feet per second.

Trout cover. The cover is poor to fair above the East Branch, and fair to good from the East Branch to Beaver Island about 1/2 mile above Shellenbarger. Cover is quite poor in the Shellenbarger lowlands, and only fair from there to the canoe camp. Cover improves, as does trout habitat in general, from the canoe camp to Burtons Landing.

Water Quality

General. Concentrations of nitrate-nitrogen continue to diminish in a downstream direction, except for a rather sharp increase immediately below Grayling. This increase is due mostly to the higher concentrations in the East Branch, that are a result of natural conditions. No appreciable increase in phosphate-phosphorus or coliform bacteria has been recorded at I-75, just below Grayling, since the shut down of the sewage treatment plant. All other constituents tested were in normal ranges, although chlorides increased sharply between sampling stations above and below Grayling. This increase (about 2 ppm) is associated with Grayling.

Quality index (WQI). Because of atypical weather patterns during the late summer of 1972, the indexes below are based on temperature and oxygen values from observations recorded by the WRC during July 1971. There was a noticeable response of the index below Grayling to depressed dissolved oxygen levels while the sewage treatment plant was operating. These values have undoubtedly improved since the sewage effluent diversion and will be demonstrated by WRC investigations in a follow-up survey. The ranges of fluctuation in dissolved oxygen levels at Gildner's and above Mud Creek were 2.7 ppm and 3.9 ppm, respectively (Figs. 45 and 46).

	Station	Miles above mouth	WQI
4	Maple Street	113.7	89.44
5	I-75	112.7	87.71
5A	Gildner's residence	112.0	80.10
5B	Harland residence	110.9	81.00
6	Burtons Landing	108.7	84.41

Quality reflected by biota. Bottom-dwelling insect communities, above and below the former location of the outfall of the Grayling treatment plant, are now well represented by intolerant insect species. Compared to the 1966 WRC collections, the mouth of the East Branch now has more intolerant insect species than either the lower East Branch Station or the station below the WWTP had in 1966. The sampling location at I-75, 0.8 of a mile below the old plant, shows the most improvement. While insect populations have rapidly responded to the diversion of the effluent from the river, any change in fish-community composition will take longer. The heavy growths of Sphaerotilus (commonly miscalled sewage fungus), observed in late summer 1971 along the north side of the river below the treatment plant, were not evident in 1972. Insect samples taken at Allison's old residence 0.8 mile below I-75 had a low diversity and were indicative of rather poor habitat quality. Another collection at the canoe camp, 1 mile above Burtons Landing, was indicative of better environmental quality.

The fish-seine collection at the mouth of the East Branch shows that conditions have changed little at this point since 1916. The ponds above Grayling and the dumping of sewage were well established even then. In fact, the bank cover in this immediate vicinity is probably better now, and there are less residents living in Grayling presently.

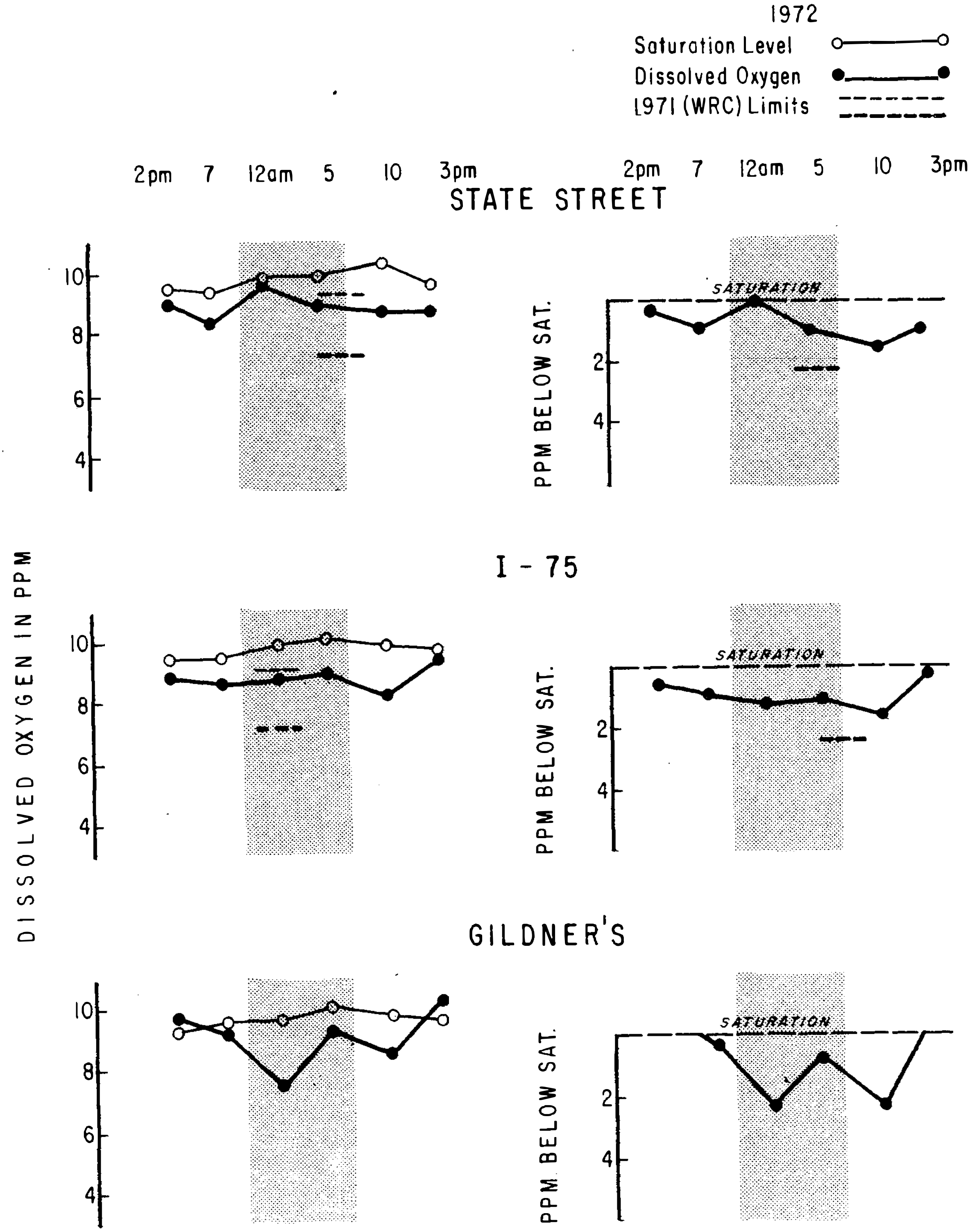


Figure 45. Dissolved oxygen concentrations observed for three stations, one at, and two immediately downstream from Grayling (approximately 1 and 1.8 miles respectively) on August 3 and 4, 1972.

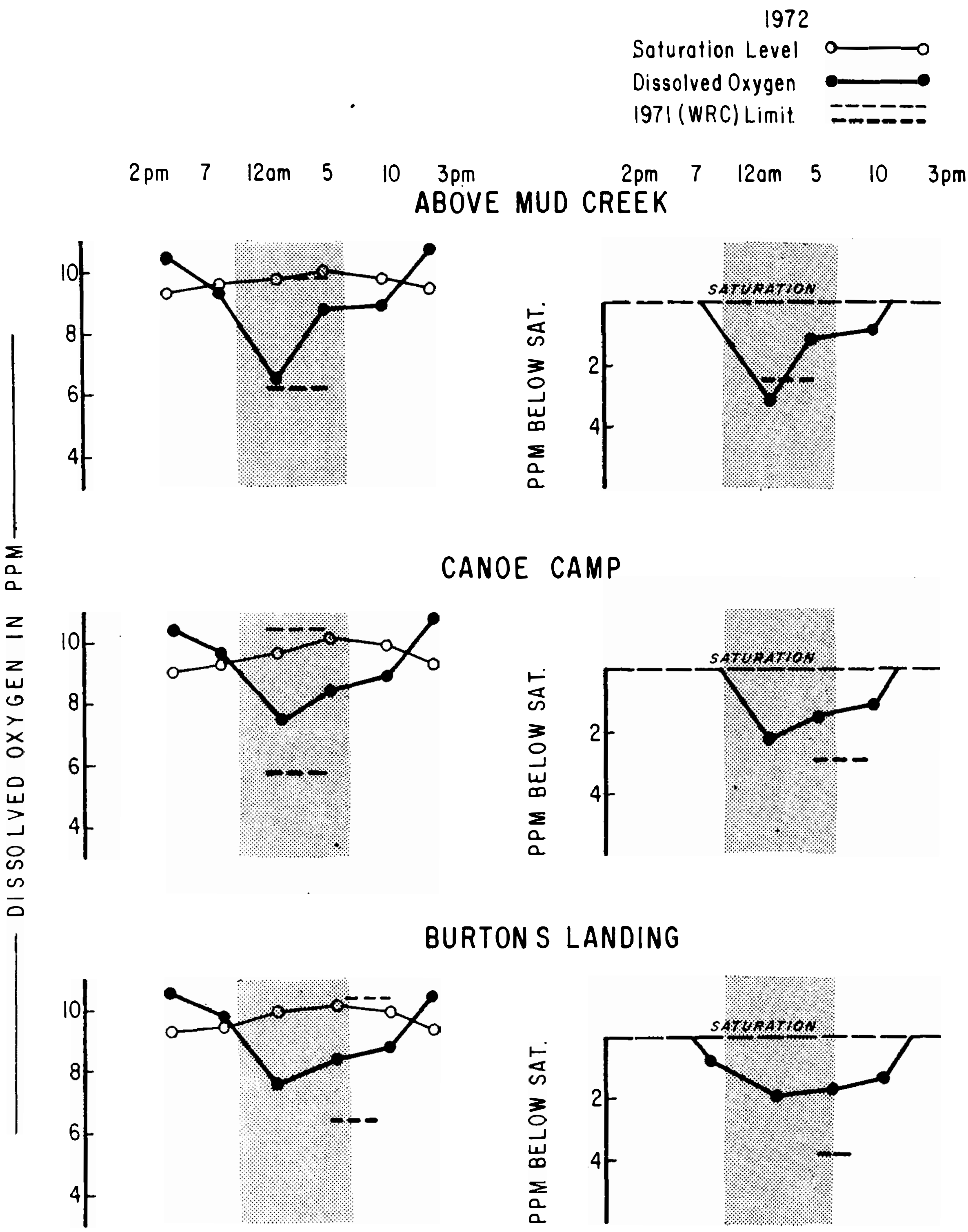


Figure 46. Dissolved oxygen concentrations observed for three stations on the Au Sable River 3, 4.5 and 5 miles downstream from Grayling on August 3 and 4, 1972.

Electrofishing collections made below Maple Street and the mouth of the East Branch, indicate marginal-quality trout water, while a similar collection at I-75 indicates fair conditions for trout.

There are two trout population estimate stations in this part of the river, one at Allison's and one at the "pullover" above the canoe camp. The estimate made at Allison's was lower by 54% in 1972, than it was during the baseline years of the early sixties. Many intermediate and warmwater species were observed during last fall's survey. A seine collection (qualitative), taken near the mouth of Mud Creek in 1924, two miles below I-75, produced a variety of intermediate and warmwater species, but no trout. During the 1972 float trips, warmwater species were observed in and near the Shellenbarger outlet area. The trout population estimate at the pullover revealed even more brown trout than were found in the early sixties.

Periphyton samples taken at Pollack Bridge above town and at I-75 below town, show an increase in primary productivity associated with nutrient inputs from Grayling (surface runoff, dam ponds, fertilizers, etc.), and the high nitrate levels in the East Branch.

Human Impact

Problems. Since the sewage effluent was removed from the river in November 1971, the major inputs of polluting materials and siltation come from surface runoff (urban) that is drained directly into the river. The Fish Hatchery appears to contribute some enrichment, based on visual observations of algal streamers above and below ponds, and the high level of periphyton production at the hospital bridge. However, studies failed to demonstrate any increase in temperature due to the increased water area exposed in the ponds and raceways.

Dredging of bottomlands below Grayling has disturbed aquatic life and restructured insect communities, and has had an adverse effect on predators higher up in the food chain--namely trout. Development of adjacent lowlands could have a permanent effect on both aquatic and terrestrial life. In 1957, half a mile above Mud Creek and 1.2 miles below I-75, a channel was dredged to provide fill for development along the north bank. The bottom was dredged to a depth of 8 feet in places and Mud Creek was also dredged about 1/4 mile upstream from its mouth. As reported by Gerth Hendrickson, the modification of channel characteristics has significantly reduced streamflow velocity (Hendrickson, 1966). Another channel was dredged above the Shellenbarger bend (Fig. 47), that if connected, would cut off over a mile of the Mainstream. The 1/4-mile-long channel was dredged to provide fill for development along its length, and to provide access to the Mainstream. There are now seven residences, mostly full time, along this 3/4 mile stretch of river. Three or four feet of sand fill does not provide adequate soil to neutralize septic matter delivered to drain fields. Dorance Brege, a Michigan State University graduate student, who did a study on stream enrichment from private

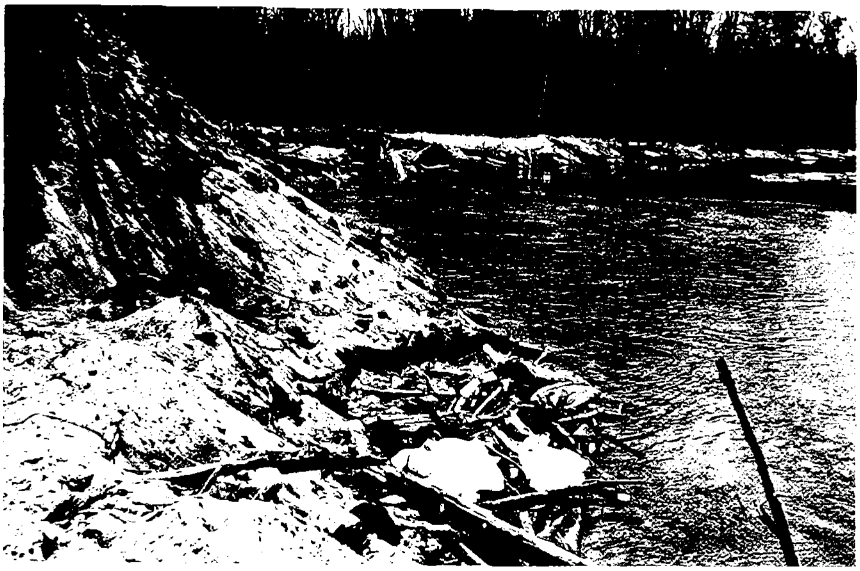


Figure 47. Upper: An extensive dredging occurred along the Au Sable Mainstream, about three miles below Grayling, during the late 1950's, to provide fill for a subdivision development.

Lower: A channel dredged to provide fill for building and access to the Mainstream as well. This dredging was undertaken concurrently with the project in the upper photo.

septic systems from above Grayling to below Wakeley Bridge in 1968, recommended further study in this sector.[20]

Given a very conservative estimate that an average of only 1 foot of bottomland was removed from the dredged area of Mainstream (reportedly it was 8 feet deep in places), it is possible to make some calculations. A stream reach 1/2 mile long, averaging 70 feet in width, and 1 foot in depth, would hold 184,000 cubic feet, or enough sand to cover a football field to the height of a 6-foot man.[21]

A second dredge occurred about 3/4 mile downstream from I-75 in 1963. About 1,000 feet of frontage was dredged along the north bank to provide fill behind a sheet piling seawall. Another channel (about 100 feet long) was dredged downstream for bank fill. A pond was constructed across a river bend here on the north bank, reportedly to raise trout for the river. Other riparians dissuaded the owner-builder from operating the pond, but it remains intact today, enclosed by sheet piling and surrounded by a chain-link fence. Sand has partially clogged the inlet and outlet, and there has been deposition in the pond as well.

In the fall of 1960, construction of the I-75 expressway bridge below Grayling was started. During construction much sand was washed into the Au Sable. Most of the riparians along the river downstream agreed that the input of sand was considerable.

Mr. W. E. Miles, located two bends below I-75 on the Mainstream, reported that gravel and aquatic plants in front of his cottage disappeared for a period of several years, then reappeared about 1968 when the bottom deposits had eroded back to the original grade. An 8-foot hole in front of Gildner's residence by Beaver Island is now filled with sand. Trout fishermen (including Len Allison and Duane Brooks of DNR) also witnessed that several holes in the vicinity had filled with sand.

The late Dr. David S. Shetter, in charge of the Hunt Creek Fisheries Research Station at that time, was quite critical of the lack of preventive measures taken to avoid sedimentation from the I-75 bridge crossing. He described several hundred yards of sand that occupied about 1/2 of the eventual river width, being protected only by a snow fence.[22] Dr. Leonard Allison, former fish pathologist at Grayling, witnessed a bulldozer "pushing sand into the river for working space," and alluded to a 200-foot long bank of sand eroding gradually into the river.[23]

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[20] Brege, Dorance, 3-28-1973. Personal communication.

[21] Burgoyne, George E. 1972. Doctoral Fellow on the Au Sable River Project, in cooperation with the University of Michigan provided the calculations.

[22] Shetter, Dr. D. S. In Charge, DNR Hunt Creek Fish Research Station, 1960 letter to Dr. G. P. Cooper, Director, IFR.

[23] Allison, Dr. L. A. DNR fish pathologist, Grayling. 1960. Letter to Hathaway Hanes, DNR Engineering Division, referred to fine sand deposition from I-75 crossing (Mainstream) extending 1/2 mile downstream at that time.

Straightening and relocating streams to accommodate road crossings is a serious disruption of the stream habitat. The bottom type of a stream directly affects its productivity, with rubble and gravel beds the most productive and sand the least (Michigan Department of Natural Resources, and U.S. Forest Service, 1970). Many references attest to the damage, and the reduction in numbers of game fish, in streams subjected to channel straightening and highway construction (King and Ball, 1964).

The Red Cedar River near Lansing was subjected to an enormous amount of sediment input from the I-96 highway construction in 1961. Many of the pools in the Williamston to Okemos area were filled with sand. Since smallmouth bass success is related to the number and depth of pools present, this species suffered the most as a result of the sedimentation (King and Ball, 1964). Indications are that trout populations in the Au Sable below the I-75 highway crossings on the East Branch and Mainstream, have likewise suffered from loss of cover and food organisms as a result of this activity. The Red Cedar underwent gross reductions in the standing crop of invertebrates and primary producers because of heavy sediment deposition, and the Au Sable likely experienced similar changes.

A gas pipeline crossing 6/10 of a mile below I-75 on the Au Sable Mainstream also contributed a significant amount of sand. Dr. Len Allison, just downstream from this crossing in 1966, attested to the fact that the river looked like "a sea of mud" during the installation of this pipeline. The dredged areas below Grayling described previously, have been at least partially refilled with sand chiefly from these sources. Thus it appears most likely that the bulk of sand introduced from the pipeline and I-75 crossing, have merely replaced spoil dredged from the bottom in preceding years. Even though this area has always been predominantly sand, the man-made alterations would seriously disturb trout reproduction and trout food organisms. Act 346, "The Inland Lakes and Streams Act of 1972" requires a permit to dredge or fill or place structures in waterways with definite banks and continuous flow, regardless of navigability, and should help to prevent needless destruction of habitat in the future.

Eroding bank area was calculated to be some 13,885 square feet for this river reach. However, much of this has already been stabilized by the ongoing stream improvement work and more is scheduled for 1973.

While there are obvious man-induced effects on water and habitat quality that extend several miles below Grayling, it is not clear how good conditions would be if these effects were removed. This is because of the natural characteristics of the habitat just below town. The Shellenbarger swamp region is one of low current velocities and sandy bottom because of the low gradient. The Shellenbarger outlet is a warmwater feeder. Mud Creek is spring fed, but because of its broad surface area and slow velocity, it enters the Mainstream at just about the same temperature as the Mainstream. This area of braided channels covers less than a mile of stream length, but even though warmwater fish are endemic to the general area, there is suitable trout habitat available upstream. The sewage effluent has already been diverted from the river, the hatchery on the East Branch keeps only small stocks of trout for research purposes and display, and other habitat related problems are being corrected by stream improvement programs. The most serious effect remaining is the impounded area above town that is exposed to solar radiation. Removal of these dams should restore temperature ranges that are more favorable for trout (see model design, Section IV). However, storm drains (eight in the Grayling area) continue to supply polluting materials to the stream. Because Grayling is located right on the stream channel it would be difficult indeed to collect surface runoff for treatment. Some new communities have designed a series of intercept basins for processing surface runoff for community use (i.e., industrial, lawns, fires, etc.--even domestic). The problem at Grayling is that there is no space available for off-river collection of storm water runoff. This problem can, of course, be avoided by not building communities on river channels.

Storm drains at Grayling regularly contribute polluting materials to the river as described in Section III, Part A. The impact of this runoff will increase in magnitude as the impervious surface area of Grayling increases. The impurities and nutrient matter that make up the constituents of storm water are adsorbed on the leaf litter, dirt, and trash (cardboard, paper, etc.) from gutters and hard surfaces. Because Grayling is on both sides and close to the river channel, intercept basins would appear to be impractical. The smaller catch basins would need frequent cleaning to prevent the flushing of stored sediment and noxious matter to the stream during subsequent storms. Large surges of heavily concentrated organic matter have been observed to enter waterways from such catch basins during flash storms. Contribution of polluting materials provides more of a detriment to aquatic plant and animal communities in receiving waters in this manner, than where storm drains empty directly to the river (Sandoski, 1972).

The alternative is to keep streets, gutters, and other hard surfaces as clean as possible with a regular 'sweeping' program carried out by village crews.

Grayling sewage treatment plant shutdown, November 1971. As previously mentioned, the upper Au Sable Watershed is extremely sensitive to enrichment because of its natural low turbidity, shallowness, moderate velocities, and suitable substrate for rooted aquatics. While in operation, the sewage effluent from the treatment plant at Grayling had stimulated the growth of algae and rooted aquatics downstream. This resulted in diurnal dissolved oxygen values below 5 ppm because of the heavy oxygen demand during nighttime hours. Data collected since the shutdown of Grayling sewage treatment plant in November 1971 indicate some improvement. Nitrate-nitrogen values do not rise as sharply below Grayling as they did in 1971 (Fig. 48). The peak concentration of phosphate-phosphorus, recorded in 1971, was not found in 1972 samples (Fig. 49). The $B.O.D._5$ is slightly lower than in 1971 (Fig. 50), and fecal coliform counts are now within standards (<200 orgs per 100 ml), recommended by the WRC (Fig. 51). The insect communities, immediately below Grayling, are becoming more diverse and have greater proportions of intolerant species than before.

Outlook. Removal of impounded waters above Grayling, should reduce normal maximum temperatures by 5-10°F (see model, Section IV). The cooler waters of Simpson Creek and the East Branch, combined with good groundwater yield at Grayling, could restore temperature ranges and D.O. levels more suitable for trout. Brown trout, as a result, would be much more competitive with warmwater species.

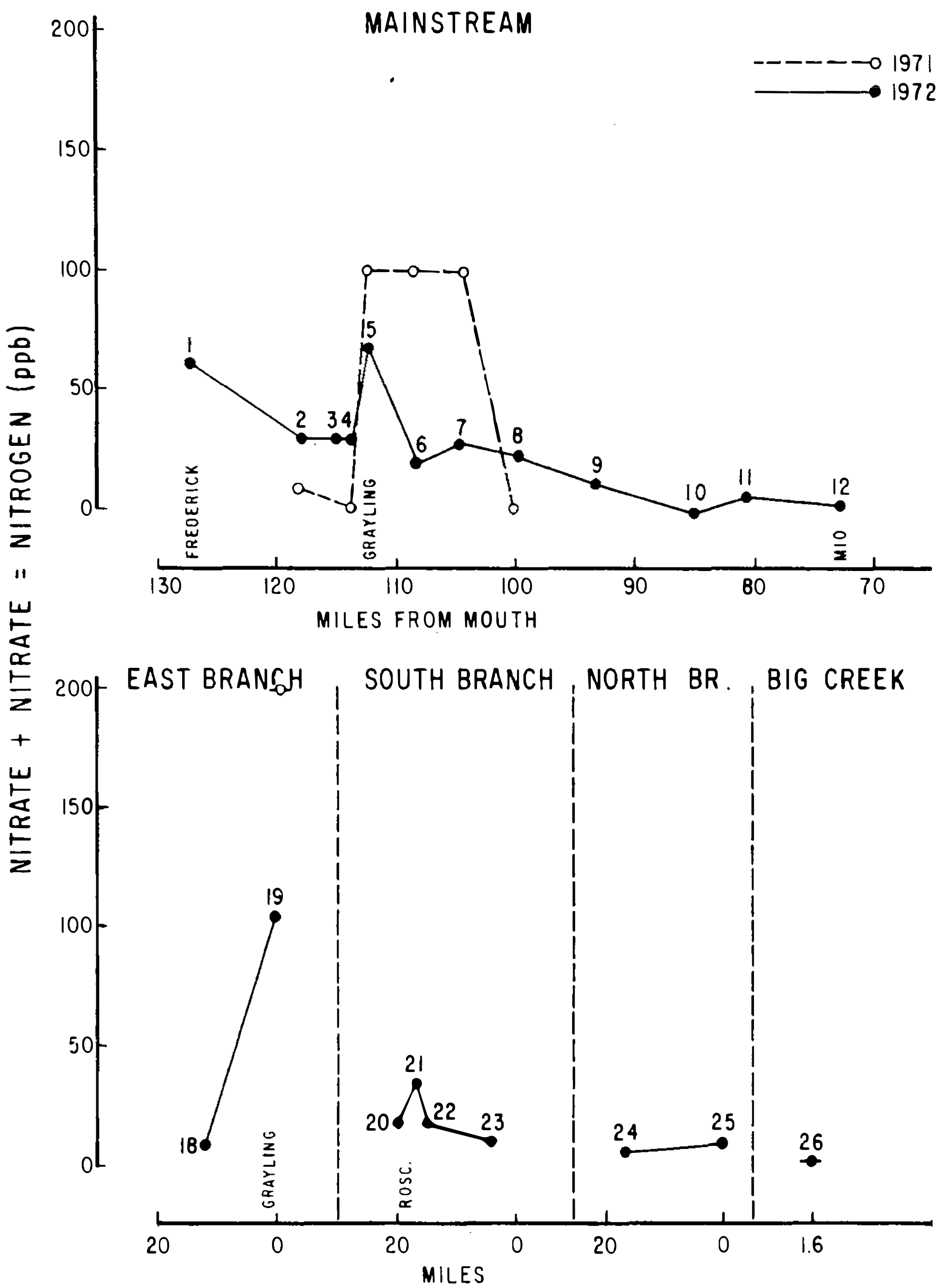

Figure 48. Nitrate-nitrogen values in July before and after the Grayling sewage treatment plant shutdown. The peak concentration below Grayling is considerably reduced in 1972 although influenced by the East Branch.

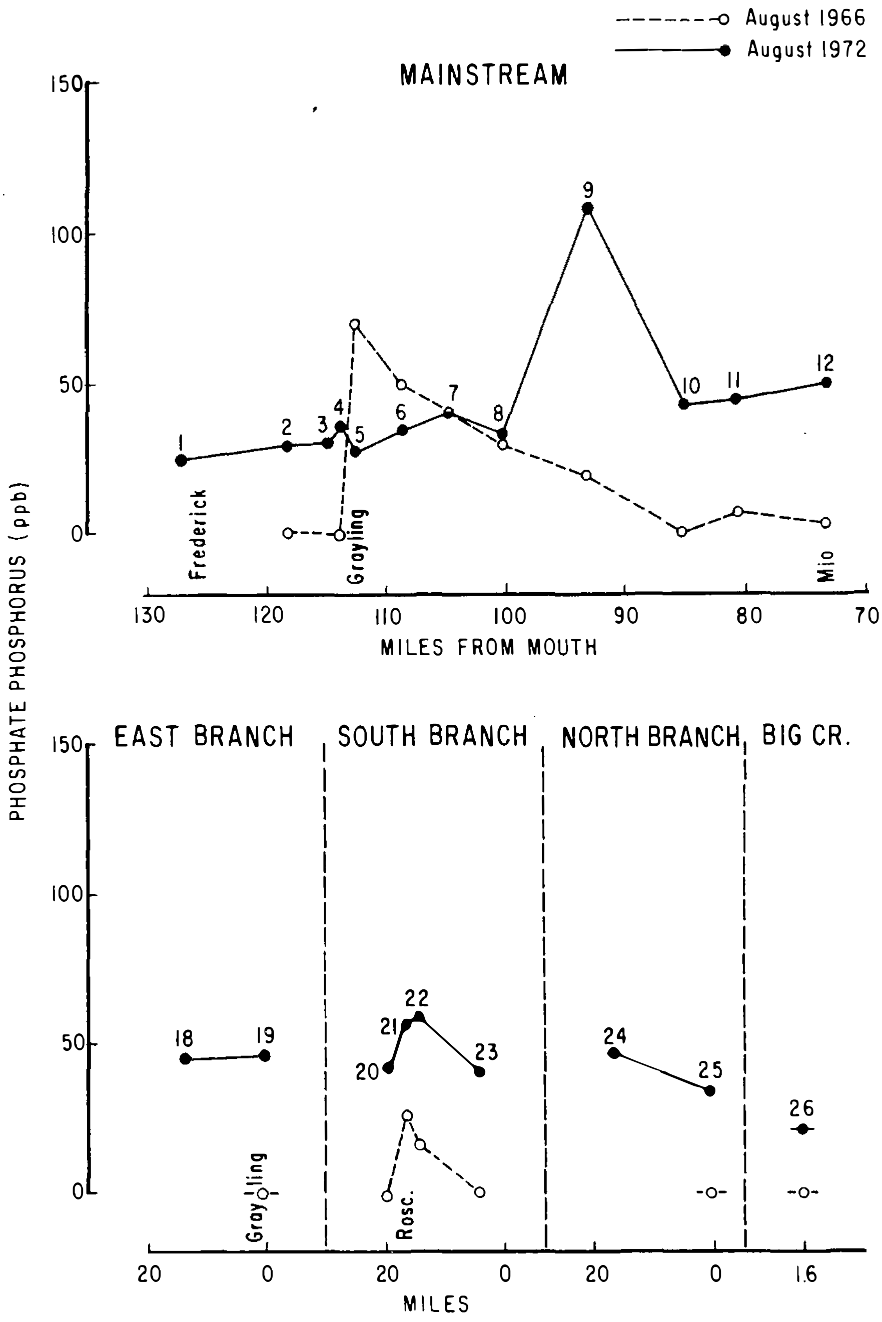

Figure 49. Phosphate-phosphorus values before and after the Grayling sewage treatment plant shutdown. The sharp increase in phosphate concentration below Grayling was not evident in 1972 samples.

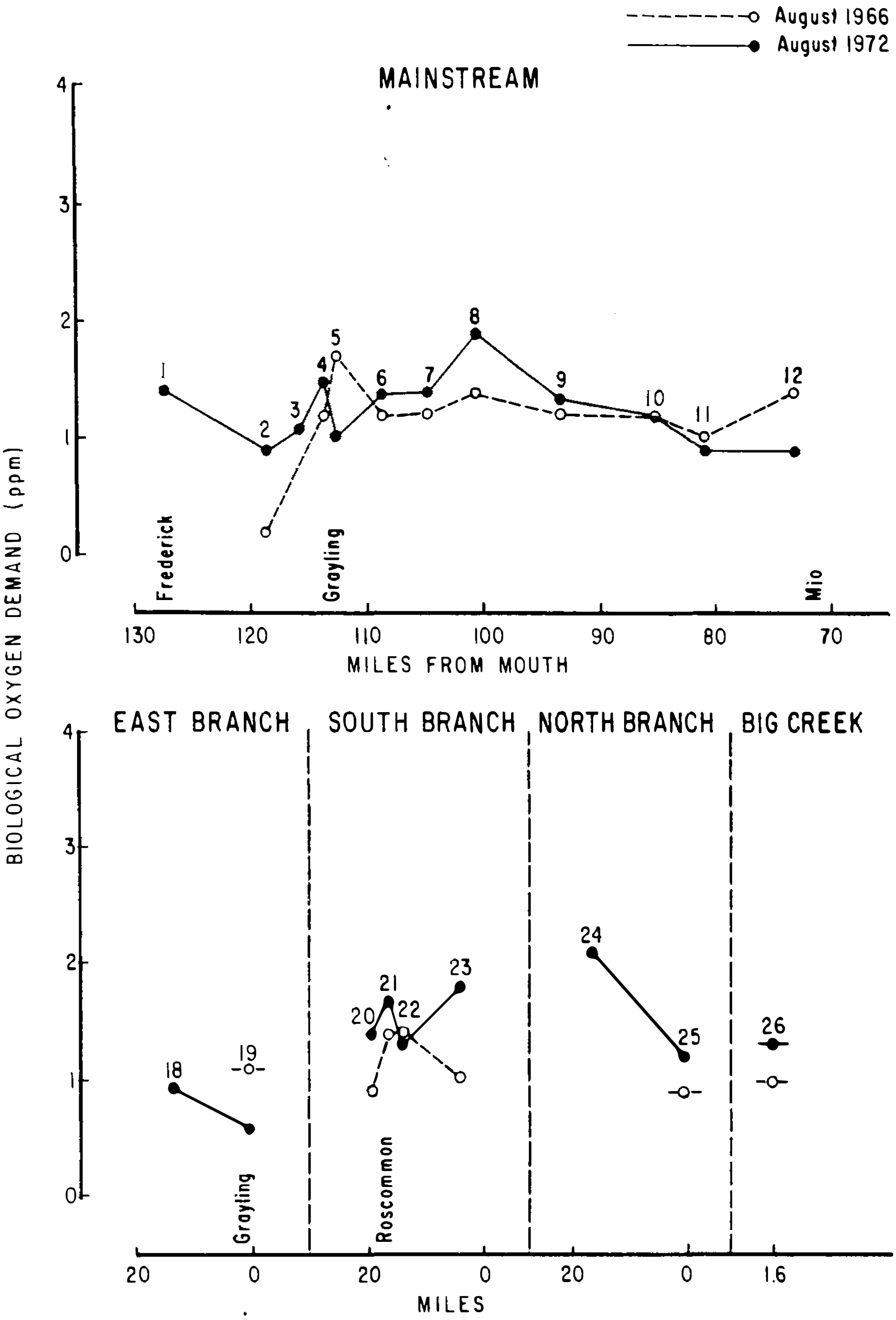

Figure 50. Biological oxygen demand before and after the Grayling sewage treatment plant shutdown in November, 1971.

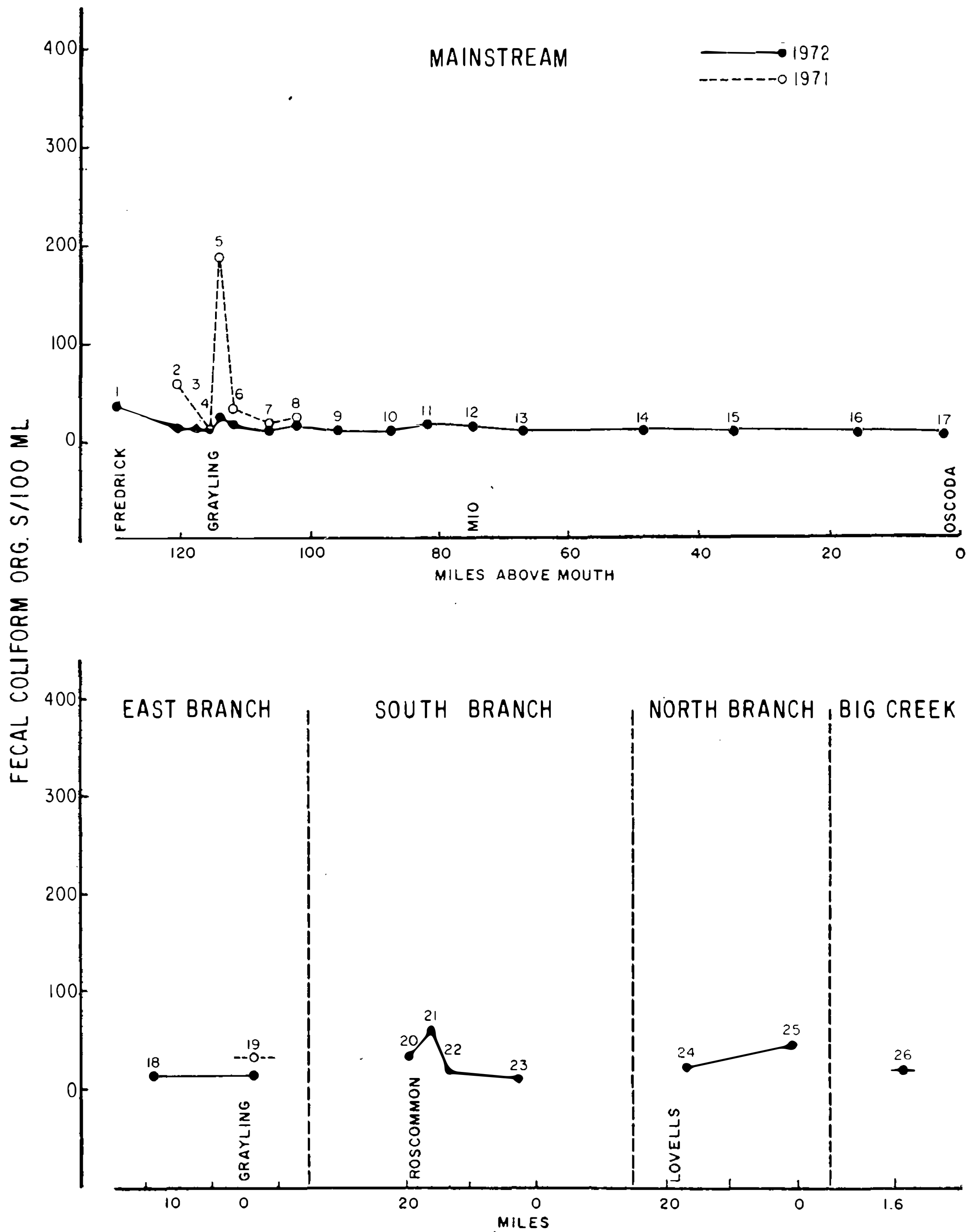

Figure 51. Fecal coliform counts before and after shutdown of the Grayling sewage treatment plant in November, 1971. The peak count below Grayling (I-75, station 5) was within the WRC standard for "surface water supply use" of 100 organisms per 100 ml of sample in 1972.

The stream improvement effort (bank stabilization for reduction of sediment input, as well as the construction of in-stream structures for habitat improvement), by addressing an underlying cause of poor success in the maintenance of trout and trout food organisms, is an important step in improving conditions for brown trout (Fig. 52). District Supervisor Gary Schnicke has also proposed work to restrict the channel in the Shellenbarger area, by blocking off some channels to restrict the flow, and improve the temperature regime.

Use

Canoeing makes up about 70% of the recreational use of this stream segment. Fishing activity was reportedly at a higher level in past years, than presently, and most fishermen feel that trout are not as plentiful as they were a decade or two ago. While brown trout numbers were down by 54% from baseline estimates of the early 60's at Allison's, brown trout numbers were up in estimates at the Pullover in 1972. In any case, several years of data will be needed to properly evaluate any population changes. Most of the conflict in regard to river use here is between canoeists and river-front riparians. Complaints from cottage owners toward canoeists are trespass, litter, and obnoxious behavior (especially from large groups).

BURTONS LANDING TO WAKELEY BRIDGE

Habitat Features

General. This river section contains the quality trout waters of the upper Mainstream. An excellent ratio of pool to riffle areas, swift current, and clean gravel and rubble with abundant insect populations, characterize this part of the river. There is also very good groundwater pick up through most of this area. The flow velocity generally ranges from a little less than 1 mile to over 1 1/2 miles per hour from Burtons Landing to Stephans Bridge, and accelerates to more than 2 miles per hour in places between Stephans and Wakeley Bridge. There are many spring and flowing wells along this segment, and two small feeder streams enter just above Wakeley Bridge. Cottage development is relatively heavy owing to the excellent natural character of this classic trout stream area.

Bottom type. The bottom is predominantly gravel, with some sand stretches and patches of clay. Many long riffles serve to compensate for effects of dense aquatic weed beds on diurnal dissolved oxygen values, by effecting physical reaeration of oxygen-depleted waters during night-time hours.

Trout cover. The cover for trout is also very good, with many pools available, as well as log jams and sweepers. Trout productivity calculated in terms of standing crop is the highest of any river area in the state (Table 20).

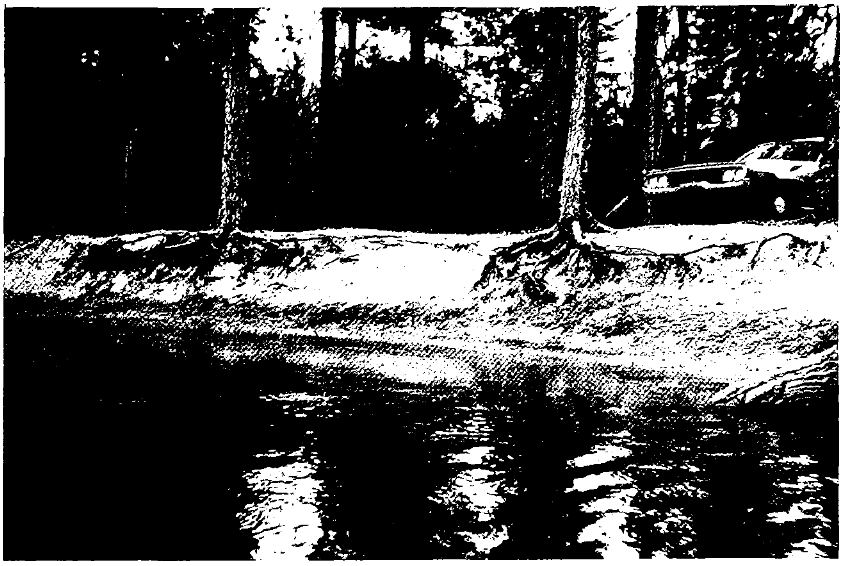

Figure 52. Upper: One of several badly eroding access points along the Au Sable River to be included in the stream improvement program.

Lower: Stream improvement work at the site of the old sewage treatment plant at Grayling. The outfall pipe has been removed and lies along the bank at the left center of the photo.

Table 20. Standing crop of trout populations for the Au Sable River and major tributaries, and for some other streams in the upper part of Michigan's Lower Peninsula. Courtesy of Gaylord R. Alexander, Biologist-in-Charge, Hunt Creek Fisheries Research Station, Lewiston, Michigan.

Stream	Fall Trout Population	
	No. Per Acre	Lbs. Per Acre
Gamble Creek	688	73.3
Rifle River	98	26.1
Pigeon River	609	28.4
Hunt Creek	1,809	52.8
Boardman River	877	49.6
Au Sable - South Branch	393	42.4
Au Sable - North Branch		
Upper	906	48.0
Middle	987	62.0
Lower	1,475	69.4
Au Sable - Mainstream		
Upper	54	14.0
Lower	1,499	148.2
Pere Marquette (Little South Branch)		
Upper	705	87.2
Lower	299	36.2
Au Sable - East Branch	878	33.2
Fuller Creek	1,227	44.7
Poplar Grove Creek	1,492	78.2
Silver Creek	1,836	68.9

Water Quality

General. Concentrations of chemical constituents show a consistent pattern of being diluted by groundwater contribution. This is especially true of chloride concentrations, which being conservative in nature (not taken up by biological productivity, or otherwise chemically bound) generally increase in a downstream direction. This diluting effect is also demonstrated in lower conductance readings in this segment compared to the area at Grayling. Nutrients are rapidly utilized because of a relatively high level of productivity here, and nitrates may be a limiting factor to productivity (Martin, 1972).

Quality index (WQI). The index gradually increases as temperature and dissolved oxygen regimes are improved because of groundwater input and the physical characterics of the area. Downstream, the index value is 84.41 at Burtons Landing, 89.84 at Keystone Landing, 90.35 at Stephans Bridge, and 91.71 at Wakeley Bridge. The 24-hour D.O. values fluctuated by 4.1 ppm at Burtons, 3.9 ppm at Stephans, and 3.1 ppm at Wakeley Bridge for an average of 3.7 ppm (Michigan Bureau of Water Management, 1971). While these values reflect an appreciable amount of stream respiration, no actual 24-hour D.O. values below 6 ppm were recorded in this segment (Fig. 53). A maximum D.O. depression below saturation was 3.9 ppm at Burtons Landing. By comparison values recorded in August, 1972 (24-hour D.O.) had a range in the fluctuation of D.O. values of only 3.0, 2.3, and 3.1, respectively (average, 2.8 ppm) and a maximum departure of 2.6 ppm below saturation. Because the flow was higher and temperatures lower than normal in August, 1972, the extremes of dissolved oxygen fluctuations may have been greatly moderated by these conditions. In order to properly evaluate any changes as a result of the shutdown of the Grayling sewage treatment plant, the 24-hour D.O. survey should be repeated under more typical weather conditions.

Quality reflected by biota. Insect diversity continues to increase in a downstream direction through this river segment, as water and habitat conditions improve. The percentage of intolerant insect forms increases in the same manner (See Fig. 34, page 71).

The seined fish collections show that conditions for trout have improved in the Wa Wa Sum and Stephans area since collections were made in the 1920's. Below Stephans and at Wakeley Bridge, numbers of trout present are about the same now as then, although the relative abundance of non-coldwater species is now higher at Wakeley's than it was in 1924. Electrofishing collections indicate good trout waters throughout this area. The trout population estimates at Wa Wa Sum and Stephans showed brown trout to be at the same or higher levels of abundance, as they were during the early 1960's, despite restructuring of age groups. Brook trout were at significantly lower levels than previously, but more data are needed to confirm a real change in abundance. Electrofishing collections made on Barker Creek, just above Wakeley's, produced good numbers of trout as well.

Trout population estimates at Wa Wa Sum in 1971 and 1972 showed that brown trout numbers were down by some 23% overall, and that browns over 12 inches were down 16% since the baseline years of the late 50's and early 60's. The same figures for Stephans showed that brown trout

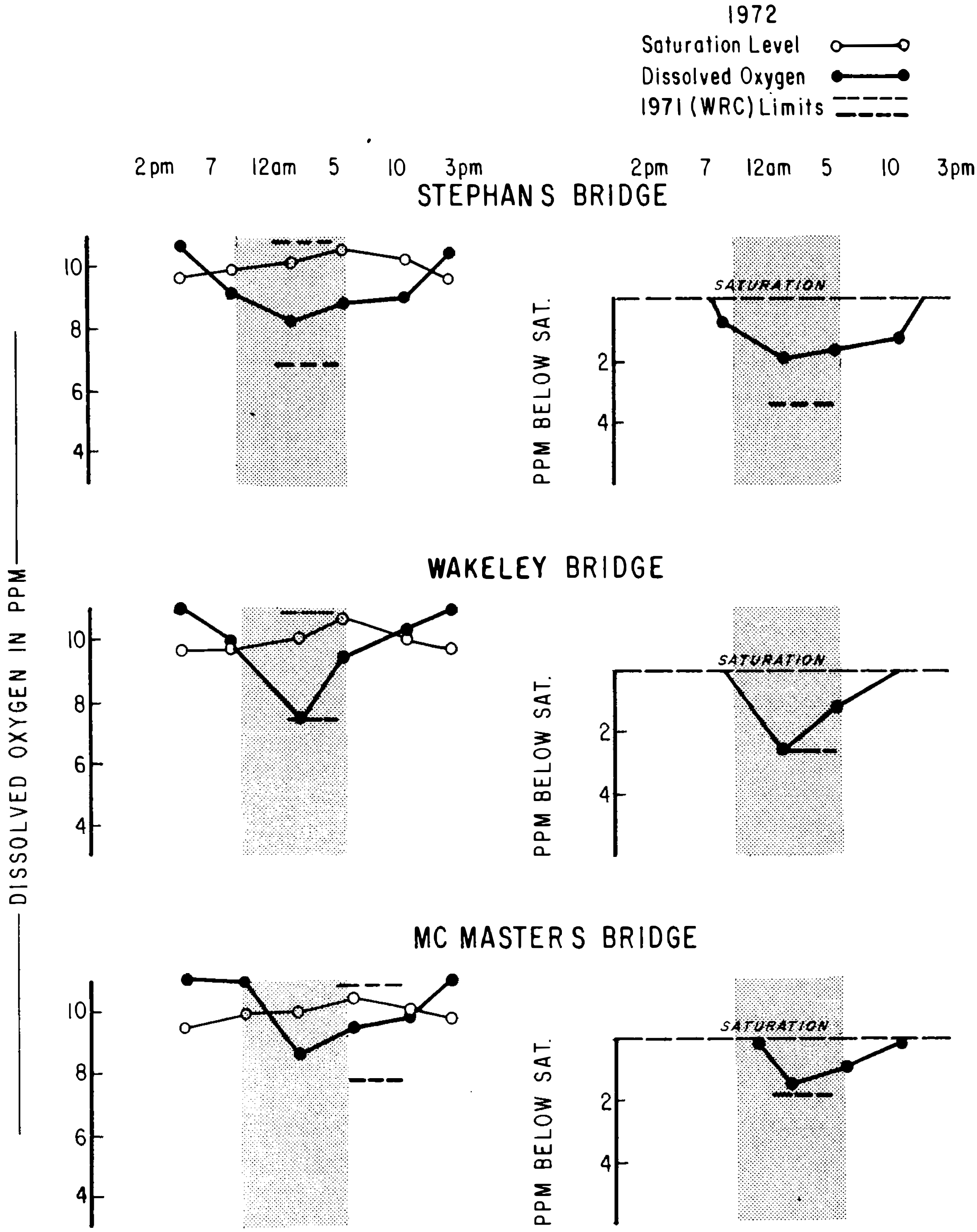

Figure 53. Dissolved oxygen concentrations observed for three Mainstream stations 9, 13.5 and 20.5 miles downstream from Grayling on August 3 and 4, 1972.

were up by 12% overall, while browns over 12 inches were down by 9%. The net result was no change in the overall brown trout population, for the stream segment, although larger browns were down slightly from the early 60's. Gary Schnicke, District 7 Fisheries Biologist, is conducting a tagging operation in this area in an attempt to determine the exploitation rate.

Periphyton analysis shows that primary productivity increases at the canoe camp over upstream levels, and again at Pine Road, one mile below Stephans Bridge, a trend that continues to the stillwater area.

Human Impact

Problems. These waters are heavily fished, and accordingly there are many access points. Erosion problems are associated with nearly all of these sites, and they are in need of repair to prevent further sediment input. In all, there are eight road ends, two campgrounds, two fish access sites, two bridge crossings and six eroding banks to be considered for stabilization. While it is true that there are not as many road ends and bridges as there were during the early part of the century, there is appreciably more use of the remaining access areas.

The increasing number of cottages along this stretch not only disturbs aesthetic values, but constitutes a threat to habitat quality. This is because of the risk of nutrient seepage that stimulates aquatic plant production in these prime trout waters. Increased plant cover results in increased sedimentation, increased siltation, wider D.O. fluctuation, slower current velocity, increased temperature, and their combined effects on aquatic insects and ultimately on trout. One possible solution would be to install a collection system in problem areas, where cottage density could result in a nutrient impact. However, financing, operating, and maintaining such a system, would be a very expensive proposition. Preventive measures would provide the best cure, where zoning ordinances would prohibit building in sensitive areas, where a high risk of contamination exists.

Heavy cottage concentration begins at Louies Landing and extends past Wa Wa Sum. One-half mile above Stephans to one mile below Wakeley Bridge, cottage density is again very heavy with the exception of the middle mile. Unfortunately, cottage development is the highest of any place on the river in these prime trout fishing waters.

The highest density of cottages occurs between Stephans and Wakeley bridges. No measurable increase in nutrients (through this area) can be derived from the water quality data, except for a slight increase in nitrates in winter. However, seepage of nutrients to the river would likely be masked by dilution resulting from generous groundwater contribution.

Outlook. This quality area should continue to be productive for trout for many years to come. The diversion of the sewage effluent at Grayling should eventually result in a reduction in downstream aquatic productivity, especially the macrophytes. Enforcement of adequate Greenbelt ordinances will improve both aesthetic and biological character of the river (Fig. 54). Many examples of homesites that loom out as artificial, unnatural scars on the river scene can currently be found. There are mammoth seawalls, palatial estates with huge terraced and manicured lawns, elaborate boat houses, low bridges, and long docks. In all fairness, good examples of the "Greenbelt spirit" can also be found (i.e., a buffer zone between cottage and river with 1/3rd of the frontage or less cleared, a 50-foot setback, and modest docking facility). The ongoing streambank improvement program will stabilize problem areas and minimize the sediment load.

Use

Canoeing comprised about two-thirds of the recreational use of the area from Grayling to McMasters Bridge in 1963 (Alexander and Shetter, 1967). The canoe traffic reaches such a density in the quality trout fishing waters (Burtons Landing to Wakeley Bridge), that daytime and early evening fishing (during peak use periods in summer) is nearly impossible. River-use rules, that are designed to limit the number of canoes using the quality fishing waters on weekends and holidays during late spring and summer, are being challenged in the courts. The rules, if adopted, would also require the livery owners to furnish information and instructions regarding river use to canoeists, provide litter bags, and affix the livery name and canoe number on the rental craft for identification. The natural beauty of this part of the stream is, of course, highly desired for all uses including cottage living.

WAKELEY BRIDGE TO McMASTERS BRIDGE

Habitat Features

General. The first mile below Wakeley Bridge and the last 2 miles above McMasters Bridge contain many riffles and high average current velocities (Wakeley, 2.9 fps; McMasters, 3.2 fps). There are many deep pools, and good numbers of large brown trout are reported by anglers. The remainder is a low-lying, wide stretch of river about 6 miles long having a low average velocity (1.3 fps at White Pine campground). Here the river passes over deep holes and broad sand bars. This area, the "stillwaters," is a settling basin for sediment and nutrient matter from the upper river, and from the south branch which meanders in from the south near the middle of the segment. Some observers say that the percent of sand here, has noticeably increased since the 1940's,[24] and that there are places during low flow that a motor will drag bottom now where it would not have in past years. Of course, a sand bottom type is constantly shifting and moving, but this is a sediment deposition area and there should be a net accumulation of sand over the years depending on the rate of contribution.

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24 Peterson, H. L. State Fisheries Supervisor, 1965. Letter to Troy Yoder, Region II Manager, suggesting channel modification to accelerate the current because of the accumulation of sand, over the years.

Figure 54. Upper: This cottage was built on a fill consisting of spoil dredged from the river bottom. Because it was built on the river bank and has an inadequate depth of soil to prevent seepage to ground water, it provides a good example of what Greenbelt zoning is designed to prevent.

Lower: This cottage provides a good example of adequate set-back from the waters' edge, and buffer zone to maintain the river frontage in the most natural state.

Bottom type. The beginning and end of this segment consist of a high percentage of gravel-riffles, while the "stillwaters" has an almost completely sand bottom with many clay banks in evidence. There are dense weed beds in places, but they are generally associated with silt beds in bayous and along the river margin. By comparison, the vicinity near Stephans Bridge has a much higher percentage of its area supporting rooted aquatic plants.

Trout cover. Cover is generally good in the upper part of the segment, having many deep holes and log jams. Below the mouth of the South Branch, the river widens considerably (200 feet in places) and cover is poor to Conner's Flats about two miles downstream. The riffle to pool ratio is very good from this point to McMasters, and brown trout are in good supply (based on reports from fishermen).

Water Quality

General. There is a noticeable increase in phosphate-phosphorus concentrations from Wakeley Bridge to McMasters Bridge. Much of this increase is due to the entry of South Branch where phosphates are higher due to the input from the WWTP at Roscommon. There is also a rise in chloride levels here, again due mostly to the higher concentrations in the South Branch. Other constituents were found to be in normal ranges relative to other areas sampled in the watershed.

Quality index (WQI). The index values for this segment continue to rise from upstream readings. The value for Wakeley Bridge again was 91.71, and at McMasters the value was 92.44. The 24-hour dissolved oxygen values measured in August, 1972, showed a fluctuation of only 2.5 ppm. Even though the phosphate levels were considerably higher at McMasters than at Wakeley, they were low relative to more enriched watersheds and the penalty exacted by the significance rating (SR) was small (See Part A-1).

Quality reflected by biota. Benthic samples taken at McMasters revealed a low diversity, and low percentage of intolerant insects. The results are tempered by the poor sampling substrate available.

Electrofishing collections at Conner's Flats and McMasters showed 4% and 11% trout present, respectively. Despite these low percentages, the waters from Conner's Flats to McMasters are considered good trout waters based on angler reports. However, because of the greater stream discharge here, this area is harder to survey and trout are more difficult to capture during electrofishing surveys conducted by a single crew.

A seined fish collection, taken just below the South Branch confluence with the Mainstream, produced no trout in 1972. In 1924, almost 50% of the species captured were trout. The results, when checked by an electrofishing survey, were reinforced when only 11 small trout were captured. These findings indicate a significant species shift in favor of warmwater types due to continuing changes in habitat features, and possibly water quality as well.

Periphyton data collected in the "stillwaters" (White Pine camp) registered the highest productivity level of any station tested. There seems to be a nutrient buildup in this area, perhaps due to the lower percentage of rooted aquatic plant activity compared with the upstream area.

Human Impact

Problems. The "stillwaters" is an area influenced by use of the river and uplands upstream. It is a natural area of bed load sediment deposition, and is similar in this respect to the area just below Grayling. The upper end of the stillwaters is quite deep in places with good trout cover available. Stream discharge measurements indicate that there may actually be a loss of streamflow to groundwater storage, in the "stillwaters" and in the lower South Branch. The shift in fish species noted previously indicates a very significant change in habitat quality. This collection should be repeated to confirm the results.

There are erosion problems associated with the White Pine campground and the Conner's Flat campground. The soil types here contain a much higher percentage of clay, are very compacted, and therefore less subject to erosion. Use of these areas is not as high as it is upstream, and they will have a lower priority. However, these sites should be included in the overall stream improvement plan.

Cottage density is not nearly as high as it is upstream except near the bridges. Docks are quite long below the South Branch because of the long sand bars along the bends in the river. In one case a dock extends out nearly 100 feet. According to law, a riparian has the right to wharf out to navigable water as long as it does not interfere with navigation. The river traveler must swing wide around this dock to stay in the river channel in any case, but there is a question as to whether the dock itself is causing addition deposition of sand along the upstream side in the navigable channel. If it is, it should be moved back as far as necessary to prevent this effect.

Outlook. Land use practices in the upper Mainstream, East and South branches, have an effect on the stillwaters region. Competition between trout, intermediate, and warmwater fish species (notably suckers and northern pike) is intensive, as it has likely been in years past.

Use

Cottage density is much lower than in the segment just upstream that contains the quality trout fishing waters. The area receives moderate to fairly heavy use by trout fishermen, and has two campgrounds on the north bank, the White Pine campground just upstream from the South Branch confluence and Conner's Flats campground downstream from the South Branch. A considerable amount of the fishing is done by boat, and outboard motors are in common use. Although these waters do not contain the numbers of trout as the upstream quality waters, there are reportedly fair numbers of large brown trout available.

This segment also receives much attention from canoeists, as McMasters Bridge is the last major take-out point for upper Mainstream and South Branch float trips.

McMASTERS TO PARMALEE BRIDGE

Habitat Features

General. The upper third of this segment has many riffle areas and a swift current, while the remaining two-thirds has a slower current, deeper holes, and mostly sand bottom. The North Branch enters the Mainstream from the north about two miles below McMasters Bridge. The North Branch confluence increases the flow of the main river by 52%. Four small tributaries also enter the Mainstream in sections 5 and 6, but contribute little flow.

Bottom type. The bottom is mostly of a gravel type in upper part, and mostly of a sand type from the North Branch to Parmalee Bridge. A nice riffle area exists a ways above the Parmalee Bridge. Rooted aquatic vegetation is not abundant, but increases noticeably in occurrence in the last mile above Parmalee, most likely because of the change in substrate type.

Trout cover. Good cover exists in the form of pools, deep holes, and many log jams.

Water Quality

General. All chemical constituents tested for at Parmalee Bridge were in normal ranges for unpolluted river systems. Most of these constituents are reduced from readings at McMasters because of the influence of the North Branch where concentrations are lower.

Quality index (WQI). The WQI at Parmalee Bridge is the highest recorded on the Mainstream. This is due to the favorable temperature and dissolved oxygen regime. Dissolved oxygen is the most heavily weighted of the included parameters.

Quality reflected by biota. Benthic samples indicate good water quality at Parmalee Bridge. The primary productivity (periphyton) at Parmalee Bridge was reduced considerably due in part to the diluting effect of the North Branch which had the lowest levels of any station tested.

Human Impact

Problems. Cottages are fairly dense from McMasters downstream past the North Branch confluence (over 20 per mile). Almost half of these were judged to be too close to the river to meet Greenbelt standards. (They were, of course, built before the ordinance was in effect in Crawford County.) There is no public access to the river between McMasters and Parmalee. There are two low-head dams on Beaver Creek, which enters the Mainstream just above Parmalee, but they likely have little effect on the river.

There are 23 eroding banks in the section, having about 18,330 square feet exposed or bare of cover. One bank in particular just below the North Branch is a major problem.

There is another fairly heavy concentration of cottages between McMasters Bridge and the North Branch. Again, chemical data collected do not show any significant increase in nutrient concentrations. Sampling stations are widely separated here and the river has received about 60% of its discharge after it picks up the North Branch. Nevertheless, the presence of so many cottages, long seawalls, and large boat houses with screened in decks, disrupts the natural scene of the river.

Outlook. There is a need for additional access to the river in this segment, although fishermen can float the section in about 3 hours and many do. The campground across from the canoe landing at Parmalee was a problem area (erosion), but the bank has been repaired and a barrier of boulder-sized stone placed along the campsite area (by forestry crews) to prevent auto traffic from reaching the bank (Fig. 55). Streambank-stabilization work will include the existing major erosion areas.

Use

As mentioned above, there is heavy use of the river between McMasters Bridge and the North Branch by riparians for cottage living. There is also heavy use of this same area by trout fishermen--some by wading and some from canoes and Au Sable River boats. This segment reportedly furnishes a very good brown trout fishery.

The segment also receives considerable attention from the canoeing faction, though use is not as great as upstream. However, any relocation of rental canoes to Wakeley Bridge and downstream areas due to restrictions on the use of the waters above Wakeley Bridge, would of course result in an increase in use by canoeists below McMasters Bridge.

PARMALEE BRIDGE TO MIO

Habitat Features

General. As described by Gerth Hendrickson in 1963, the Au Sable river downstream from the North Branch "takes on a big river character," ranging up to 250 feet wide and having many deep holes and a slow to moderate current velocity. The river near Parmalee freezes over during very cold weather, suggesting low groundwater contribution relative to stream discharge, as well as slower current velocities. Big Creek (south) enters from the south 2.8 miles below Parmalee Bridge. Big Creek is a very good cold water feeder, but only increases the flow of the Mainstream at this point by about 10%. Several smaller, but significant, feeders enter the river on both sides just above and in the Mio Pond area.

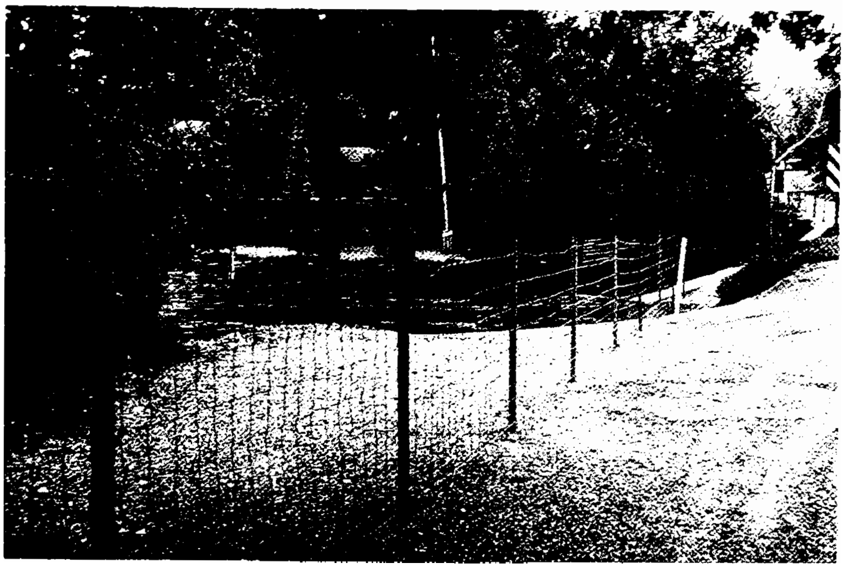


Figure 55. Upper: These large boulders were placed between the campground and river bank at Parmalee Bridge on the Au Sable Mainstream, to prevent vehicles from driving up to the river bank. The area to the right of the boulders was mostly bare ground before DNR Forestry crews repaired the site.

Lower: A fence was built across a problem access area at Wakeley Bridge on the Au Sable Mainstream in 1972. There is a take-out point just a few hundred feet downstream.

Bottom type. Some rubble bottom is evident, but the bottom type in this segment consists mostly of a sand and clay substrate. Much sand and silt exists in bayous of Mio Pond.

Trout cover. The cover is fair to good above the upper end of Mio Pond, but there is heavy competition between suckers and trout. Trout habitat is minimal in the Mio backwater area.

Water Quality

General. Constituents were in ranges considered normal for coldwater streams. No increase in nutrients from Mio Pond were observed.

Quality index (WQI). The high index reading of 93.29 at Parmalee Bridge is reduced to 87.09 at the public access site on Co. Road 606 two miles downstream. This lower rating is the product of a low dissolved oxygen reading in 1966 by the WRC, during a 24-hour D.O. survey. This is likely the result of a very local condition and not typical of water quality conditions at this station. Therefore, an additional survey might yield an index comparable to that found at Parmalee Bridge. The index at Mio below the dam was 92.14. Although temperatures were higher here, dissolved oxygen was always near the saturation level because of the reaeration caused by the spill over the dam.

Quality reflected by biota. Insect collections at Parmalee and below Big Creek indicate good water and habitat quality. A low insect diversity and a low percentage of intolerant insect species below Mio Dam demonstrate a degraded environment due to the impoundment. A 1972 fish seining effort at the mouth of Big Creek produced a slightly higher percentage of coldwater species (10%) than the 20's collection (7%), but was not judged to be significant. The collection below Mio Dam was essentially the same (3% in 1924, 1% in 1972) and shows good agreement with the insect results.

Results from periphyton sampling about 1/3 mile below Mio Dam produced a significant increase over the levels found at Parmalee in terms of primary productivity. This is unquestionably due to the effect of the impounded waters upstream.

Human Impact

Problems. Mio Pond is a warmwater basin which has many undesirable effects on the river extending both up and downstream from the ponded area. At present about 63% of the fish species found in the pond are of the rough fish variety, and very few trout were found during survey efforts. In addition to this the warm surface water flowing out of the basin, rich in nutrient matter, has a pronounced effect on fish below the dam. Suckers and pike periodically move upstream above the backwater and may affect trout populations there as well. Temperatures may be influenced by Honeywell Creek, a warmwater tributary entering the Mio pond on the north side 2 miles above the dam. Honeywell Creek is a warmwater feeder having a total of six dams that have a range of 6 to 18 feet of head over its 6-mile length. Lost Creek, considered a coldwater tributary, enters from the south 7 1/2 miles upstream, and has four dams ranging from 6 to 10 feet of head.

The impounded waters at Mio Dam have a direct effect on over 15 miles of river above and below the dam. The conversion of the backwater from a high value coldwater fishery to a low value warmwater fishery (dominated by rough fish species) is nearly complete.

Outlook. Little can be done to improve conditions in this area because of the impoundments. A treatment for removal of rough fish species in Mio Pond, even during a drawdown to reduce the area, would be impractical because of the expense and the difficulty in preventing a downstream kill of trout. Such an improvement, if effected, would only be temporary.

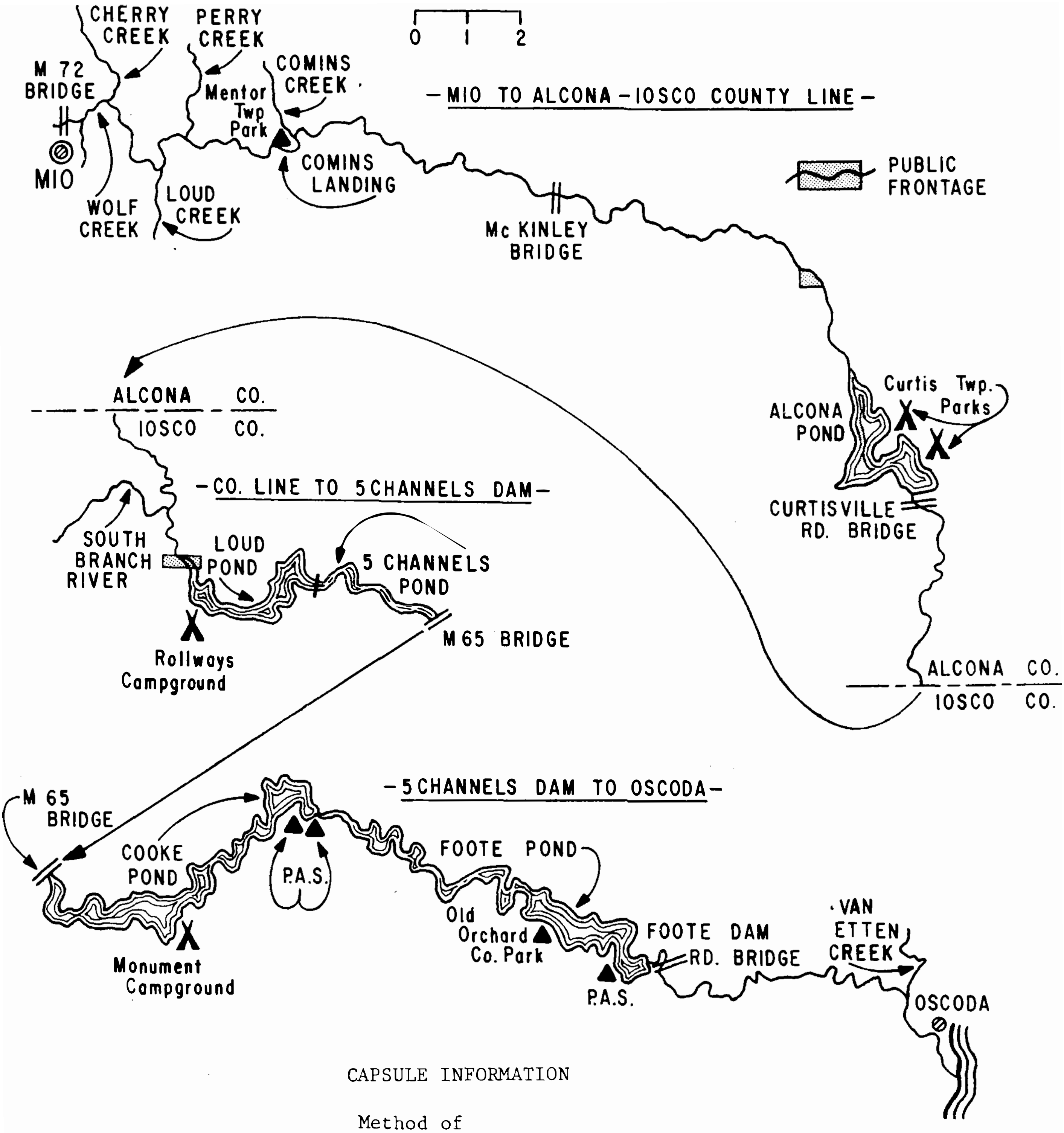
Use

The fishing in this segment takes place mostly on Mio Pond, and below Mio Dam. Fishing on the pond (Mio Dam backwater) is almost exclusively for warmwater species. There is fair to good fishing for trout from Parmalee Bridge downstream to the public access at Co. Road 606. This stretch contains the confluence with Big Creek (South) which is an excellent coldwater tributary.

Canoeing in this segment is considered minimal, and the density of cottages is light to moderate.

SECTION III

PART B-3 MAINSTREAM-MIO TO OSCODA



CAPSULE INFORMATION

Villages	Population	Method of Sewage Disposal
Oscoda	7,000(est)	Private Septic Tanks

Miles of Stream in Section

	Public	Private
Mainstream	3.5	64.3
Tributaries	41.6	69.6
Total	45.1	133.9

Capsule Information, continued

Main Tributaries

Stream	Class	Mile Point	No. Dams
Wolf Creek	coldwater	72.7	4
Loud Creek	coldwater	69.8	1
Cherry Creek	coldwater	72.1	4
Perry Creek	coldwater	67.2	4
Comins Creek	coldwater	65.0	2
South Branch River	coldwater below Hubble Creek	38.7	1
Van Etten	coldwater	2.0	20

Mainstream Dams	Head	Pond Acres	Year Built	Mile Point
Alcona	39.0'	1,075	1924	46.5
Loud	27.0'	790	1913	33.7
5 Channels	35.5'	250	1912	30.7
Cooke	38.5'	1,800	1911	22.2
Foote	39.0'	1,850	1918	13.7

(All are active Consumers dams)

Drainage area - 1,800 sq. miles

Average discharge at Oscoda (1966) - 1,937 cfs

Gradient feet per mile - 4.78

Streamflow Measurement

Location	Mile Point	Discharge (cfs)
Mio	73.0	982 (Ave. - 1966)
Alcona	50.0	1,350 (Ave. - 1909-1914)
Oscoda	0.2	1,937 (Ave. - 1966)

Occurrence of permanent and seasonal dwellings along the riverfront, by section(s), where the density exceeds 20 units per section or linear mile:

T 23N, R 9E Sections 3, 4, 10 (Oscoda area). Almost all of the frontage in this segment is controlled by Consumers Power Company. There are presently 280 leases for cottage development to private citizens on the Au Sable River.

Habitat Features

General. Of the 73 miles from Mio to Oscoda, over 1/3 or 26.5 linear miles are covered by the impounded waters of five hydroelectric basins. This creates 5,765 acres of warmwater fish habitat. The drainage basin narrows considerably here, and the river picks up about 50% of its flow between Mio and Oscoda. The hydroelectric basins completely alter the character of the lower river, changing coldwater and anadromous habitat to warmwater habitat. The dams raise water temperature, increase nutrient load, and block spawning migrations of trout and salmon.

One major tributary enters this section, in addition to Pine River system which does not join the Mainstream until a point just above Oscoda, where the river empties into Lake Huron. This is the South Branch river which joins the main river from the west just above the Loud Dam backwater. The South Branch River is warmwater at its beginning because of lakes in the headwater area, as are most other tributaries, then becomes fair trout water (for large browns) near the mouth where groundwater cools the stream. The Pine River system contains 170 linear miles of stream, two impoundments and ten connecting lakes.[25] Fish species present were reported to be mostly trout, although the area surveyed was upstream from Van Etten Lake.

Bottom type. Good gravel stretches are found below Mio Dam downstream to Alcona backwater. There are also good gravel reaches between Alcona and Loud Dam backwaters, with aquatic plant production mostly in bayou areas and upper backwater of Loud Basin. The river bottom below Foote Dam downstream to the mouth at Oscoda, is mostly sand.

Trout cover. The first 23 miles below Mio to Alcona backwater is considered good trout habitat, with suitable temperatures, good cover and food supply. The 6-mile stretch below Alcona is also considered good trout habitat, but not as good as the area immediately below Mio.[26] From Foote Dam to the river mouth is a distance of 12 river miles, with variable flow regulated by Foote Dam. There are deep pools, many log jams and rubble bottom in places.

Water Quality

General. Nitrates are much lower in this part of the river, because they have been removed by biological production upstream. At these levels (<10 ppb--summer), they are probably a limiting factor to productivity, while phosphates are at slightly higher levels of concentration than found above Mio. Chlorides continue to increase slightly in concentrations, as would be expected.

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[25] Spaulding, Willard. MDNR Fisheries Biologist, 1962. Watershed Survey Report, Pine River Watershed. Survey and Plans Report. Michigan Department of Conservation--Fish Division. 30 pp.

[26] Schnicke, Gary T. District 7 Fisheries Biologist, Mio. 1971. Personal communication.

Quality index (WQI). Mio at mile point 73.0 has an index of 92.14 and Oscoda at mile point 0.2 has an index of 86.34. A lower index value at Oscoda is mostly due to the higher concentrations of phosphate, and to the effect of higher temperature and lower D.O. levels.

Quality reflected by biota. Insect communities sampled below dams from Mio downstream, reflect poor quality waters in three out of four investigations in terms of diversity and percentage of intolerant species present. The sample taken below Five Channels Dam reflected better quality conditions. The most plausible reason for this anomaly is that the Five Channels basin is the smallest and is more riverine in character than the others. This could easily result in a lower level of stress acting on animal communities. Factors that are likely responsible for the depressed state of bottom-dwelling insect communities below impoundments include: warmer water temperature, increased productivity (organic loading), and the variability of stream discharge. The five lowest insect diversity values on the Mainstream all occurred below impoundments (Fig. 34, page 71).

The seined fish collection results are again in close agreement with the insect results. Collections taken below the dams failed to produce any coldwater species either in 1924 or in 1972. At Comins Landing, 6 miles below Mio Dam, coldwater species had increased slightly (1 to 3%) but this was not at a significant level. There is evidence that some of the trout captured in 1972 may have been hatchery fish. Comparison of results from these seined fish collections with results from similar collections in the 1920's demonstrate significant reduction in species diversity representing the greatest shift in fish species (as indicated by the Jaccard Index) of all habitat types surveyed, a decline in minnow species intolerant of silt and increased turbidity, and an increase in minnow species tolerant to these conditions (Fig. 21, page 51).

Trout population estimate stations below Mio Dam (six stations from Mio to Comins Landing) surveyed in 1971, showed a reduction in trout populations since 1967 ranging from 15 to 20%. As stated previously, this is felt to be more a result of two preceding severe winters and normal population fluctuations than an actual loss of water quality. These population estimate stations will be periodically surveyed by Fisheries personnel. District Fisheries Biologist Gary T. Schnicke, points out that insect populations suffer significant losses during the drawdown of water level to enable wading. Consequently these estimates will be run only every two or three years to prevent serious reductions in fish food organisms. Periphyton analysis below Mio pond reflects an increase in primary productivity from upstream values though levels are not as high as in the "stillwaters."

The backwater areas of the hydroelectric basins have undergone similar changes as indicated by an almost total disappearance of trout, changes in the growth patterns and distribution of warmwater game fish, and the increasing dominance by warmwater fish species. Productivity in newly formed impoundments (especially large ones) is usually good initially, then gradually becomes less than that of natural lakes due to nutrient loss and sedimentation. Impoundments typically favor introduced species because of the vast changes in physical and chemical conditions. Over a period of many years, rough fish species generally gain dominance. This condition is now taking place in the Au Sable hydroelectric basins.

Human Impact

Problems. Man's impact on the habitat below Mio is almost exclusively related to the impounding of its waters. The foregoing analysis describes the negative response of animal communities (insects and fish) below the dams, and undesirable changes in fish species composition within the impoundments as well. Management of these impounded waters, for a good quality warmwater fishery, would require treatment for removal of rough fish species. Based on existing techniques, costs of accomplishing this task would be prohibitive. In order to sustain fishable population levels of the most desired species, trout and walleyes, a maintenance stocking program would be necessary. Perhaps development of the new warmwater hatchery will eventually furnish walleyes of a size that can be stocked with reference to a good expectant survival rate. However, the immediate outlook is that these large warmwater basins will continue to provide a mediocre fishery.

District Fisheries Biologist Gary Schnicke feels that physical conditions (winter severity, ice and spring flooding) play a primary role in governing conditions for success of brown trout populations. Anchor ice and spring floods can result in scouring of the channel, and serious depletion of small trout and trout food organisms. The six miles of open river below Alcona to Loud Dam backwater is subject to the same forces. Cyclic response of trout populations is well fitted to severity of recent winters and springtime flow conditions. The wide fluctuations in stream levels from regulation of impounded waters can be observed in the Mainstream above Loud basin (Fig. 56).

Outlook. Nearly all of the frontage along the lower river is owned by the Consumers Power Company. The time will come when these dams will no longer be needed to produce electric power. It is hoped that these lands could then pass into public ownership, rather than be sold to the highest bidder. Some four miles of river near McKinley Bridge are being considered for wild river designation by the federal government. Under these provisions, a 400-foot wide belt either side of the river would be subject to stringent controls regarding use and development.

There is likely some contribution of nutrient matter to the river from the village of Mio. Due to the good groundwater contribution, and the low levels of chemical concentrations tested at Comins Landing, this effect is probably minimal. However, it is certain that the groundwater aquifer is being contaminated by septic systems in Mio proper, because of contaminated well water found in samples tested by the Michigan Department of Public Health. From the standpoint of river water quality, this problem should be addressed by correcting the sewage disposal methods rather than by using a different water supply.

Because Oscoda is situated at the river mouth, its effect on the river is limited. This station is periodically sampled by the WRC to detect any significant changes and to identify the cause of same.

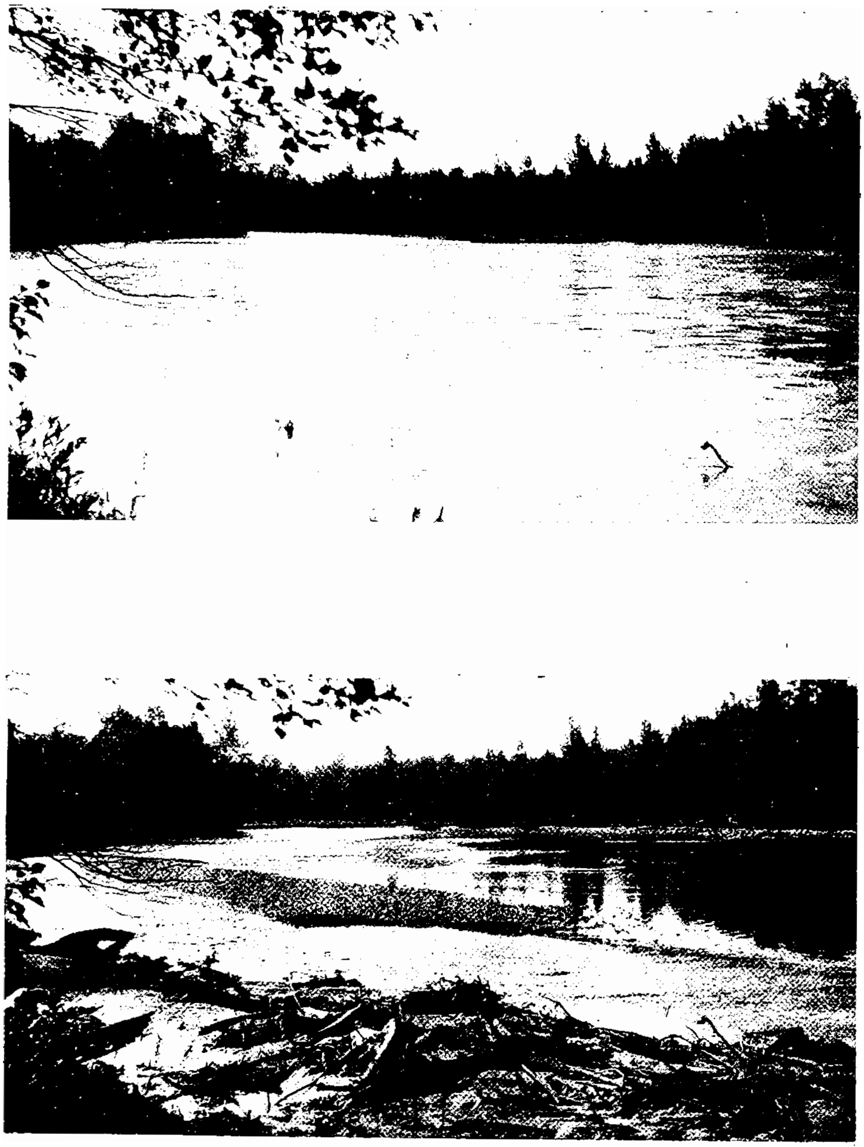


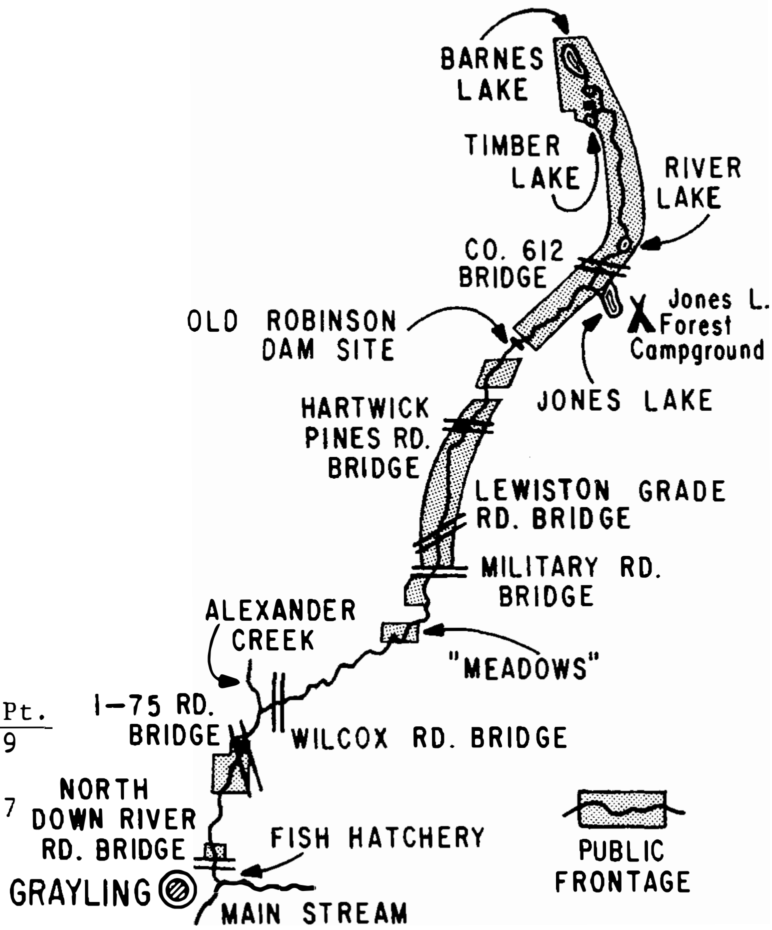
Figure 56. Upper: Mainstream of the Au Sable River below the mouth of the lower South Branch, Iosco County, looking downstream at high water level.

Lower: The same location as upper photo during low water level.

Use

Based on the 1970 Fish Division survey of licensed fishermen (mailed questionnaire--R & D Division) 50% of all fishing days on the river were spent in Alcona and Iosco counties. This figure reflects year round impoundment fishing from Alcona downstream as well as the anadromous fishery below Foote Dam. Since it is estimated that 1.6% of all resident angler days spent in Michigan were on the Au Sable, this is a significant effort. Despite the large number of angler days spent fishing these impoundments, it is the opinion of this study team that natural coldwater river systems, such as the Au Sable, should be preserved in their native state. These unique rivers are even now few in number, while lakes, reservoirs, and warm river systems are plentiful in Michigan. The lower Au Sable, after removal of these dams, could provide a coldwater anadromous fishery of excellent quality over some 73 river miles from Oscoda to Mio.

SECTION III PART B-4 EAST BRANCH



CAPSULE INFORMATION

Miles of Stream in Section

	Public	Private
East Branch	11.0	5.0
Tributaries	2.8	1.0
Total	13.8	6.0

Main Tributaries

Stream	Class	Mile Pt.
Jones Lake Outlet	warmwater	13.9
Alexander Cr.	coldwater	3.7

East Branch

Dams	Head	Pond Acres	Year Built	Mile Pt.
Robinson		--- removed ---		
Holland (off river)	2'	1	1965	7.1
Burndt		--- removed ---		
Hatchery (3)	2'	---	1915	.4

Drainage area - 76 sq. miles

Average discharge at Hatchery - 43.3 cfs

Maximum to mean discharge ratio (stability index) - 4.6:1 (at Grayling)

Increases Mainstream flow by approximately - 50 percent

Gradient feet per mile - 5.2 (est.)

Capsule Information, continued

Streamflow Measurement (February 1, 1973)

Location	Mile Point	Discharge (cfs)	Increase In cfs Per Mile	Increase In Percent Per Mile
Co. Road 612	13.3	18	---	----
Below Jones Lake	12.6	22	5.7	31.7
Robinson Dam	10.8	35	7.2	32.8
Military Road	7.5	41	1.8	5.2
Wilcox Bridge	3.7	44	0.8	1.9
Hatchery	0.4	55	3.3	7.6

Occurrence of permanent and seasonal dwellings along the riverfront, by section(s), where the density exceeds 20 units per section or linear mile:

None. Cottage development is the most dense just above North Down River Road near Grayling and just above Wilcox Bridge where a subdivision is in progress along the south banks. A private campground is operated at a trout pond below Military Road.

Habitat Features

General. The East Branch receives runoff from about 78 square miles, all in Crawford County, lying between the upper Mainstream and North Branch basins. There are six lakes in the headwaters of the East Branch totaling 105 surface acres. Because all of the lakes are on state land, there is little development. These are all natural lakes of an organic type shoreline and basin. Maximum temperatures above Co. Road 612 are normally (normal maximums) about 70°F, and are accordingly poor trout waters. Below Co. 612 and the Jones Lake outlet, 13 miles above the mouth, the stream picks up velocity and a generous supply of groundwater. The groundwater input remains good downstream to Military Road about halfway to the mouth. The rate of fall (gradient) levels off at the "meadows," where the current is slower, the groundwater input is much lower, and the temperatures rise. Spring activity above Grayling again lowers temperatures to where they are normally in the mid to upper 60's during summer months.

Bottom type. The East Branch has mostly a sand type bottom with only limited patches of gravel, but the temperature regime is very suitable for b~~rook tr~~out below Co. Road 612. Aquatic plant growth is mainly restricted to marginal areas of the stream because of the predominantly sand bottom type.

Trout cover. The cover is good, especially between Co. 612 and the meadows, consisting of undercut banks, brush, logs, and many stream improvement devices. The cover from Wilcox Bridge Road downstream is fair to good. Access to the river is limited between Military Road and North Down River Road.

Water Quality

General. Nitrate-nitrogen concentrations are higher in the East Branch than anywhere else in the system. Results from winter samples were twice as high as summer sample results (Fig. 7, page 21) because of nitrate uptake by aquatic plants during summer months. A partial series of samples were collected in April, May, and June, and a complete series was collected in September and January of 1973. These additional samples confirm that nitrates are being introduced to the system in areas where very little human activity is found. The increases of nitrates coincide well with increases in discharge from groundwater input. There is also mention in the literature of nitrate contribution to surface waters from areas where tag alders are dense (Hynes, 1970). Tag alder (*Alnus* sp.) is a common riparian along the East Branch and is a nitrogen fixer. Its shed leaves contain four times as much nitrogen as other species (Goldman, 1961). While nitrate levels were high, phosphate concentrations were lower than those found in the other tributaries. Chlorides rise abruptly in the lower part of the system in the vicinity of Wilcox Road above I-75. While the results here were not consistent, the rise in chlorides was not coincidental with nitrate increases.

Quality index (WQI). The index at Co. 612, 13.3 miles above the mouth, was 90.94. The index at Hospital Bridge, 0.2 mile above the mouth, was 91.87. The slight increase in the index at Hospital Bridge is due to cooler temperatures, though water quality throughout is obviously good. Warmer water temperatures cause a wider range in 24-hour D.O. values at Co. Road 612 (Fig. 57).

Quality reflected by biota. Insect collections show a low diversity, compared to other tributaries, due to the predominantly sand substrate. Percentage of intolerant species increases downstream in response to cooler water temperatures. Just above the hatchery, substrate is very poor (shifting sand), but water quality is good. The sample at Co. Road 612 contained just 4% intolerant insects, while at North Down River Road there were 55% intolerant insects.

Two samples taken on the East Branch in 1966 were unfortunately not repeated in 1972. However, they may help to put 1972 data in a better perspective (see Table 21).

The mean percentage of intolerant insects in the 1966 samples (Table 21) appears to be slightly greater than that of 1972 (25.43%), while the average diversity in 1966 was 1.498 compared to the overall 1972 average of 1.131.

The sand substrate is the predominating bottom type in the East Branch. A stream improvement program on the North Branch was evaluated in the 1930's, and found to have increased insect production by causing an underlying gravel type substrate to wash clear. This resulted in an increase in trout food organisms. Similar current deflecting devices placed in the lower East Branch might produce a favorable response in insect production as well.

Both fish and insect collections demonstrate a high percentage of intolerant forms, but low diversity at the hatchery just above North Down River Road. Seined fish collections demonstrate that habitat at Co. Road 612 is strictly warmwater, as it was in 1924. Another collection at Lewiston Grade Road indicated a reduction in percentage of coldwater fish species present. An inspection of the habitat seined, reveals many stream improvement structures that were not present in 1924. It was judged to be nearly impossible to collect trout effectively from these structures. Therefore, an electrofishing survey was conducted producing

Table 21. Data for additional East Branch stations sampled in June 1966 by the Michigan Water Resources Commission

Site	Diversity	Intolerant insects (%)	Facultative insects (%)
Wilcox Bridge	2.005	43.3	56.7
200 feet upstream from mouth (East Branch)	0.901	20.83	79.17

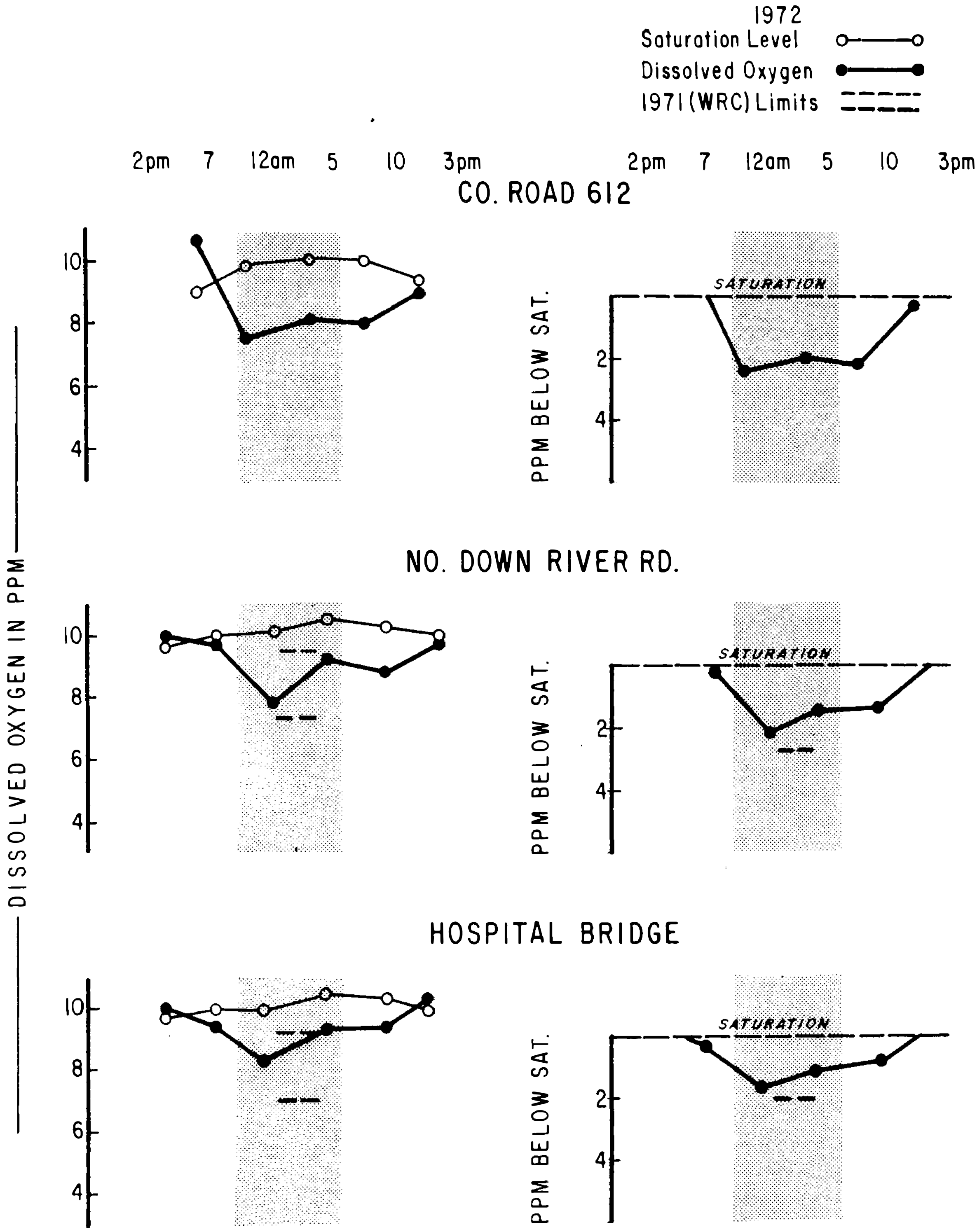


Figure 57. Dissolved oxygen concentrations observed for three East Branch stations 13, .4 and .2 miles above the confluence with the Mainstream on August 3 and 4, 1972.

8 brook trout and 6 browns. In 1926, 16 brook trout were captured by seine. This shift toward brown trout has been repeated in other tributaries and is apparently still continuing (see trout population estimates). Except for the occurrence of rare species, the collections indicated that little change in quality has occurred at this station. The final station sampled was above the hatchery. The percentage of coldwater species has increased here, though the change is effected by a decrease in intermediate species types. As mentioned above, fish and insect communities respond in the same manner. While trout cover and temperature ranges are good, bedload sediment movement is heavy due at least in part to the I-75 crossing (construction) two miles upstream. This part of the stream can be observed to be extremely turbid during storms, due to silt input at the meadows.[27] Electrofishing collections (13 in all) indicate very good quality trout waters (chiefly brook trout) below Co. 612. Collections in the meadows area produced fair trout numbers, while above Co. 612 waters are marginal for trout at best. The one tributary (Alexander Creek) has little velocity, silt and muck bottom at the upper end, and no trout; while the lower end has good gravel and a good brook trout population.

Human Impact

In addition to the increase of housing units along the river, there was a major habitat impact from the I-75 bridge crossing. Several fishermen who frequented this area in the early 60's attested to the fact that heavy inputs of sand from this project filled many holes between I-75 and North Down River Road. Former Fish Hatchery Superintendent Barnie Engel reported heavy siltation at the hatchery ponds at the time of the I-75 expressway East Branch crossing.[28] Much silt is introduced to the stream from the meadows area.

Problems. East Branch frontage above Military Road is nearly all state land, while below that point it is mostly private. Cottage development is still sparse above "the meadows," but is increasing downstream. There is a new subdivision just above Wilcox Bridge Road, a trailer park near the meadows, and another development along the stream above North Down River Road. In this last mile near Grayling, the dwelling density reaches 20 to the mile. Many of these dwellings along the margin of the stream are in low-lying areas where seepage from septic systems is a likely prospect.

Outlook. Because of the excellent groundwater contribution, and because the upper watershed is in public ownership with good cover maintained on the upland, the stream should remain excellent quality brook

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27 Bohland, Richard. 1954. Letter to O. H. Clark, Fish Division, in regard to float trip to determine source of silt and sand input in the East Branch.

28 Engel, Barnie. Grayling Hatchery Superintendent, 1960. Letter to Max Hunt, Regional Fish Chief, Roscommon.

trout water. An engineering firm has been consulted (Rich Svendory of Traverse City) for recommendations to solve sewer needs for the housing area between I-75 and Grayling along the lower East Branch. The firm has recommended that this area tie into the Grayling system (lagoon) at an estimated cost of one million dollars.[29]

Use

Nearly all of the recreational use of the East Branch is trout fishing, although (as in many areas of the Mainstream) homesteading and cottage living are also becoming major uses.

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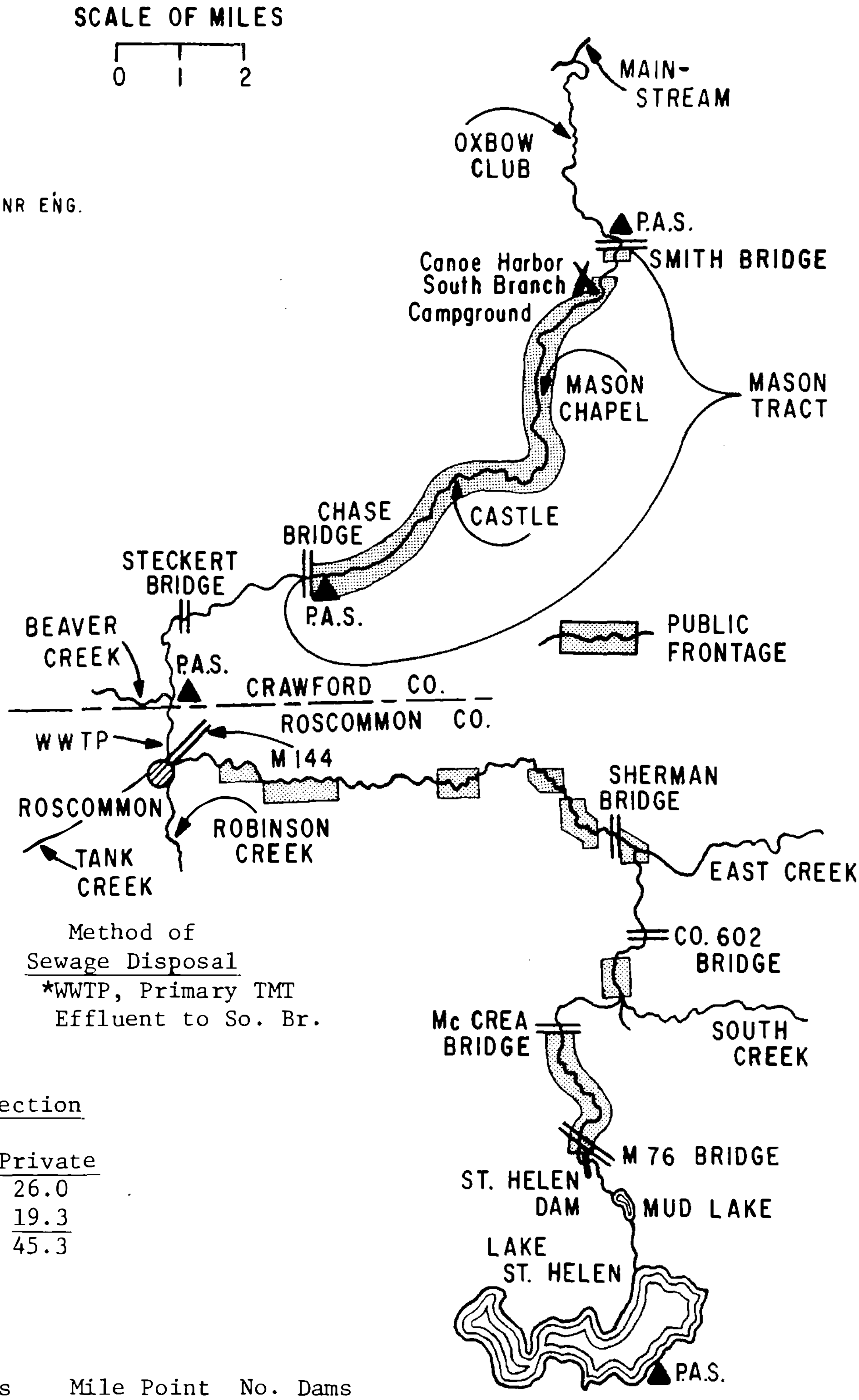
[29] Byelich, G. H. Au Sable River Watershed Project coordinator. N.E. Regional Plan. & Develop. Comm. 1973. (personal communication)

SECTION III PART B-5 SOUTH BRANCH



CARTOGRAPHIC SERVICES/DNR ENG.

CAPSULE INFORMATION

Villages	Population	Method of Sewage Disposal
Roscommon	810	*WWTP, Primary TMT Effluent to So. Br.

Miles of Stream in Section

	Public	Private
So. Br.	22.3	26.0
Tributaries	50.3	19.3
Total	72.6	45.3

Main Tributaries

Stream	Class	Mile Point	No. Dams
South Cr.	coldwater	34.5	0
East Cr.	coldwater	31.5	0
Robinson Cr.	coldwater	19.7	0
Tank Cr.	coldwater	19.1	1
Beaver Cr.	coldwater	17.9	1

* Off river disposal facility due for completion before 1974.

Capsule Information, continued

South Branch Dams	Head	Pond Acres	Year Built	Mile Point
Lake St. Helen	Lake Level	2,400	1930	39.2

Drainage area - 401 sq. miles

Average discharge at Smith Bridge - 229 cfs (estimated to be 252 cfs at river mouth)

Maximum to mean discharge ratio (stability index) - 4.1:1 (at Smith Bridge)

Increases Mainstream flow by approximately - 60 percent

Gradient feet per mile - 4.4 (Roscommon to mouth)

Streamflow Measurement (August 15, 1972)

Location	Mile Point	Discharge (cfs)	Increase In cfs Per Mile	Increase In Percent Per Mile
Chase Bridge	14.3	91	--	--
Smith Bridge	4.6	136	4.6	5.1
Oxbow	1.9	178	15.6	11.4
Mouth	0	133	-23.7	-13.3

Occurrence of permanent and seasonal dwellings along the riverfront, by section(s), where the density exceeds 20 units per section or linear mile:

T 23N, R 1W Section 8 (near Lake St. Helen Dam)
T 24N, R 2W Section 5, 6, and
T 25N, R 2W Sections 31, 30, 29, 28 (at Roscommon and downstream to Chase Bridge)
Cottage development below Smith Bridge is increasing, and is presently in 10-15 range per section.

HEADWATERS TO ROSCOMMON

Habitat Features

General. The South Branch has its beginning at Lake St. Helen located in the east central part of Roscommon County. Lake St. Helen is a 2,400-acre natural lake, consisting of mostly mineral soils, and a warmwater fishery. Just downstream from the St. Helen outlet (3/4 mile) is Mud Lake, having a mostly organic basin and shoreline type, 95 acres, and a strictly warmwater fishery. There is a lake level dam 3/4 mile further downstream and 1 mile above M-76. This total lake area of 2,500 surface acres exposed to solar radiation has a very pronounced effect on plant and animal populations of the upper South Branch. Summer temperatures are often in the 80's all the way to the village of Roscommon (Fig. 58). Upon leaving the lakes, the stream winds slowly through open marshes and cedar swamps, where the surrounding drainage lands are quite flat and organic in nature. Below Sherman Bridge the stream is very winding, clogged with log jams, flows through adjacent swamps, has many dead elms along its banks, and one area cleared for a power line crossing.

Several tributaries enter the South Branch above Roscommon, including South Creek, East Creek, Asum Creek, and Robinson Creek. South Creek, the furthest upstream (15.5 miles above Roscommon), contains marginal brook trout waters. It has a mostly gravel substrate and good bank cover (cedar, alder swamp), but only a moderate current velocity and temperatures in the low to mid 70's. Another tributary with no name joins South Creek just above the mouth. This feeder is cooler than South Creek having temperatures in the 60's, a gravel bottom and some brook trout present.

East Creek enters the South Branch just above Sherman Bridge (about 12 miles above Roscommon). This creek has a predominantly sand substrate and warmwater temperatures (mid 70's).

Asum Creek enters the South Branch about 1 mile below Sherman Bridge. The creek is a little over a mile in length and is spring fed with temperatures in the 60's. The bottom is alternating sand and silt with some gravel evident. However, it is less than 3 feet wide, only a few inches deep, and has a low current velocity.

Robinson Creek joins the Mainstream on the east end of Roscommon. It has moderate to warm summer temperatures and some trout in the lower part. The headwaters of this creek contain a wildlife flooding and Robinson Lake. Both are very marshy and shallow, and supply Robinson Creek with water that is in excess of 70°F during summer months.

Bottom type. There are some gravel patches above Roscommon, but the predominant bottom type is sand with silt and muck in the slack areas and bayous. There is heavy rooted aquatic plant growth in these silt beds along the stream margin and in the oxbows, and much algae in evidence.

Trout cover. The vegetative bank cover is dense in places, especially along the smaller tributaries. There are many open areas that

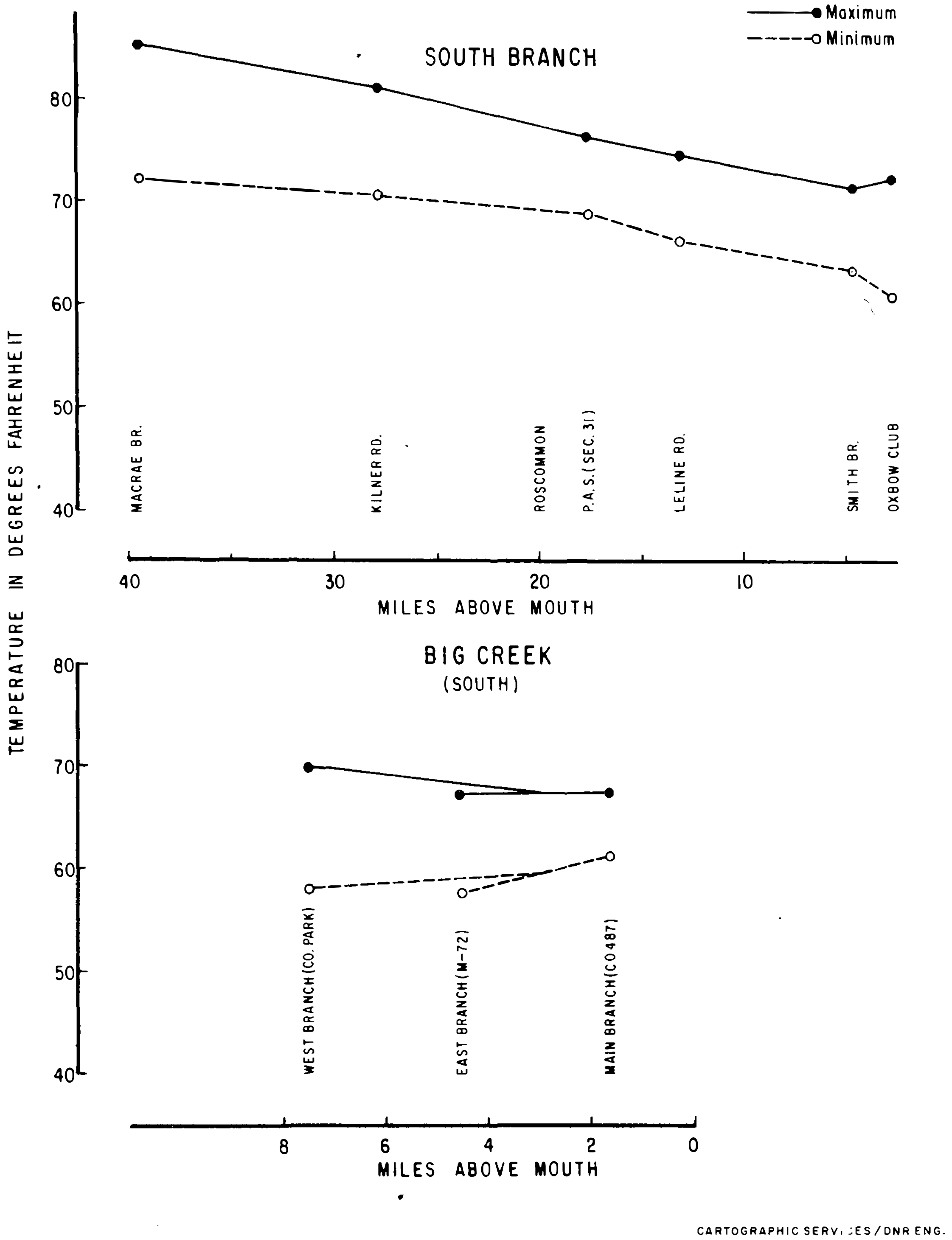


Figure 58. Maximum-minimum water temperature readings recorded in July, 1972.

expose the stream to constant solar radiation. Below Sherman Bridge, the river meanders aimlessly toward Roscommon, is characterized by many oxbows and log jams.

Water Quality

The chloride levels are of particular interest in the upper part of this stream. Although they are quite low compared to standards set for coldwater streams, they are conspicuously high compared to normal levels found in the Au Sable basin. Grab samples taken in the headwater reaches, indicate that concentrations are already high, and that this condition is characteristic of the drainage area. Another sample taken in an open swampy area was even higher, lending support to this theory. One other theory can be advanced in this regard, the possibility that there may be a leakage from pipe lines carrying salt water in the St. Helen oil field. There are over 50 active oil wells in this part of the drainage basin, and there is at least a possibility of contamination from this source.

There is a test well near Sherman Bridge, below the oil wells in the direction of groundwater flow. Samples taken in 1964, 1965, and 1966 averaged 3 ppm in chloride concentration. At that time, fresh water was injected deep into the field to rebuild pressure. This produced a dramatic increase in the number of barrels of oil produced. In 1967, the chloride concentration in the Sherman Bridge test well jumped to 22 ppm. Mr. Verco F. Sargent, State Geology-regulatory Control Supervisor, does not feel the fresh water injection would result directly in salt water seepage to groundwater.[30] A report submitted in May, 1973, by Mr. Benjamin Gunning, State Field Geologist, Mt. Pleasant, accounts for two leaks from flow lines during the past four years that required clean-up work along the South Branch.[31] The most recent losses of oil and brine escaped from a flow line near McCrae Bridge on April 6, 1972. This location corresponds well with increases in chloride levels from supplemental surface water samples in the upper South Branch. A surface swamp water sample taken at the center of the South line of section 20 (T-24N, R-1W), which is close to an abandoned tank battery, registered 13 ppm chloride, indicating possible leakage. The Sun Oil Co. has since replaced a number of lines to eliminate river crossings.

While the levels of chlorides found in surface waters (8-16 ppm) are not likely to cause problems with aquatic life, these test wells need to be continuously monitored to detect changes in chloride concentrations that may indicate problems with flowlines or storage areas.

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30 Sargent, Verco F. State of Michigan Geol. Survey, Regulatory Control Supervisor. Personal communication.

31 Gunning, Benjamin. State of Michigan Geol. Survey, Field Geologist at Mt. Pleasant. Answer to a directive from Mr. Sargent in regard to an inquiry based on data (chloride concentration) from Au Sable water samples.

Other constituents that were tested for in supplemental samples were in ranges that are normal for unpolluted systems.

Quality reflected by biota. No trout were captured in electrofishing surveys above Roscommon, except in tributary streams (East Creek). Water temperatures are normally in the 80's F in this stream segment during warm summer months.

Human Impact

Problems. There is very little development along this part of the river. The warmwater character and slow velocity of the stream make it much less desirable for cabin building. This part of the stream passes directly through the St. Helen oil field. There have been over 90 wells drilled, and 55 are still active today. Leaks in flow lines have resulted in oil and brine reaching the river on a few occasions. The Sun Oil Co. has since made improvements to prevent recurrence of this problem.

Outlook. The South Branch habitat upstream from Roscommon has always been strictly of a warmwater type. There are several eroding banks from Co. Road 602 downstream, the largest having about 600 square feet exposed.

Use

There is very little recreational use of this part of the South Branch below Lake St. Helen. Some canoeing is done, but the slow current velocities, winding nature of the stream and many log jams tend to detract from the experience. There is a fair amount of trout fishing in lower parts of Robinson Creek, near Roscommon, and some fishing in the tributaries above Sherman Bridge.

ROSCOMMON TO MAINSTREAM

Habitat Features

General. The South Branch from Roscommon to Chase Bridge (beginning of Mason Tract) is transitional between a warmwater stream and a very good coldwater trout stream. The river receives a coldwater feeder (Beaver Creek) just below Roscommon, and good groundwater contribution in the vicinity of Steckert Bridge. The Mason Tract (a 10-mile-long section of river frontage, donated to the state by the late George Mason in 1957), consists of excellent trout habitat, having the desired pool to riffle ratio indicative of good trout waters (see glossary). There are few roads leading to the river in this area, and some that did, have been blocked off by DNR crews. The Mason Tract having been dedicated as a natural area, will be preserved in its wilderness state.

At Chase Bridge (14.3 miles above the mouth) the stream has received approximately 55% of its flow. In the Mason Tract, the South Branch picks up 30% of its flow in a little over 20% of its length. Five short tributaries enter the stream in the Mason Tract, all coldwater types, and the remaining flow is provided by groundwater.

Tank Creek at Roscommon receives much of the surface runoff from the village, and is often observed in a very turbid state. The South Branch, below the confluence of Tank Creek, has (at these times) a chalky white to brownish gray appearance all the way to Beaver Creek about a mile and a half downstream (Willson, 1968). This problem has been observed and reported several times since, but the source of the input has never been located. Beaver Creek is a clear, coldwater feeder stream, 6 miles long, joining the Mainstream from the west a mile above Steckert Bridge.

The upper portion of the last 4.6 miles from Smith Bridge (below Mason Tract) to the mouth, increases steadily in flow (12 cfs/mile) indicating excellent groundwater contribution. However, in the last 1 1/2 miles, the stream takes on the character of the "stillwater" on the Mainstream into which it flows. It is winding, with slow velocity, and according to discharge measurements, actually loses flow from infiltration to groundwater and evaporation. This same phenomenon apparently also occurs in the Mainstream "stillwaters."

Bottom type. From Robinson Creek to a point just above Steckert Bridge the bottom is nearly all sand. Gravel patches begin to appear about 1 mile below Beaver Creek. Growth of rooted aquatic plants and algae is greatly accelerated by the Roscommon WWTP, and these effects are prominent and extend downstream some 5 river miles to Deerheart Valley (Willson, 1968). From Steckert Bridge downstream to a point below the Oxbow Club, good gravel riffle areas are frequent in occurrence. The upper Mason Tract, from Chase Bridge to Douglas Creek is dominated by a good gravel riffle type. The stream is rather slow from this point to the Mason Chapel where the gradient again increases. Heavy algae growth extend over 3 miles into the Mason Tract, but is greatly reduced from the "Castle" downstream (see map preceding this segment).

Trout cover. Cover is excellent from beginning of Mason Tract to the Oxbow Club over 12 miles downstream, consisting of many pools, log jams, and good bank cover.

Water Quality

General. Nutrient concentrations noticeably increase below the WWTP at Roscommon. The increase in phosphate is particularly noteworthy, as levels remain high all the way to the Mainstream. Nitrate levels fall off downstream in summer months, but remain higher than levels found in the North Branch. While phosphate levels are nearly identical to those found in the North Branch, comparing upstream areas, levels near the mouth are half again as high in the South Branch as in the North Branch. Phosphate levels now found in the lower South Branch, are comparable to levels found below Grayling before the treatment plant shutdown in late 1971. Chloride levels have diminished somewhat from values above Roscommon, but concentrations are still higher than those in the receiving waters of the Mainstream above the South Branch confluence, and in the other tributaries. The alkalinity readings are consistently lower than those from other Au Sable sampling stations because of outflow from swampy lowlands. Conductance is also lower, as would be expected.

Quality index (WQI). The effect of the WWTP below M-144 is reflected in the WQI, as is the recovery of water quality downstream from Roscommon (see index figures below). A 24-hour D.O. survey conducted by the WRC in 1966, showed a 1.9 ppm fluctuation in D.O. values at M-144 just above Roscommon. The station below the WWTP produced a fluctuation of 5 ppm, Chase Bridge 6.5 ppm, and Smith Bridge 4.6 miles above the mouth, 2.4 ppm. The indexes correlate very well with these D.O. values as would be expected (Fig. 59).

Station	Miles above mouth	WQI
M-144	19.5	90.18
Steckert Bridge	16.7	84.95
Chase Bridge	14.3	89.01
Smith Bridge	4.6	92.73

Quality reflected by biota. Insect collections taken in relation to the sewage treatment plant by the WRC in 1966 and the Au Sable Study investigators in 1972, show that diversity is depressed as far downstream as Chase Bridge, while percentages of intolerant forms are at least locally high at Steckert Bridge (Fig. 60). If, upon first inspection, these results are somewhat confusing, it should be explained that the sampled substrate was very good at Steckert Bridge. This shallow riffle area allows aeration to occur which would favor intolerant forms. As stated earlier, insect communities seem to recover more rapidly in downstream distance from pollutional inputs, than do fish communities. Results from the two years are not directly comparable because of seasonal differences.

Seined fish collections produced no coldwater species in the upper South Branch either in 1924 or in 1972. However, numbers of warmwater species have noticeably increased.

In the Mason Tract, the percentage of coldwater fish species has gone up since the 20's presumably because upland cover has been well restored. Conditions for insects look better at Smith's Bridge than at Chase Bridge because of the latter station's proximity to the sewage treatment plant.

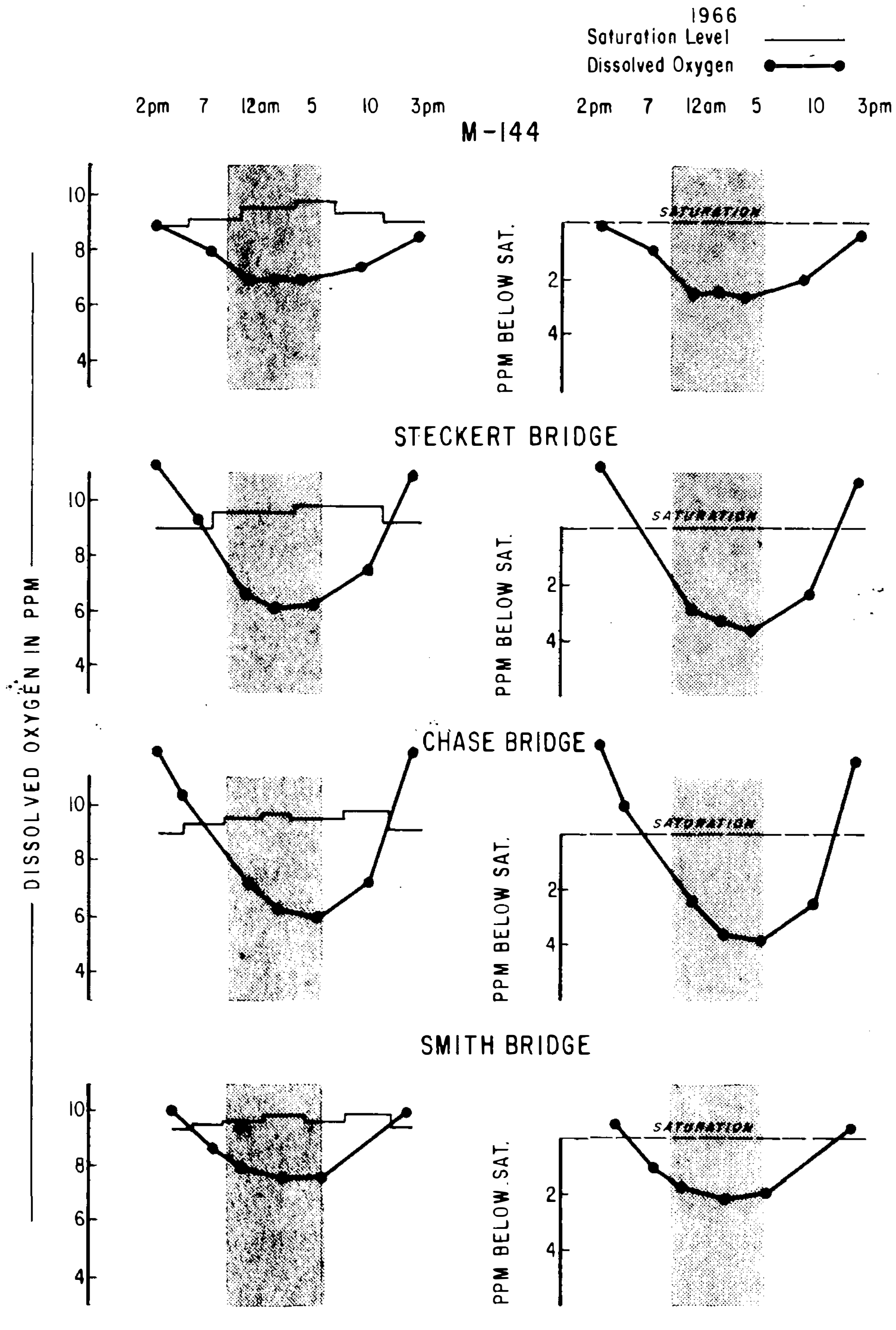


Figure 59. Dissolved oxygen concentrations observed by the Michigan Water Resources Commission on August 17, 18, and 19, 1966.

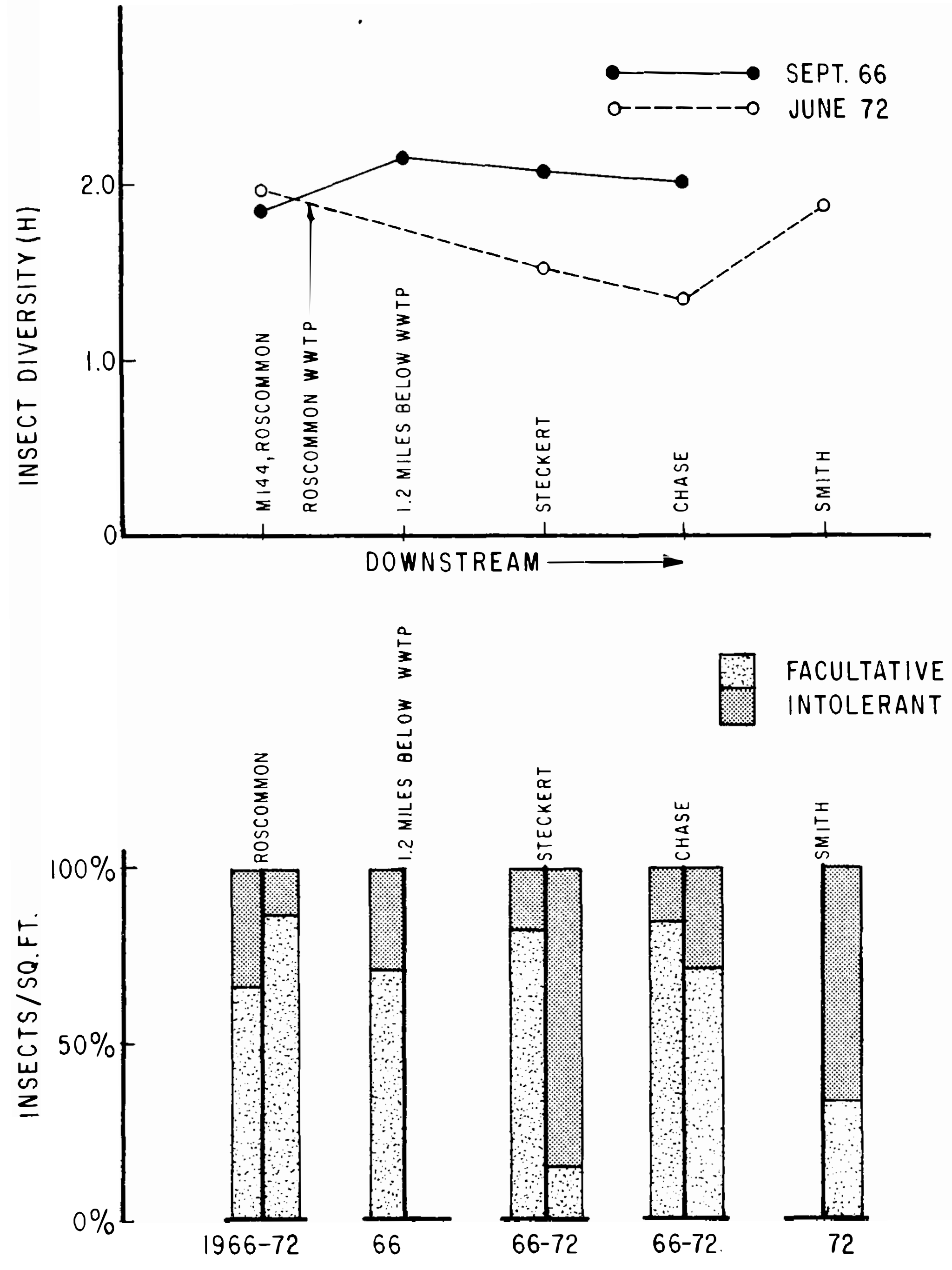


Figure 60. Comparison of the percentages of intolerant and facultative insects in bottom samples, collected in 1966 (WRC) and in 1972 on the South Branch from Roscommon downstream.

Electrofishing collections during the past 10 years (15 in all) show good quality trout waters in the Mason Tract, and no trout in collections above Roscommon, except in the smaller tributaries.

Periphyton samples taken above Smith's Bridge at the lower end of the Mason Tract, show high levels of primary productivity because of high nutrient levels (particularly phosphates). Input of nutrients at Roscommon (mostly the WWTP) results in an increase in plant growth of over 12 times from above to below the town (Willson, 1968).

Trout population estimates (three) in the Mason Tract in 1972 showed an overall increase of 25% in brown trout, and a 39% increase in brook trout. Of all size groups in species, only brook trout over 7 inches are reduced in numbers from the baseline years of the early 60's. This lends further support to the position that brook trout are extremely vulnerable to angling pressure, and are in need of extended protection in the form of a higher size limit.

Human Impact

Evidence of human use can be found at access sites where erosion problems occur. There is also rather heavy cottage development along the river from Roscommon to Chase Bridge. Below the Mason Tract cottages are also increasing, although they could not now be considered dense. The overwhelming impact is from the WWTP at Roscommon, which has an adverse effect on the biology of the stream that extends into the Mason Tract. The surface runoff at Roscommon also has an effect on the ecology of the South Branch (Table II, appendix), and is certainly worthy of study to consider methods that would improve the quality of this input (street cleaning, treatment).

Problems. The discharge from the Roscommon sewage treatment plant has a very pronounced effect on habitat quality below town. The ready availability of nutrients results in extensive plant production. The effects of this excessive growth of vegetation as noted by Willson (1968) are as follows:

A smothering of bottom types, altering habitat for fish and fish food organisms.

Entrapment of silt.

Nocturnal depression of D.O.

Creation of nutrient bank, causing problems downstream when released.

Destruction of aesthetic values of stream.

Heavy vegetation also slows current velocity and retards physical aeration of the stream. There are some major erosion problems below Roscommon, in addition to the bridge crossing and access sites that are in need of stabilization. There are some six eroding banks between Roscommon and Smith's

Bridge having about 2,560 square feet exposed. Two sites, just below Beaver Creek and at Canoe Harbor campground, are especially noteworthy.

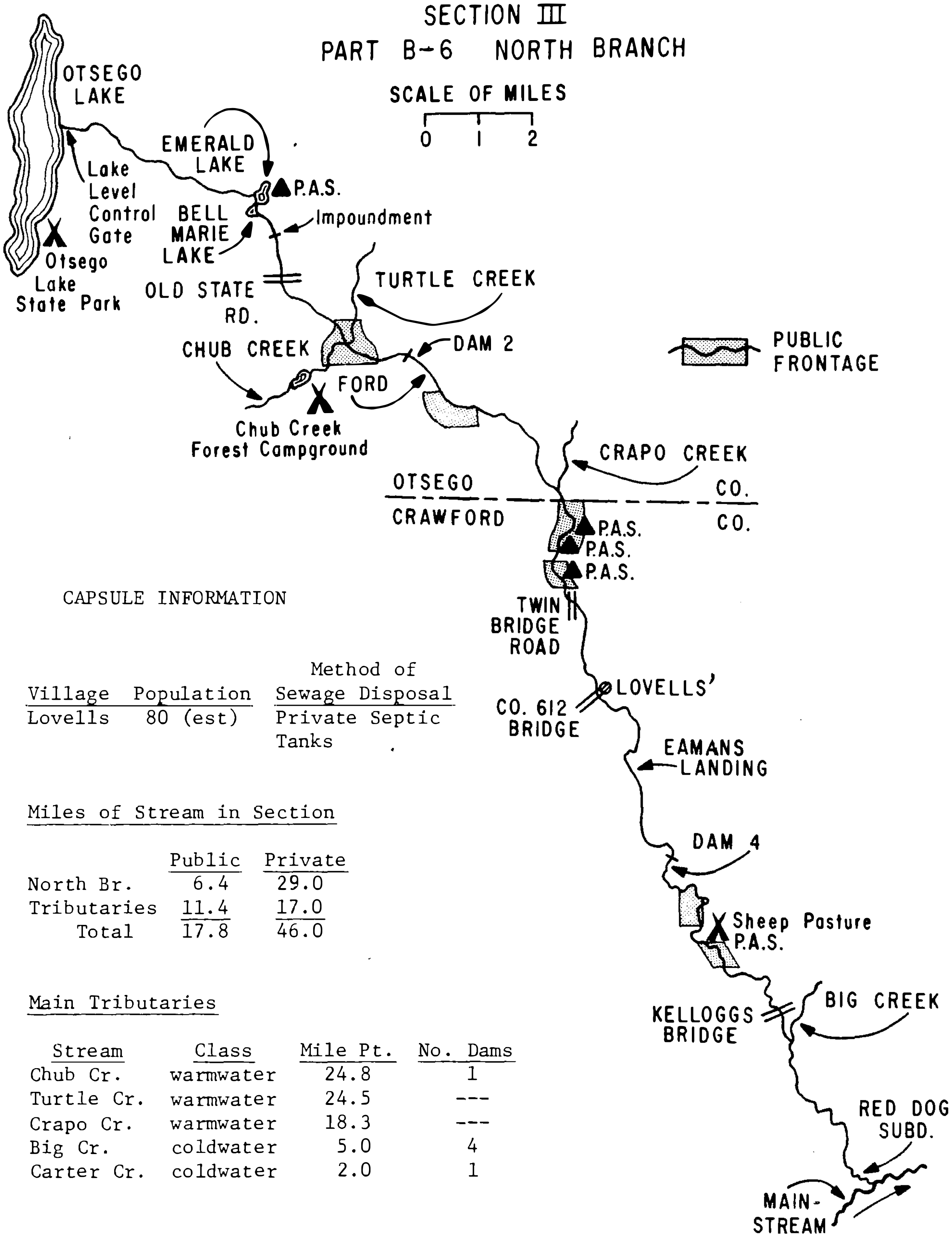
Outlook. The most outstanding adverse condition affecting the trout waters of the South Branch is the Roscommon WWTP. The community is presently converting to a lagoon and spray irrigation system off river, that will replace a facility that now effects only primary treatment.

The new disposal area is about two miles east of town and consists of oxidation lagoons, a large holding pond, diffused irrigation to seepage beds, and intercepting ditches to underdrainage. Because of the underdrainage the treated effluent must meet high standards that includes a limit of 4 ppm of B.O.D., and 6 ppm suspended solids. There will be a total of 14 test wells to monitor the groundwater at strategic locations. This new sewage treatment system should allow a high degree of recovery of water quality in the South Branch below Roscommon, thereby appreciably improving conditions for trout.

Use

Canoeing represents a higher percentage of the recreational use on the South Branch (44%) than on the Mainstream (32%) (Shetter and Alexander, 1967). There is definitely a problem of conflicting use in the Mason Tract area between canoeists and fishermen. During the hatches in May and June, there is even conflict between fishermen in this same area. In coming years, there could be a permit system in effect here to control numbers of all users on the river at any given time. Such regulation may be unavoidable in order to preserve the identity of this area in the spirit that it was dedicated.

SECTION III
PART B-6 NORTH BRANCH



CAPSULE INFORMATION

Village	Population	Method of Sewage Disposal
Lovells	80 (est)	Private Septic Tanks

Miles of Stream in Section

	Public	Private
North Br.	6.4	29.0
Tributaries	11.4	17.0
Total	17.8	46.0

Main Tributaries

Stream	Class	Mile Pt.	No. Dams
Chub Cr.	warmwater	24.8	1
Turtle Cr.	warmwater	24.5	---
Crapo Cr.	warmwater	18.3	---
Big Cr.	coldwater	5.0	4
Carter Cr.	coldwater	2.0	1

North Branch

Dams	Head	Pond Acres	Year Built	Mile Pt.
Otsego Lk.	Lake Level	1.972	1972	26.9
Private Dam	3'	1	--	26.6
Dam 2	3.5'	<3	1870	23.3

Capsule Information, continued

Drainage area - 443 sq. miles (including Big Creek)

Average discharge at mouth of stream (est.) - 344 cfs

Increases Mainstream flow by approximately - 50 percent

Gradient feet per mile - 8.7 (Dam 2 to mouth)

Streamflow Measurement June 11, 1971 (USGS)

Location	Mile Point	Discharge (cfs)	Increase In cfs Per Mile	Increase In Percent Per Mile
Old State Rd.	34.2	16	---	---
The Ford	28.1	78.7	1.9	2.9
Blackhole	21.3	125	5.2	5.9
Lovells Co. 612	16.0	161	6.8	5.4
Kelloggs Br.	4.1	204	3.6	2.2

Occurrence of permanent and seasonal dwellings along the riverfront, by section(s), where the density exceeds 20 units per section or linear mile:

T 28N, R 1W Section 19 (near Lovells)
T 27N, R 1W Sections 27, 26, 35, 36, 1, 2 (from Kelloggs Bridge to the river mouth)

HEADWATERS TO LOVELLS

Habitat Features

General. Three tributaries form the Mainstream in Otsego County just above Dam 2. The middle branch is now periodically receiving drainage from Otsego Lake, which has increased the flow at State Road (6.7 miles downstream) by about 15 cfs, during the initial effort to lower the lake level. The drawdown of Otsego Lake is being effected by the Corps of Engineers under the direction of the DNR to alleviate high water levels that are causing the contamination of groundwater supplies. Concerning the other two tributaries, Chub Creek provides about 2/3, and Turtle Creek 1/10 of the flow at Dam 2.

Three lakes and two silt laden impoundments on the middle branch (including Otsego Lake) expose over 2,000 surface acres to solar radiation. The Chub Creek system contains ten lakes having 265 surface acres, and Turtle Creek emanates at Turtle Lake having 164 surface acres. The Turtle Creek system appears to be more of a marsh than a stream over most of its length. This exposed surface water results in temperatures in the 80's during summer months, and is therefore warmwater habitat (Fig. 61).

Below Dam 2, groundwater contribution increases and habitat improves considerably. Where the stream enters Crawford County, there are fair to good quality trout waters, which improve to excellent quality trout waters below Twin Bridges. Crapo Creek enters the North Branch four miles below Dam 2 flowing through aspen and birch forest types, having an average discharge of about 12 cfs, and summer temperatures that reach 80°F on occasion.

Bottom type. There is mostly a silt bottom above the Chas. Brink Road changing to gravel with sand overlay in Opal Lake area. Gravel stretches exist above Old State Road, with mostly a sand bottom below this point. Chub Creek has a mostly sand bottom, while Turtle Creek is sand and muck with heavy aquatic plant cover including lily pads. A gravel bottom type predominates below Dam 2.

Trout cover. Cover for trout is fair in the vicinity of Old State Road and downstream in the middle branch. Cover for trout in the other tributaries is poor. Below Dam 2 the stream is wide and shallow, with few pools and little cover except for brush along the bank and some log cover devices.

Water Quality

General. No water samples were taken upstream from Lovells, in Crawford County. Temperatures are often in the low to mid 70's above Lovells, and are in the 80's in most tributaries near the headwaters.

Quality reflected by biota. The Dam 1 Fish Collection Station in Otsego County shows a slight drop in the percentage of coldwater species

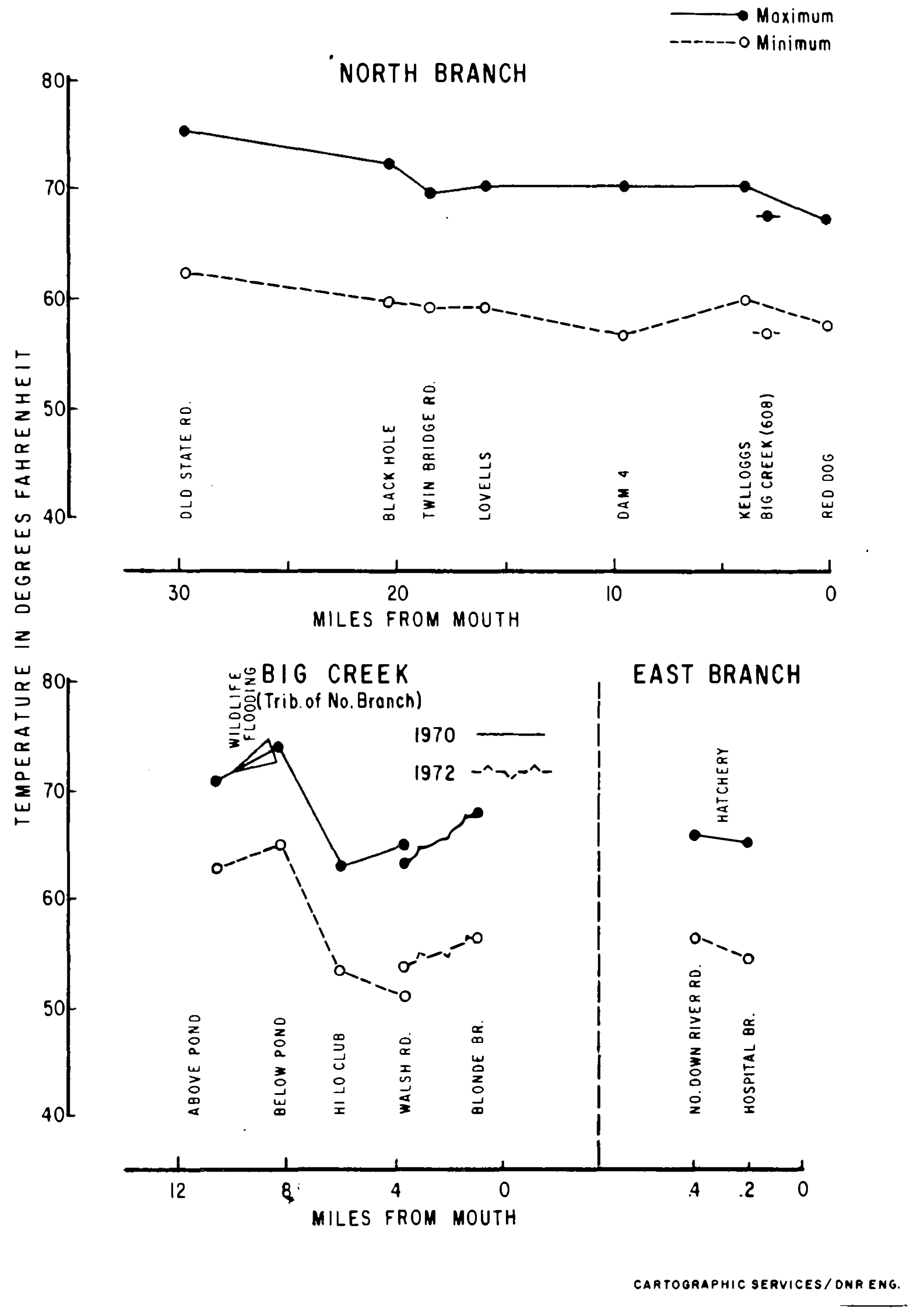


Figure 61. Maximum-minimum water temperatures recorded during July, 1972, when air temperature readings were often in the 80's°F.

present since the 1920's which could be a result of impounded waters upstream. Electrofishing collections (eight on the North Branch) show marginal trout waters below Dam 2, and fair-to-good trout waters from Otsego County line to Twin Bridges.

Trout population estimates conducted in the early 1960's produced good numbers of trout below Dam 2 downstream to the county line. However, the presence of other species in the electrofishing surveys indicates considerable competition for trout.

Human Impact

Problems. The upper North Branch (above Dam 2) is almost completely warmwater in character. There is a severe erosion problem on Range Line Road in section 6, resulting from construction at the road crossing. The immediate downstream area is almost entirely covered with sand. Other road crossings have only minor problems in this regard. At Dam 2 the structure still maintains a 3- to 4-foot head of water. This impounded water only serves to extend the effect of this warmwater area further downstream. Beaver dams in the middle branch above the Chub Creek confluence may also have an effect on the temperature regime.

Outlook. Removal of the above-mentioned dam should help downstream trout waters. A water temperature and 24-hour dissolved oxygen survey should be conducted in reference to the impoundment between Range Line Road and Old State Road, on the middle branch, to determine the impact on stream ecology. Additional trout structures downstream to the county line would provide more cover for larger trout.

Most of the old dams have been removed, although Dam 2 in Otsego County still impounds water. The habitat below Dam 2, toward the Crawford County line four miles downstream, is marginal trout water mainly because of the high normal maximum summer temperatures. It is probable that the water warmed behind this dam extends the recovery zone further downstream, and it therefore should be removed.

The drawdown of Otsego Lake through the main channel of the upper North Branch is presently under way. The situation is being closely monitored by DNR District Fisheries Biologist Stephen C. Swan at Gaylord. The task is being accomplished, with all necessary precautions observed, at a rate not to exceed 15 cubic feet per second. To date there have been no complications reported.

Use

There are few cottages along the upper North Branch until Twin Bridges in Crawford County. There is considerable fishing activity, and much interest in habitat changes that could improve the temperature ranges below Dam 2 for trout.

LOVELLS TO MAINSTREAM

Habitat Features

General. The North Branch from Lovells downstream is excellent trout water, although natural cover is rather poor in some areas. The river bed is wide and shallow over most of its length, and the channel is braided in places. The North Branch gradient averages 8.5 feet per mile in the lower part. By comparison, the steepest gradient in the upper Mainstream is 4.4 feet per mile from Stephans to Wakeley. The temperature regime from Lovells to Kelloggs has normal maximum temperatures that border on 70°F. Below Kelloggs Bridge, groundwater increases and maximum temperatures drop down in the 60's F (Fig. 61, page 170).

There is only one tributary of significant size. This is the Big Creek system that joins the stream about three miles above the confluence with the Mainstream. In lower Big Creek water temperatures are normally in the 60's F, providing cooling water to the North Branch.

Bottom type. The bottom type is predominantly of a gravel riffle type, with pools increasing in occurrence toward the river mouth. The area from just above Highbank Lodge (south line section 32) to the public access site (south line section 9) also contains a good number of pools. Clay banks begin to appear below Dam 4.

Trout cover. Cover for trout was judged to be fair in the Lovells and Eaman's Landing area, and conditions remain good on downstream to a point to just above Kelloggs Bridge. The Kelloggs area provides only fair cover for trout, and has slack zones along the stream margin that encourage intermediate species. Below Kelloggs to the mouth of the North Branch, cover is good and there are several improvement structures in evidence. There are many stream improvement structures (both bank and mid-stream) in the Eaman's to access site in section 9.

Water Quality

Nitrate concentrations are lower here than anywhere else in the system, while phosphates are about the same as elsewhere. Temperatures in the river below Lovells, are quite suitable for coldwater species. Because of the abundant supply of shallow riffle areas, dissolved oxygen is always near saturation even in areas of heavy aquatic plant activity. Chlorides are at low concentrations, especially downstream where levels are diluted by groundwater input.

Quality index (WQI). The WQI at Lovells, 16 miles above the river mouth was 89.01, and at Red Dog, 0.2 mile above the river mouth was 89.73.

Essentially the same conditions are present at Lovells and Red Dog, although Red Dog has cooler temperatures and a slightly higher fecal coliform count. Because these coliforms are of fecal origin, there may be septic seepage somewhere along the lower North Branch. However, this contamination could also be of animal origin. In any case, coliform counts are well within the acceptable limits. The widest 24-hour D.O. fluctuation (2.6 ppm) occurred at Kelloggs Bridge where the current velocity is slower due to slack areas along the stream margin and aquatic vegetation beds are more dense (Fig. 62).

Quality reflected by biota. Insect collections reflect excellent water quality as well as excellent substrate type. Diversity of species is good and the percentage of intolerant individuals present comprised 57% of the Lovells sample and 65% of the sample taken at Red Dog just above the confluence with the Mainstream. The insect data and water samples indicate that the North Branch has the best combined water and substrate conditions for the support of intolerant insect species of any stream segment in the watershed.

As noted in Section III, Part A, one of the earliest examples of the positive effects of stream improvement on bottom-dwelling communities, occurred on the North Branch. Mr. C. M. Tarzwell (1936) conducted a study during the early thirties to determine the extent and nature of changes imposed by these structures. He (Tarzwell) discovered a three- to nine-fold increase in the volume of benthic organisms per unit area. The increase was credited to the clearing of gravel substrate by deflectors, and to the silt beds that formed.

Electrofishing collections (eight on the North Branch) show marginal trout waters below Dam 2, fair trout waters from Otsego County line to Twin Bridges, and good to excellent trout waters dominating from Lovells to the Mainstream. In the vicinity of Kelloggs Bridge, conditions for trout are only fair because of silt and sand deposition and lack of cover.

Seined fish collections reveal that improvement has taken place since the 1920's from Dam 4 downstream to the campground in section 9 (Fig. 63).

Trout population estimates conducted in 1971 at the Twin Bridges, Eaman's Landing and Dam 4 stations (all in Crawford County), show a 49% overall increase in brown trout numbers, and a 29% increase in browns over 12 inches since the baseline years of the late 1950's and early 1960's. The situation regarding brook trout was just the opposite, showing a 53% reduction overall, and a 75% decline in brooks over 7 inches (legal size). This "trend" would seem to indicate that brook trout are being replaced by brown trout in this system, but such a trend cannot be confirmed without several years of data for analysis. However, it is evident that larger brook trout (over 7 inches) are being effectively cropped by anglers, because of their vulnerability to fishing pressure.

Human Impact

Much of the impact on the North Branch has come and past. Loggers have built dams along its length and removed the cover from the uplands and banks. Fires have burned over much of the area as recently as 1933. Man has also helped to restore the cover with planting programs during the CCC (Civilian Conservation Corps) days, and by landowners who have planted trees and stabilized eroding banks. Others who have come to

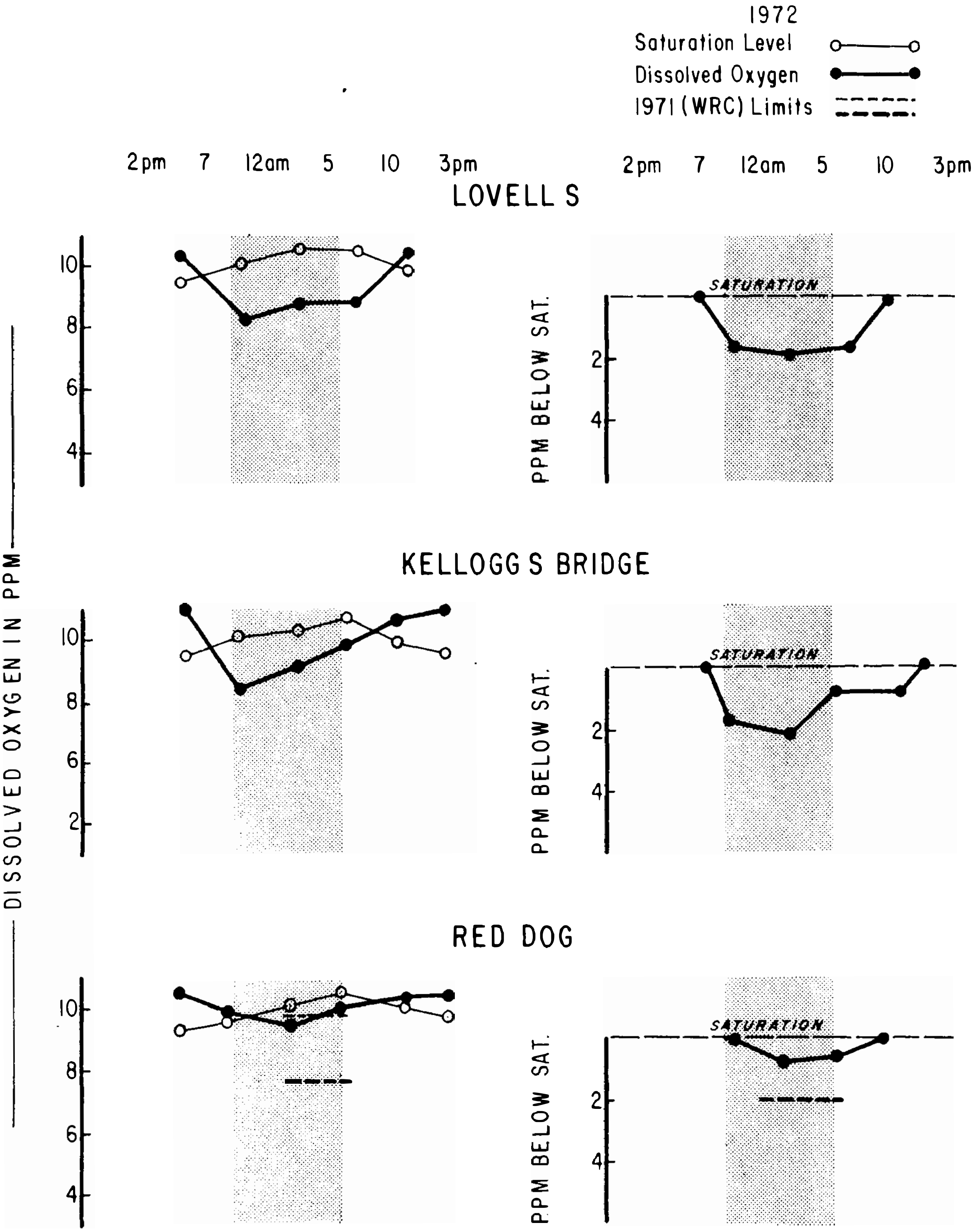


Figure 62. Dissolved oxygen concentrations observed for three North Branch stations on August 3 and 4, 1972.

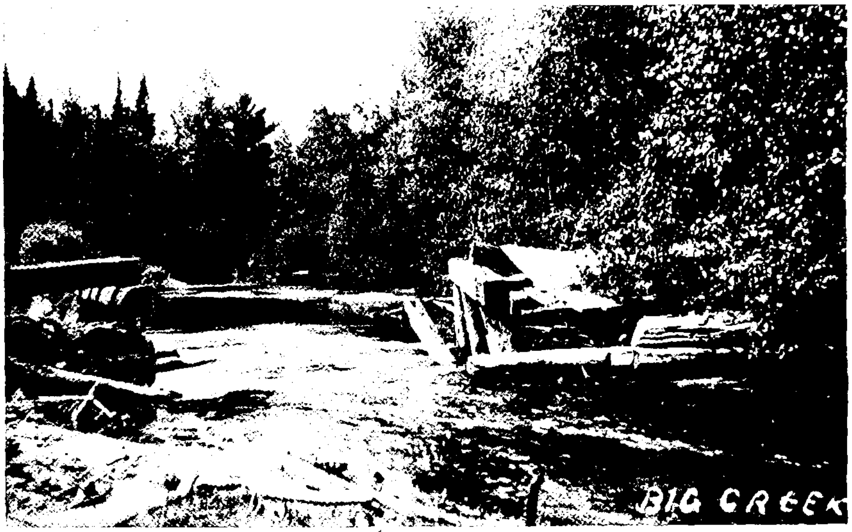


Figure 63. Upper: The Au Sable River just above Dam 4, looking downstream in 1924. Note the lack of bank cover, which is now present in the form of dense tag alder and willow.

Lower: Remains of Blonde Dam in the lower part of Big Creek near County Road 608. Photo taken during the 1920's.

stay either seasonally, or permanently, have left their mark along the river by removing the natural cover, channeling, planting lawns, building excessive docks, exercising poor placement of septic systems and causing other disruptions of the natural scene.

Problems. In the vicinity of Eaman's Landing, there is little erosion in evidence and banks are well covered by forest and brush. There are two small eroding banks below Dam 4 (about 800 square feet exposed). From the campground downstream to Kelloggs Bridge there are two more small erosion sites with some 800 square feet exposed. There is a heavy sand input from the entrance of Big Creek that extends about 300 feet downstream in the North Branch. There is a small erosion site on the first bend below Kelloggs Bridge (45 square feet exposed), and a large one 3/4 mile below the Big Creek confluence having some 750 square feet exposed. There is a deep pool below the above site that is now partially filled with sand. There are three more erosion areas a mile to 1 1/2 miles above the mouth of the North Branch with some 3,000 square feet of bank area exposed. Cottages along the North Branch frontage are the most dense in the Lovells area, and the area beginning about a mile above Kelloggs down to the Mainstream.

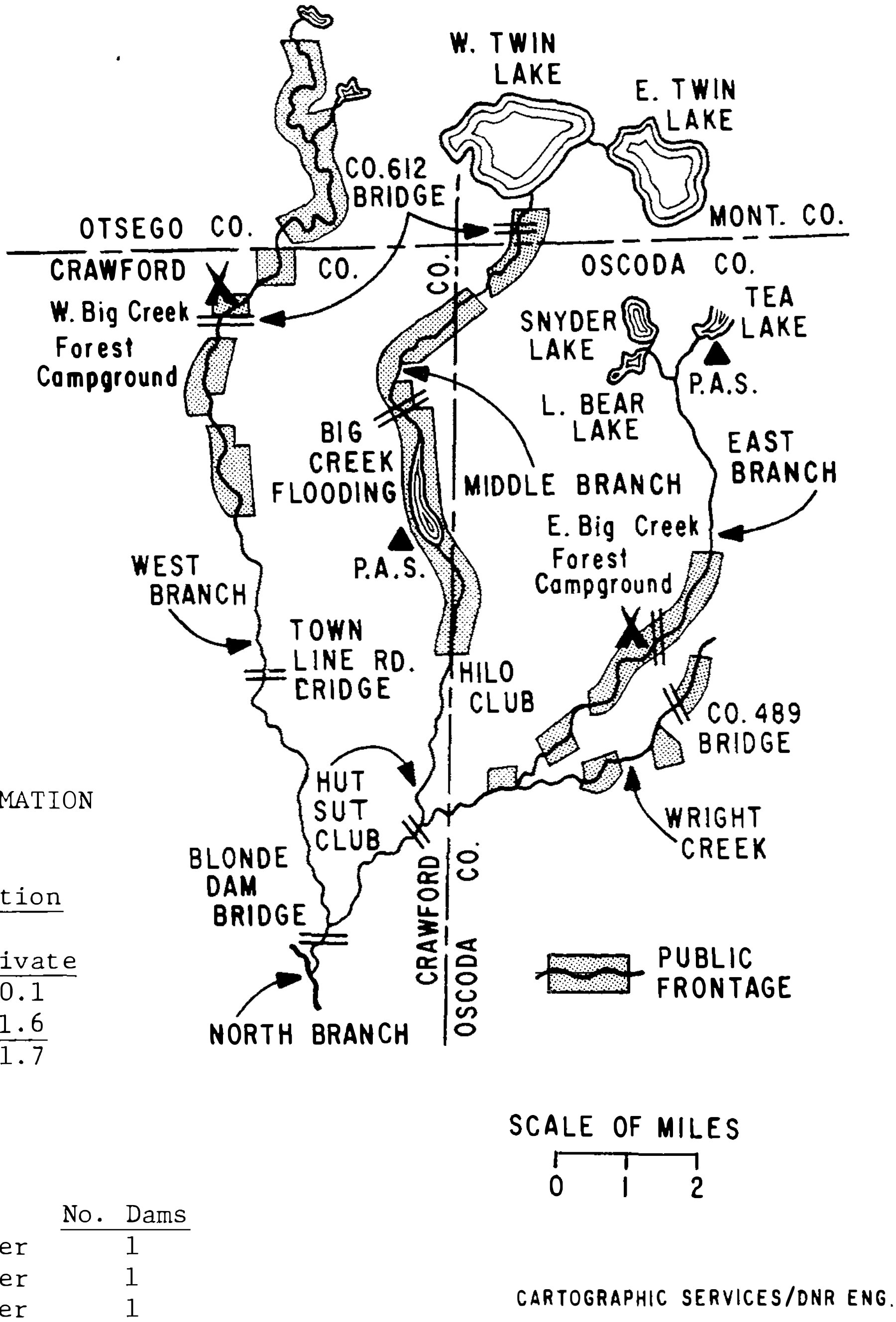
Outlook. The major tributaries of the Au Sable are to be included in the stream bank stabilization program. There are several sites from Eaman's Landing downstream in the North Branch that need attention. Many stream improvement structures have been placed in the North Branch, especially between Lovells and Kelloggs Bridge. Electrofishing collections have adequately demonstrated that trout are using these devices. However, it remains to be determined whether they offer additional cover and protection during over-wintering periods when the highest mortality occurs. Some of these areas will be electrofished in January and February to find an answer to this question. Comparison of seined fish collections, after a period of 50 years, shows conditions for trout are better now, since the area has restabilized from effects of logging and fires, than they were in the 1920's.

Use

In 1963 over 99% of the recreational activity on the North Branch was angling (Shetter and Alexander, 1967). Because the North Branch is so wide and shallow over most of its length (average width is 96 feet from Dam 2 to Kelloggs Bridge, compared to an average width of 92 feet on the Mainstream from Grayling to Wakeley), it is difficult to canoe above Dam 4 during most times of the year. Some group canoeing is undertaken on the lower North Branch and on down the Mainstream.

In the early 1960's, about eight times as much fishing was accomplished on the Mainstream, and twice as much on the South Branch, as on the North Branch (Shetter and Alexander, 1967). This is because the trout grow to a larger size in the other areas, although the numbers of trout per mile are higher in the North Branch. A change in the special regulations has been approved, and the "flies-only" waters now run unbroken from the Otsego County line to the mouth of the North Branch. Because of the low level of canoeing activity on the North Branch, the use conflict between canoeists and fishermen does not exist. However, public access is somewhat limited in the lower North Branch and there has been some conflict between riparians and fishermen. The river use rules adopted by the DNR Commission, would prohibit all boating on this tributary except for riparian use.

BIG CREEK (TRIBUTARY TO NORTH BRANCH)



CAPSULE INFORMATION

Miles of Stream in Section

	Public	Private
Big Creek	22.6	20.1
Tributaries	11.9	11.6
Total	34.5	31.7

Main Tributaries

Stream	Class	No. Dams
West Branch	coldwater	1
East Branch	coldwater	1
Middle Branch	coldwater	1
Wright Creek	coldwater	1

Big Creek Dams	Head	Pond Acreage	Year Built	Mile Point
W. Branch	6'	<1	1928	7.3
M. Branch	18'	20	1964	6.8
Wright Creek (Grant)(2)	5'	9	1954	3.3

Capsule Information, continued

Drainage area - 202 sq. miles

Average discharge at Co. 608 - 90 cfs

Maximum to mean discharge ratio (stability index) - 2.8:1 (For 7 observations in 1972 only)

Increases North Branch flow by (est.) - 47 percent

Occurrence of permanent and seasonal dwellings along the riverfront, by section(s), where the density exceeds 20 units per section or linear mile:

None. Cottage development around East and West Twin lakes at the headwaters of the Middle Branch is heavy

Habitat Features

General. Over most of its area, the Big Creek system is a good quality coldwater tributary. The creek system has three branches. The West Branch is the largest and carries about 8% less discharge than the Middle and East branches combined. At the confluence of the Middle and East branches, the East Branch carries about 60% more flow. The East Branch is joined by Wright Creek in Oscoda County, Wright Creek normally having about four more cubic feet per second at that point than the East Branch. All of the branches have long segments toward the headwaters that are in public ownership, which offers protection from development.

West Branch. The West Branch is the longest component, having only small lakes (106 surface acres combined) in the headwaters and little development along the stream. There are some beaver dams in the headwater area and few trout are present here. From Co. Road 612 downstream, there is good groundwater contribution and although cover is sparse, fair to good brook trout populations. The bottom type is mostly sand, but there are some gravel reaches.

Middle Branch. The Middle Branch flows out of the Twin Lakes (2,301 surface acres combined) in Montmorency County, where there is a heavy concentration of cottages. There are fair numbers of brook trout in some areas above the 94-acre wildlife flooding in section 25.

In the fall of 1964, prior to the flooding of the Big Creek impoundment, six miles of stream above the dam were chemically treated to remove existing stocks of fish. Only 1% of the fish recovered after the treatment were coldwater species. Electrofishing surveys, conducted in the summer of 1964 above and below the proposed flooding, also produced only 1% coldwater species. Thus the decision was made to create an impoundment which would serve as a wildlife flooding and support a good quality warmwater fishery.

Another collection, made just a few miles downstream where groundwater has dropped temperatures back in the 60's F, showed trout to be in very good supply. This branch has good gravel stretches which form the predominant bottom type. Both bank cover and in-stream cover are good. Overall, the Middle Branch has the best quality waters in the Big Creek system.

East Branch. The East Branch has its beginning in Oscoda County in three lakes having a total of 403 surface acres. In this main stem, temperatures are often in the 70's and only modest numbers of brook trout are found above the confluence with Wright Creek. The bottom type below Co. Road 489 is gravel mixed with sand, and there is a fair amount of trout cover. Wright Creek is dammed near Co. Road 489, has a bottom type of muck and sand, and no trout in the upper half. An unnamed small tributary just downstream, has moderate temperatures and fair numbers of trout. The lower end of the East Branch has a good gravel bottom, cooler temperatures, and good numbers of trout. Large quantities of sand are transported through the system, and the heaviest movement seems to be in the East Branch. A large pocket of sand was observed overlying the gravel substrate just above the junction with the Middle Branch in June, 1972, that was calculated to contain over ten cubic yards. In a week's time it had moved on downstream so that the gravel was once again bare. This could have been caused by some construction upstream, although Dr. David S. Shetter reported large movements of sand through the system in 1937.[32]

The lower main branch of Big Creek consists of good gravel areas, good cover, and temperatures that are nearly always in the 60's. Trout are present in good numbers. Above Co. Road 608 there was a dam (Blonde Dam) in existence in the 1920's when a fish collection was made by seine (Fig. 33, page 70). This area, at that time, was referred to as warm-water and no trout were captured in the seine collections. Seine collections made in 1972, long after the dam had been removed and the banks had become reforested, produced good numbers of trout (Fig. 63, page 175). These same comparisons show that trout have increased greatly in the lower Middle Branch, and are still abundant in the lower East Branch of Big Creek.

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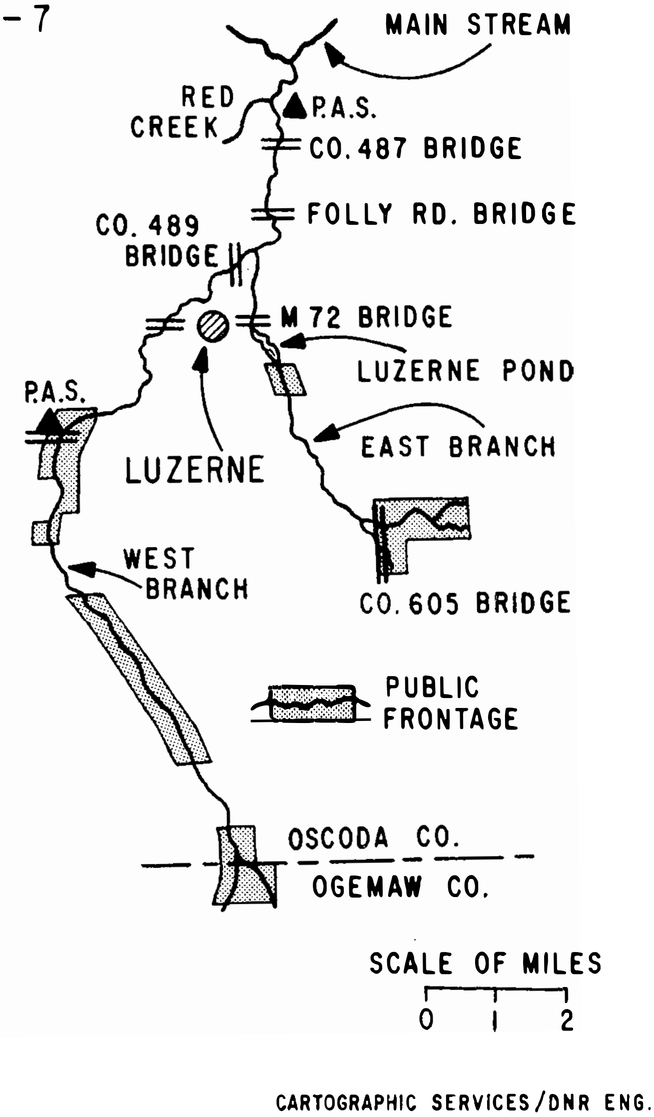
32 Shetter, Dr. D. S. In Charge, Hunt Creek Fisheries Research Station, 1937. Observations on Big Creek, Crawford County.

SECTION III PART B-7

BIG CREEK (SOUTH)



CAPSULE INFORMATION

Village	Population	Method of Sewage Disposal
Luzerne	350 (est.)	Private Septic Tanks

Miles of Stream in Section

	Public	Private
Big Creek	8.3	15.1
Tributaries	7.0	2.5
Total	15.3	17.6

Main Tributaries

Stream	Class	No. Dams
West Branch	coldwater	1
East Branch	coldwater	2
Red Creek	coldwater	1
Hunt Creek	coldwater	1

Big Creek Dams	Head	Pond Acreage	Year Built	Mile Point
Luzerne Pond	12'	10	1939 (Rec)	4.7
Side Channel	4'	0.5	1970	4.6
West Branch	Pit Pond	2	--	4.9

Drainage area - 112 sq. miles

July 1972 discharge at Co. 487 - 85 cfs

Increases flow of Mainstream by (est.) - 10 percent

Occurrence of permanent and seasonal dwellings along the riverfront, by section(s), where the density exceeds 20 units per section or linear mile:

T 26N, R 1E Section 25 (East Branch at Luzerne) Section 26, 23 (West Branch at Luzerne) Section 12, 1 (just above confluence with Mainstream).

Habitat Features

General. Big Creek is the last large tributary to enter the Mainstream above the South Branch River in Iosco County. The stream joins the Mainstream 2. miles below Parmalee Bridge. This stream is somewhat unique in this basin, having no lakes in the headwaters, and is an excellent coldwater tributary system.

West Branch. The upper 3 to 4 miles of the West Branch is characterized by slow flow, heavy silt deposits and aquatic weed growth. From the County Park on Co. 490 downstream, the current speeds up and the bottom type changes to sand and gravel. Normal maximum temperatures are about 70°F from the park on downstream (Fig. 58, page 158). which is more suitable for trout. Both the velocity of the current and the occurrence of a gravel type bottom increase in a downstream direction to the union with the East Branch.

East Branch. The East Branch is a little cooler than the West Branch, and water temperatures are nearly always in the 60°'s F. The substrate is mainly sand, although many gravel stretches are exposed. Both bed and bank cover are very good, and growth of rooted aquatic vegetation is moderate.

The main channel, below the union of the West and East branches, is characterized by mostly sand bottom, with good cover, moderate velocity, and summer water temperatures are normally in the 60°'s F.

Water Quality

Levels of all chemical constituents tested were low, including coliform counts.

Quality index (WQI). The index at Co. Road 487, 1.6 miles above the mouth, was 93.73. This is the highest index calculated for a regular sampling station in the Au Sable system.

Quality reflected by biota. Insect collections at Co. Road 487 reflect good water quality and good habitat conditions. A seined fish collection compared to a collection taken in the 1920's showed an increase in the percentage of coldwater species on the main branch. Field notes from 1924 show that the system was not even considered coldwater habitat at that time. Fisheries Supervisor Gary T. Schnicke comments that he has never observed the creek in a roily or turbid state, even during intense storms. This indicates that this feeder system is exceptionally stable, a feature of much value to resident trout species. Another collection in the upper West Branch produced fewer trout in 1972 than in 1924. It is not clear what the cause might be, as there is no human activity in the area. However, this area contains the poorest natural conditions for coldwater species found in this tributary.

Electrofishing collections (12 in all) demonstrate good to excellent trout waters in all cases except the upper West Branch, where trout are only marginal to fair.

Human Impact

There is some sand input at the Co. Road 490 Park. Movement of sand downstream is evident at M-72 on the West Branch. There are two more small erosion sites at Co. Road 489 on the West Branch and 487 on the main branch, although they are not considered serious. The culverts at the Co. Road 487 crossing appear to be well maintained by county road crews.

There is an impoundment at Luzerne on the East Branch of ten surface acres. The surface temperatures below the dam are somewhat increased but remain in the 60°'s F. There is another pond of half an acre on a side channel below the dam. The temperature was 2.5° higher, the BOD three times higher, phosphates two times higher, and a dissolved oxygen reading showed one half (5.3 ppm) the D.O. value of the Mainstream. The pond was observed to be coated with algae and appears to be of little use other than to provide a nutrient bank to the East Branch.

Use

There is moderate fishing pressure in and below the impoundment on the East Branch (which is controlled by the village of Luzerne). There is light fishing activity on the lower reaches below M-72, where access to the stream is limited to bridge crossings. There are a number of homes along both branches at Luzerne, at bridges below town, and the last mile and a half above the Mainstream. The Big Creek system is a prime coldwater feeder system, and it should be protected by a Greenbelt zoning ordinance.

SECTION III, PART B-8

OVERALL COMPARISON OF WATER AND HABITAT QUALITY FOR STREAM SECTIONS

Each Branch of the Au Sable is a micro-watershed, and has unique characteristics of its own. Not only do natural characteristics vary, but the degree of human development and recreational use are also different.

The river segments were ranked according to the results of quantitative sampling in the basin for which adequate data were available including water quality and the diversity and sensitivity of insect and fish species (Table 22).

This grading system is very much open to debate, especially in regard to the diversity of fish species. In a coldwater river system, such as the Au Sable, one would expect to find a relatively low diversity in the cold headwater areas, and in the cold small- to moderate-sized feeder streams. Therefore, it would appear that Big Creek (south) and the Upper Mainstream are being unduly penalized, and this is likely true. However, the Lower Mainstream also shows a low diversity which represents a dramatic change since the 1920's when the hydroelectric dams were recent events (see Fig. 21, page 51). This drop in the diversity of fish species is related to the adverse effect of these impoundments.

The high ranking of the North Branch and Big Creek (north) systems reflects an excellent substrate type, along with good water quality. The South Branch is penalized because of the poor habitat type above Roscommon, and of the input of sewage effluent and storm runoff at Roscommon. The East Branch is downgraded because of the heavy sand movement over much of its length. Despite the excellent quality waters from Burtons Landing to Wakeley Bridge, the Middle Mainstream has the adverse effects of the Grayling Impoundments, surface runoff, poor habitat type (for trout) in the Shellenbarger and "stillwater" areas, and the influence of the Mio Pond. The Lower Mainstream is dominated by the effects of the hydroelectric basins, which undoubtedly play a part in the overall low rating of this segment.

The large river character from the "stillwater" area downstream, plays a role in determining the low ranking of these two segments. The diversity of insect populations and percent of intolerant insects present are simply not as high as that found in the smaller stream segments. The same is generally true of fish species, except where diversity is low in the smaller branches due to the cooler temperatures, swifter currents and other physical characteristics that favor trout and sculpins. The Upper Mainstream ranks low because of the physical characteristics that cause warmer water temperatures, and D.O. fluctuations that are unfavorable for trout.

From another point of view the Au Sable is more than an important river or physical resource. It is the stream where present trout fishing and trout management philosophy have been developed through intensive scientific research and great public interest.

Table 22. Following are rankings of stream segments according to the results of the water quality, aquatic insect and fish investigations in the Watershed

Water Quality Index	Diversity of Insect Species	Percent Intolerant Insects
Big Creek (south)	North Branch	North Branch
Big Creek (north)	Big Creek (north)	South Branch
East Branch	Mainstream (upper)	Mainstream (middle)
North Branch	Mainstream (middle)	Big Creek (north)
Mainstream (upper)	South Branch	Mainstream (upper)
Mainstream (lower)	Big Creek (south)	Big Creek (south)
South Branch	East Branch	East Branch
Mainstream (middle)	Mainstream (lower)	Mainstream (lower)

Diversity of Fish Species	Percent of Cold-water Fish Species (by seine)	Percent of Cold-water Fish Species (by electrofishing)
North Branch	Big Creek (north)	Big Creek (south)
East Branch	South Branch	South Branch
Big Creek (north)	North Branch	East Branch
South Branch	Mainstream (middle)	Big Creek (north)
Mainstream (middle)	East Branch	North Branch
Mainstream (lower)	Big Creek (south)	Mainstream (middle)
Mainstream (upper)	Mainstream (upper)	Mainstream (upper)
Big Creek (south)	Mainstream (lower)	Mainstream (lower)

Overall rating based on combined parameters:

Segment	Rankings	Ave. Rank	Ave. Discharge (cfs) at Down-stream Limit
North Branch	4, 1, 1, 1, 3, 5	2.33	254[2]*
Big Creek (north)	2, 2, 4, 3, 1, 4	2.66	90[2]
South Branch	7, 5, 2, 4, 2, 2	3.50	250[2]
East Branch	3, 7, 7, 2, 5, 3	4.33	43[1]
Big Creek (south)	1, 6, 6, 8, 6, 1	4.66	85[2]
Mainstream (middle)	8, 4, 3, 5, 4, 6	4.83	957[1]
Mainstream (upper)	5, 3, 5, 7, 7, 7	5.50	75[1]
Mainstream (lower)	6, 8, 8, 6, 8, 8	7.17	1,879[3]

1 Based on several years of record (USGS).
2 Approximation based on current metering results.
3 Approximation based on monthly records (WRC-1966).
* At Kelloggs Bridge

SECTION IV

MATHEMATICAL MODELS FOR AU SABLE RIVER ECOSYSTEMS *

By George E. Burgoyne, Jr.

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INTRODUCTION

This introductory segment will serve to: (1) define a model, (2) outline its use, and (3) provide some examples of its use on the Au Sable River.

Webster defines a model as follows: "a description or analogy used to help visualize something that cannot be directly observed."

A model is an abstraction of some aspect of the real world. It is never perfect in the sense that it does not exactly duplicate reality. This would be too complex. Instead, a model is useful because it provides ease of handling by considering only the major factors affecting the true, real world situation. Thus no model will provide exact predictions but it should at least predict major trends.

All of us, in our own way, use models every day. Our mind (mechanically) works with models or images of the real world. However,

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the human brain is limited to considering only a few factors in order to simplify using its model. The mathematical model is not quite so easy to use, but is able to simultaneously consider a much larger set of factors to predict outcomes.

One of the main advantages of the mathematical model is that the user is forced to explicitly define relationships. Hence, these relationships are out in the open where they can be discussed, evaluated, and modified in cooperation with other experts whose ideas might be slightly different. Thus, the mathematical model forms a means of bringing together a multitude of relationships to be evaluated concurrently. Together these should provide a better model of the real world, than the model of any one individual.

There are two basic reasons for building models. The model may be formulated to test a hypothesis about the real world, or to understand some aspect of nature. This is a major step in the "scientific method." On the other hand, if the mechanism is at least partially understood, a model may be developed as a predictive tool. These two purposes certainly are not independent, but may be considered as different short term goals.

While the first objective should certainly be kept in mind, the scope of this project did not include a major effort toward researching basic mechanisms. We have instead attempted to organize existing knowledge into useful predictive models.

Basic Modeling Method for the Au Sable Project

Whether modeling fish, or temperature, or the concentration of some pollutant, we will use the following basic approach. First, we will divide the river into a number of uniform sections. Then, for each section, we can write the following equation:

$$Xt_2 = Xt_1 \pm \text{Change}$$

Amount of substance X in section at time t_2	=	Amount of substance X in section at time t_1	±	Change in amount of X in section during time t_1 to t_2

If the change is positive, there will be more of substance X in the section at time t_2 than there was at time t_1. If the change is negative, there will be less of substance X in the section at time t_2.

Thus, in order to predict future amounts of substance X in the section, we must know: (1) how much of substance X is in the section now, and (2) how does this amount change with time.

We can further break down the change factor as follows:

Change in amount of X in the section during time t_1 to t_2	=	Amount of X which comes into the section from other sections during time t_1 to t_2	-	Amount of X which goes out of the section to other sections during time t_1 to t_2

+	Amount of X which is formed in the section during time t_1 to t_2	-	Amount of X which is destroyed in the section during time t_1 to t_2

or in short:

$$CHANGE = IN - OUT + SOURCE - SINK$$

For a more specific illustration of these equations we shall consider a fish population in some imaginary section of the river. The first equation then becomes:

Number of fish in the section on February 1	=	Number of fish in the section on January 1	±	The change in number of fish in the section during January

The second equation for this example would be as follows:

Change in number of fish during January	=	Number of fish which came into this section during January	-	Number of fish which left this section during January	+	Number of fish hatched in this section during January	-	Number of fish which died in this section during January

For example, let us say we have 1,000 fish in the section on January 1, and that we counted 50 fish coming into the section and 65 fish going out. We also observed that predators killed 10 fish and 5 died of other unknown causes. Assume that January is too early for fish eggs to be hatching or the fishing season to be open. Now we can calculate how many fish will be in the section on February 1.

First calculate the change:

$$\text{Change} = +50 - 65 + 0 - 15$$

$$\text{Change} = -30$$

then calculate the new condition:

$$\text{Number of fish (Feb. 1)} = 1{,}000 - 30$$

$$\text{Number of fish (Feb. 1)} = 970$$

This example shows how the model works in general. For actual predictive use we would formulate how the four individual components of change actually come about, rather than by counting. For example, we might know from field studies that during January, 1% of the fish which are alive at the beginning of the month will die by the end of the month. Then, instead of using field counts, this particular component of change would be computed:

$$\text{Number of fish which die during January} = 0.01 \times \text{Number of fish in the section on January 1}$$

Likewise, we could define relationships for the other components. Perhaps we could further refine the model by observing that the fraction of fish that died during January is not a constant 1%. Instead this fraction might vary depending on some other factors such as oxygen concentration and water temperature.

The model development is not finished once it has been formulated. It must be verified. It must be tested against the real world to see whether it mimics reality with sufficient accuracy to be useful as a predictive tool. Schematically the model development should proceed as outlined in Figure 64.

THE MODELS

Analysis: Thermal Effects of the Grayling Impoundments

Problem: Are the impoundments above Grayling having a deleterious effect on the river by heating the water? Would their removal significantly improve the trout habitat in and below Grayling?

Factors to be considered:

- Temperature of incoming water
- Solar radiation
- Heat exchange with air mass
  - Radiation
  - Evaporation
- Cooling effect of groundwater
- Surface area of river segments
- Volume of river segments

The model for thermal effects on the river was developed to predict the stream temperatures throughout the day. The predictive value of this model has been reasonably verified against field data. For a hot July day the model predicts that water leaving the stump pond could be as warm as 82°F. Actual surface water records show temperatures at this spot at the same time of year do indeed reach 83°F. Similarly, the temperature increase in the model stump pond is quite similar to the values which were observed in the field. The model was also checked against a

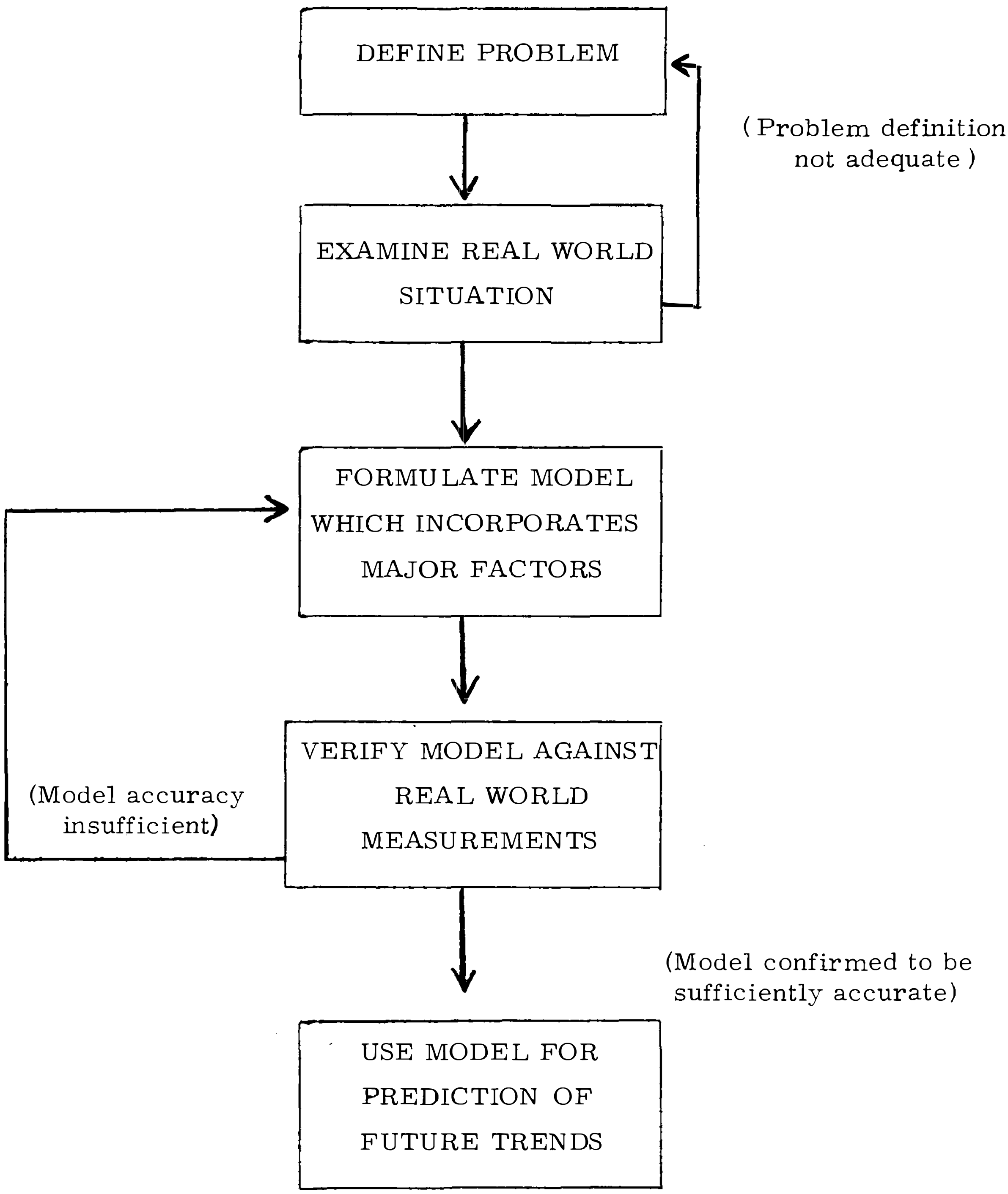

Figure 64. Model design for use in interpreting present conditions in Au Sable River system, and predicting future trends.

set of temperatures taken in 1953 when the upper impoundment had been drawn down. Again the model predictions and the real measurement correspond closely.

However, there is one point on which the model and real world measurements have consistently differed. The model always predicts a higher temperature rise for the upper impoundment than the real world observations. This difference could be attributed to a number of factors which the model at present ignores. For the most part the upper impoundment is long and relatively narrow, it has substantial forest growth along the sides, and it is oriented in a general north-south direction. This might provide considerable shading during the early morning and late afternoon. This would lower the temperature peak for this impoundment.

The model can thus be used to predict the direction and approximate magnitude of changes in the river temperatures due to man-made effects.

We will look at the results of removing first one, and then both, of the impoundments above Grayling. (Although we could examine the effects of removing either of the impoundments we will only consider the stump pond as a single alteration.)

Figure 65 shows the daily maximums for the end point of each river cell. This reflects the net effects of heating and cooling encountered in that cell. Keep in mind that temperatures above 70°F are unfavorable for trout. To illustrate what could happen under the worst conditions we have chosen a hot day in late July during which there is little cloud cover and little wind.

First consider the upper curve in the diagram. It represents the maximum daily temperatures which might be expected on such a day with the river in its present condition. There are several things to observe. Both of the impoundments raise the maximum temperature of the water considerably. On a hot day each could add about 4 to 6° F. to the maximum temperature of water feeding into the impoundment. As noted in Section III, Part A of this report, there is a considerable input of groundwater into the section of stream between US-27 and the old waste water treatment plant. This groundwater is coming in at a temperature of approximately 48°F. The model indicates that this could essentially negate the heating effect of the stump pond. The addition of cool water from the East Branch further cools the Mainstream. If it were not for this input of cool water, the heating effects of the impoundment would extend much farther downstream. Finally, observe that the model predicts that there could be as much as a 2- to 3-degree rise in temperature as the water passes through the stretch between the Shellenbarger outlet and Burtons Landing. Beginning here, groundwater input once again begins to cool the river.

The second curve represents the maximum temperatures which might be encountered if the low-head dam at US-27 were removed, and the river returned to its original channel. Notice that this change would lower

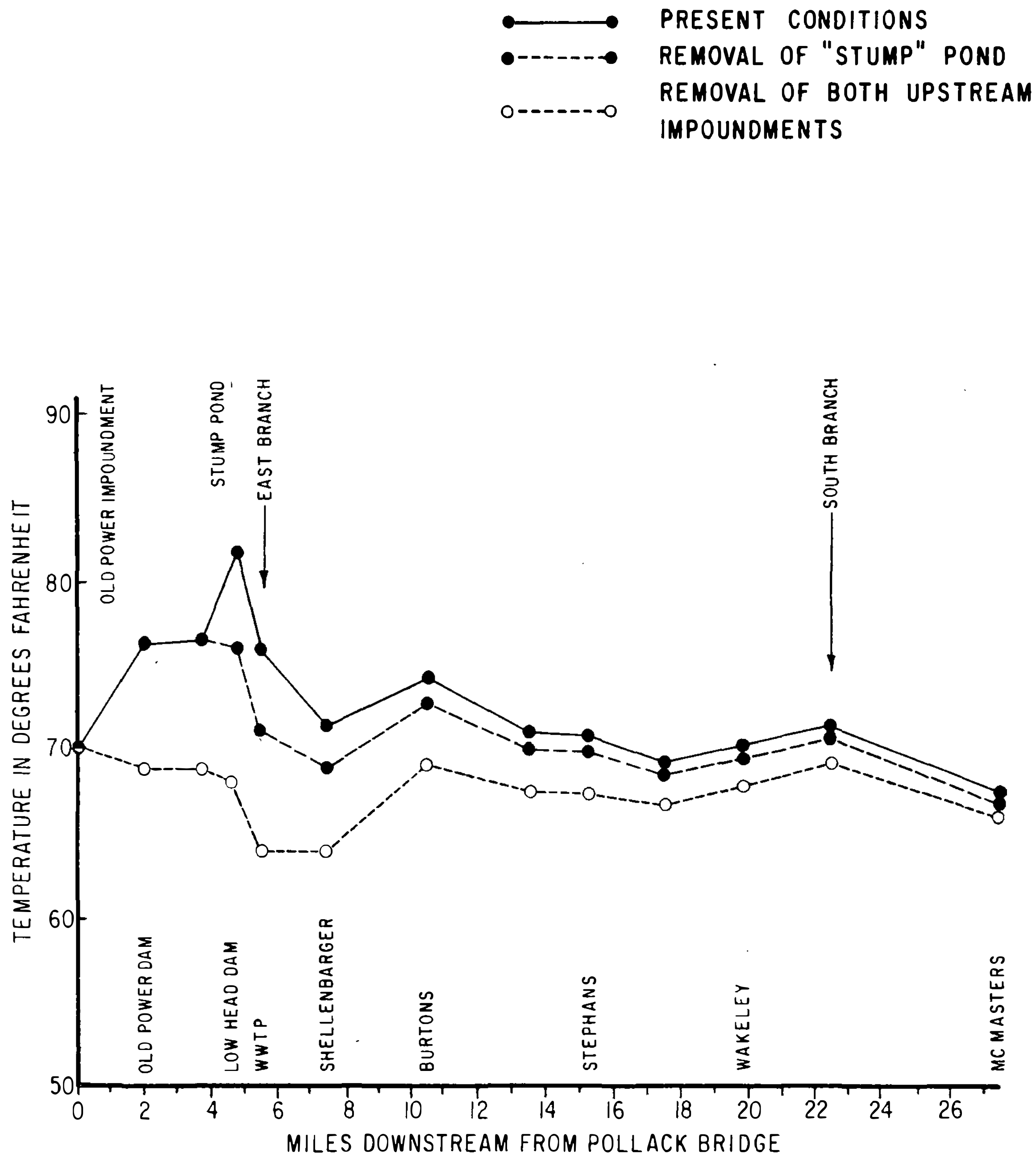

Figure 65. Maximum temperatures in river cells from Grayling downstream on a hot July day under present conditions, and predicted temperatures upon removal of one, and both, upstream impoundments.

the peak temperature considerably in the area immediately below Grayling. Further downstream, the effect is only a degree or two at most.

Finally, consider the last curve on this figure. This represents the approximate maximum temperatures which might be encountered on this stretch of river if both the impoundments had been removed. Notice that this would keep the temperatures for the whole stretch below the "critical" 70°F boundary.

Hence, it appears that the removal of the impoundments would contribute considerably to the temperature regime of the river. It would be much more favorable for the reestablishment of trout in the stretch of river near Grayling.

If the groundwater input to the river at Grayling remained the same after the removal of the impoundment(s), the cooling effect of this groundwater would, in a sense, be better utilized. Instead of having to counter the effects of upstream heat additions, it would be pushing the stream temperature down to more suitable levels for trout.

The model could likewise be used to estimate the change in stream water temperatures should a water-using industry begin adding heat to the river.

Analysis: Relationship Between Precipitation and Stream Discharge

Problem: Is the stable discharge of the Au Sable River a result of the time delay in the delivery of precipitation to the river?

Factors to be considered:

Precipitation records for a "normal" season
Stream flow records over this same period
Log time between occurrence of precipitation and resultant discharge peaks

Included in the mathematical section of the project is the analysis of certain measurable features of the Au Sable River. One item of particular interest is the very stable flow of the river. This has been pointed to as one of the main features of the river which makes it valuable for all types of recreation. This stable flow provides ideal conditions for trout. In addition, it makes the stream suitable for canoeing all summer long, since there is no major drop in streamflow in late summer. Finally, the stable flow has allowed land owners to build virtually at the water's edge without fear of flooding. This type of use, however, can seriously detract from the river's aesthetics and purity.

The stable flow is a result of precipitation entering the stream indirectly by way of the groundwater rather than entering directly as surface runoff. If the majority of the precipitation entered the stream as surface runoff, one would expect the stream to exhibit a "flashy" flow. That is, the maximum flow would vary greatly from day to day, in response to the precipitation falling on a particular day.

If, instead, the precipitation enters the stream through the groundwater, one would expect a more stable flow. This would arise, in part, from the groundwater flow acting as a delay between the actual precipitation and its subsequent contribution to the river flow.

Hence, it was felt that a statistical analysis of records on flow and precipitation might clarify this aspect of the river's stable flow. It is important to discover whether such a delay exists, as well as the duration of such a delay. To avoid the influence of an atypical year, Mr. Robert Larson, USGS hydrologist at Grayling, was consulted. Mr. Larson selected the summer period of 1968, as having typical weather patterns (precipitation and temperature ranges) for the upper Au Sable River Basin.

The headwaters of the Mainstream above Grayling provide the ideal spot for such an analysis. The flow out of the headwaters is measured by a single gauge at Grayling (USGS records), and there are precipitation records for this area (U.S. Weather Bureau). The only complicating factor is the existence of two major impoundments in this section. However, since neither impoundment has been actively regulated in recent times, it was reasoned that their effect on daily maximum flows could be disregarded. It was hypothesized that the river's flow at Grayling must consist of two basic portions. First, some part of the flow is constant due to the average groundwater contribution. Secondly, part of the flow is determined by the precipitation on some set of the previous days. That is, the differences in maximum flow from day to day are assumed to result from the precipitation of the previous few days entering the stream as additional groundwater.

If this hypothesis (model!) is realistic, a significant relationship (correlation) between the change in maximum daily flow and the precipitation on some previous days would be expected.

This is, in fact, what was found (Fig. 66). The change in maximum flow from day to day is significantly correlated to the precipitation on several of the previous days. This implies that the stream is, in fact, receiving precipitation through the groundwater. The groundwater is acting as a delay between the precipitation and the peak river flow which results from that precipitation. However, the groundwater is also acting as an averaging mechanism. The change in daily flow appears to result from the precipitation on a number of previous days.

Thus, the difference between yesterday's maximum flow and today's flow is partly due to today's rainfall, partly due to yesterday's rainfall, and partly due to the previous day's rainfall. A heavy rainfall on a certain day will influence the river flow for a number of days afterward. But its effects are unlikely to be drastic on any subsequent day since its contribution is mixed with the contributions from a number of other days.

Hence, it appears that the stable flow in the upper Au Sable is due to the fact that little precipitation enters the stream as surface runoff. If it did so, the river would show an immediate increase in flow. Instead, much of the precipitation which reaches the stream does

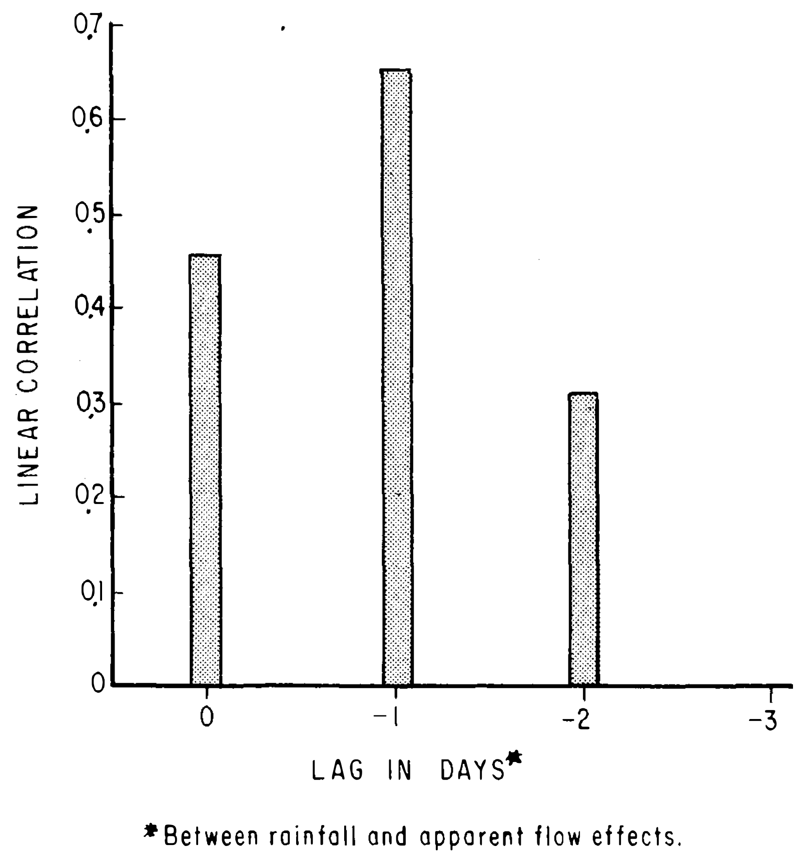

Figure 66. Correlation between precipitation events in the upper Au Sable Basin, and resultant streamflow increases at Grayling based on the time delay in days.

so through the groundwater. Here the daily contributions are delayed, and mixed with the precipitation of several other days. This produces an averaging effect which further contributes to the river's stable flow.

Analysis: Comparison of the Volume of Surface Runoff from Grayling to Stream Discharge During Low-Flow Periods

Problem: Does surface runoff from urban areas contribute significantly to the river discharge, so that concentrations of storm water constituents could have an impact on biological communities?

Factors to be considered:

Volume of storm water runoff from Grayling
Coincident low-flow conditions at Grayling
Predicted chloride concentrations under these conditions

When an area is urbanized, some of the precipitation is diverted from entering the groundwater. In addition, this water is often collected and funneled directly into local streams through storm drains. This may significantly affect the local groundwater table. Without a doubt it will have a significant effect on the stability of the streamflow, during periods of heavy rainfall.

The city of Grayling presents just such an example. The city spreads over an area of approximately 300 acres. Mr. Robert Larson estimates that storm water runoff from Grayling could, at times, make up 10 to 20% of the river's flow. Under drought conditions, it could be as high as 40%. My own calculations from approximate values for urban runoff rates (30% of precipitation) indicate storm water contributions of the same magnitude. Hence, surface runoff from the city of Grayling can significantly affect the river's flow. In addition, the storm water runoff from the city streets carries chemical substances potentially harmful to the stream's biological life. However, there are few actual measurements of storm water effects on the Au Sable. Therefore, the simulation of this aspect of the runoff can provide some insight into whether this is a potential problem that justifies further study.

Of the factors for which we do have some information, chlorides will provide a good illustration. During runoff on March 5, 1973, samples were collected above and below town. These samples show an increase in chloride concentrations from 3 ppm above town to 6 ppm below town (see Appendix Table II). Knowing the approximate flow, it is possible to calculate the amount of chlorides coming in with the runoff from Grayling.

In addition, the model must account for the diluting effects of groundwater and the various tributaries. Figure 67 shows the changing volume of flow in a downstream direction. The gradual increases come from groundwater input. The abrupt increases indicate the confluence of a significant tributary. The chloride values derived from data furnished by the Michigan Geological Survey Division for groundwater levels (0-37 ppm) for Crawford County, leaves considerable uncertainty about actual values. For experimental purposes the values 1.0 and 4.0 ppm were chosen as representing a reasonable range for groundwater. The river was then simulated and checked against actual measurement of instream chloride levels. The lower value (1.0 ppm) seems to be too low to be reasonable. It results in predicted concentrations in areas of of significant groundwater input that are much lower than actual measurements. The higher value (4.0 ppm) may be in about the correct range since it produces a reasonable fit of actual stream measurements. Figure 68 shows the simulated stream concentrations along with approximate measurements taken by D. C. Brege (1969). This figure also shows the effect of subjecting the simulated river to a chloride loading approximately equal to that which was calculated from actual measurements. As expected, the simulated river shows an increase from about 3 ppm above the point where the runoff is added, to about 6 ppm below this point. Downstream, the volume of groundwater entering the stream dilutes the concentration of chlorides.

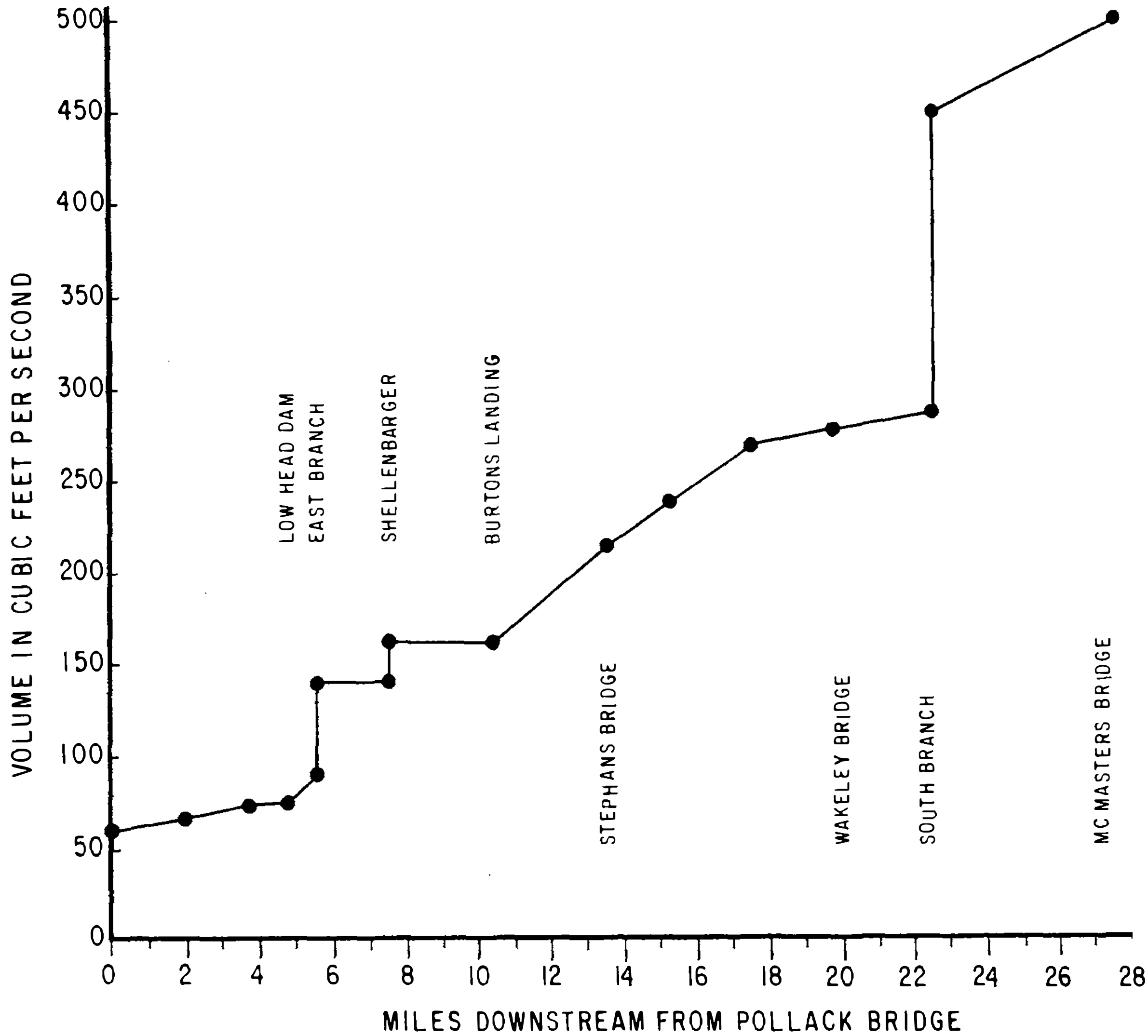

Figure 67. Increase in discharge vs downstream distance between Pollack Bridge and McMasters Bridge, under normal conditions.

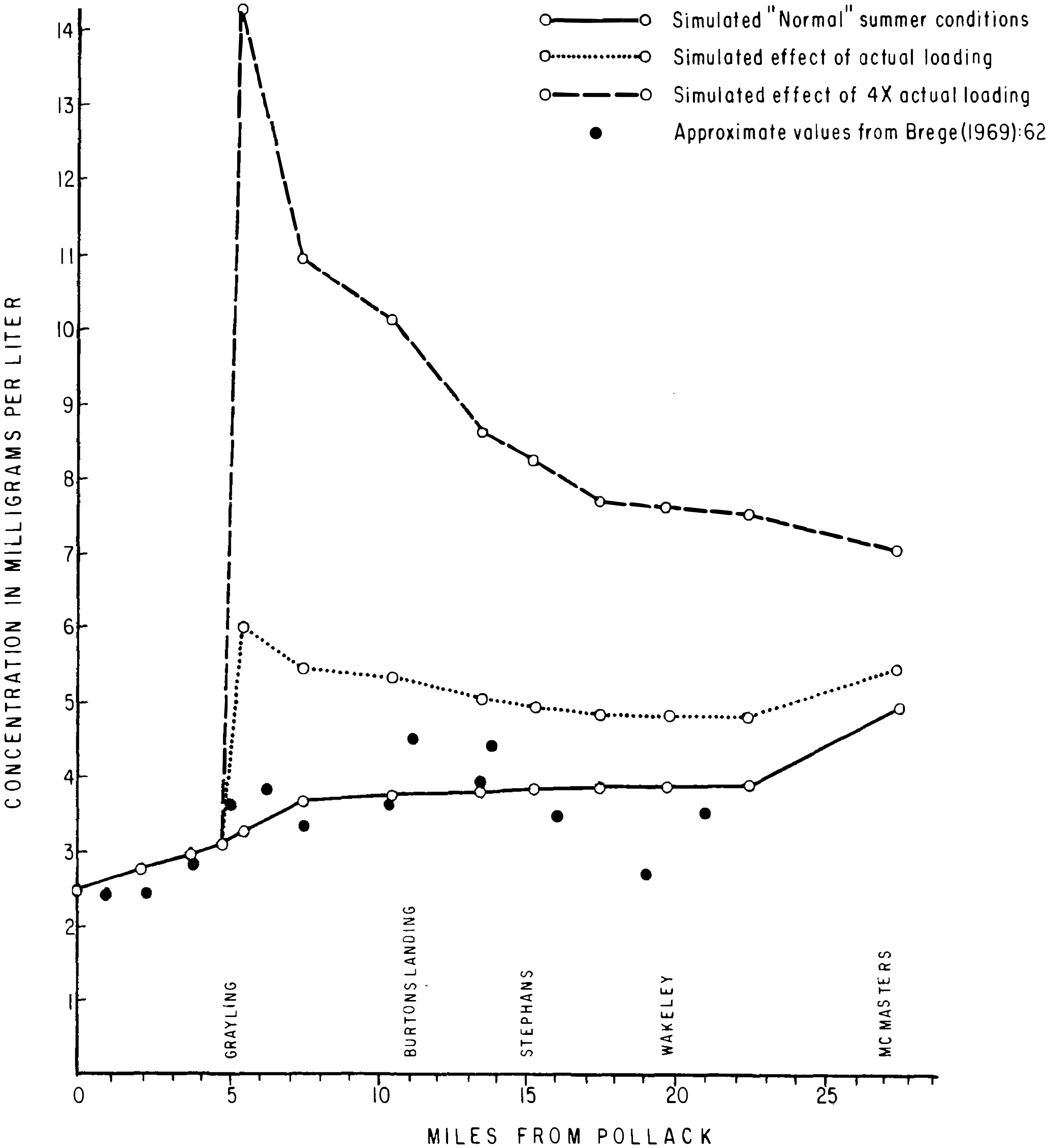

Figure 68. Simulated runs of predicted chloride concentrations in the Au Sable River below Grayling under normal and storm water loading conditions.

Figure 68 also shows the effect of subjecting the simulated river to a runoff loading which is four times as large as the loading computed for the actual runoff data. Even in this case, the chloride concentrations stay well below those concentrations known to be harmful to trout (see Section III, Part A-1, page 18 in this report). This is a guideline, indicating that chlorides from Grayling storm water probably do not, at present, pose a threat to the trout. However, too little field data are available to say with certainty that runoff loadings are unlikely to exceed this hypothetical heavy loading.

These predictions were derived with a steady state, non-dispersive model. Hence it should be reasonable to use these as upper limits which would be approached by a short-term input at the same rate. These concentrations would not occur simultaneously throughout the stream section. Instead, these predictions represent the peak as the "package" of runoff water moves downstream. Figure 69 shows approximate cumulative travel times calculated for this stretch of stream from Pollack to McMasters Bridge.

Thus the model suggests that chlorides, at present, are unlikely to be a problem for the trout population. But, as the cities continue to grow and the entire watershed is further urbanized, more and more precipitation may be diverted away from the groundwater and directed into the river. These surges of storm runoff carry sediment, bacteria, and many other noxious substances which are deleterious to the river's biological community. Diverting this runoff from immediate entry into the river is solving only part of the problem. If the precipitation no longer enters the groundwater table, there may be an effect on the groundwater contribution to the river. This groundwater contribution not only provides a stable flow, it also provides a moderating effect on temperatures and chemical pollution. Wastes are diluted by the generally pure groundwater. The river is cooled in summer and warmed in winter by the groundwater.

New development in the watershed should therefore include a design that would prevent the diversion of surface runoff directly to the stream. Such a design could consist of intercept basins that would allow groundwater recharge, or provide temporary storage of water for other purposes.

Analysis: How the Regimes of Temperature and Dissolved Oxygen Affect Trout Populations in a Small Segment of Stream

Problem: Are the temperature and oxygen regimes imposed by the Grayling impoundment sufficient to suppress a trout population in the river area downstream from these impoundments to the confluence with the East Branch?

Factors to be considered:

Temperature and oxygen levels for the Au Sable at Grayling with and without the impoundments
Response of trout to these conditions

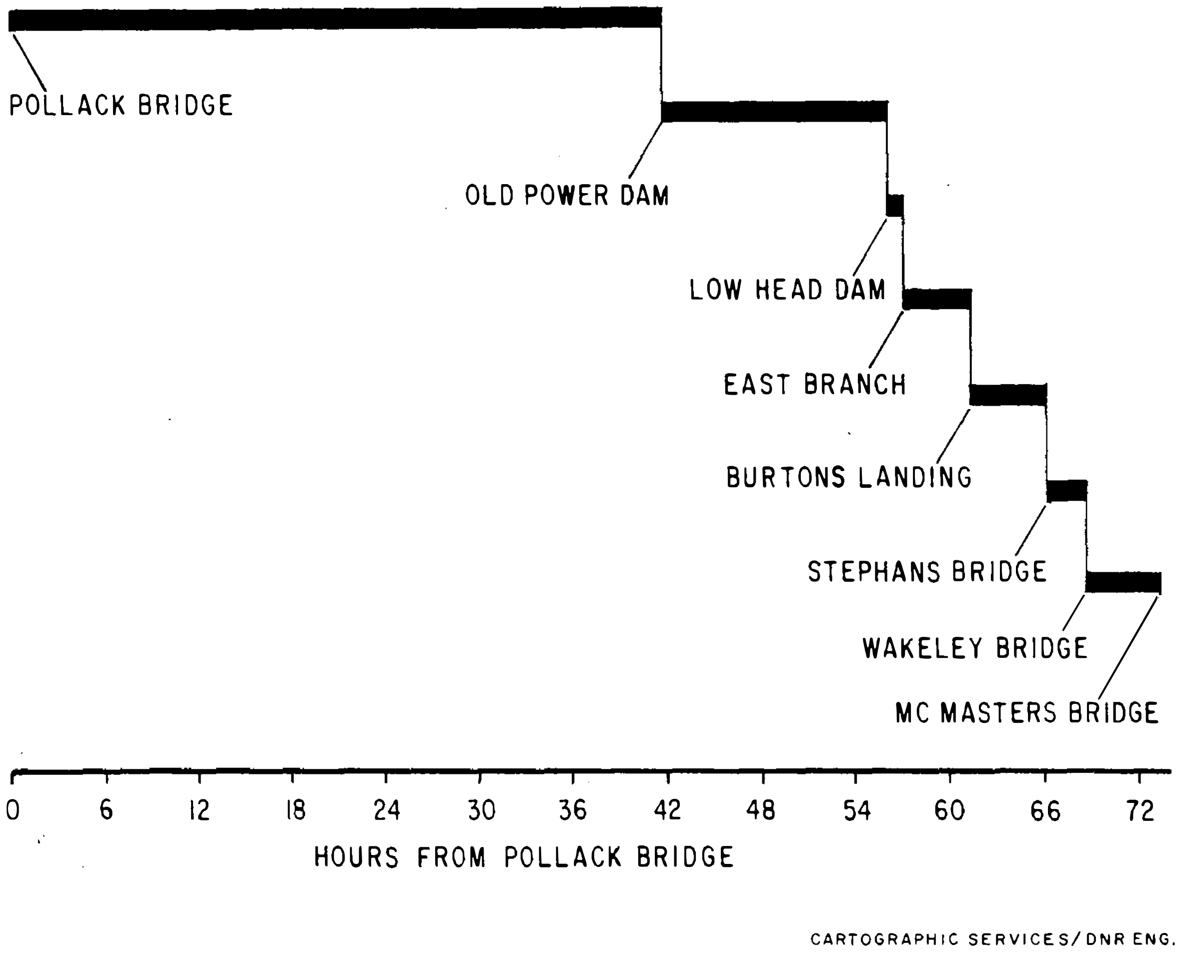

Figure 69. Accumulative time of water travel from Pollack Bridge to McMasters Bridge under normal conditions.

One of the final steps in the process of modeling a system such as the Au Sable River is to begin to tie some of the separate models together. By doing this it is recognized that we have simply been looking at different aspects of one, large, interrelated system. In reality the physical, chemical, biological, and human systems are tied together with a complex web of interactions.

As an example, a model of trout mortality and its relationship to the stream's temperature and oxygen levels will be formulated and exercised in this section. In order for a stream to support a significant trout population, the summer temperatures should seldom rise above 70°F, and oxygen levels should not fall below 6 ppm for extended periods. Certainly other factors affect the trout population, but these are the two major ones. In addition, at least the lethal limits for these two factors have been defined in the literature. (For general reference see Hynes, 1970; Mills, 1971.) Temperatures which approach 80°F are highly detrimental to trout populations. Also, oxygen levels which drop much below 6 ppm begin to have an adverse effect on the trout's survival, especially from evading predators (Hynes, 1970).

Before tying these factors directly to mortality, one of the many confounding factors encountered when using the results of laboratory studies on natural systems should be recognized. A fish which is subjected to extreme values of temperature or oxygen concentration in an aquarium must either endure or die. In a natural system the fish often has a third alternative when he encounters unfavorable conditions. He may leave in search of better environment. This may be limited by certain natural or man-made conditions. Still, poor conditions in a section of stream may not directly cause fish mortality. But these conditions may lead to a depletion of the fish population by forcing the fish to emigrate. Hence, the factor which this model calls mortality is really a combination of actual mortality and emigration. The model will keep track of the number of fish in a section of stream. It will be concerned only with the fact that some fish are gone regardless of whether they die or swim away.

Although the majority of information available defines only lethal limits, it is still possible to formulate a simple fish model which uses this knowledge regarding oxygen and temperature.

Begin with the following equation:

$$\text{Mortality} + \text{Emigration} = \text{Expected Mortality} + \text{Temperature Effect} + \text{Oxygen Effect}$$

This model ignores any interactive effect for changing both temperature and oxygen. It could be argued that the combined effect of both temperature and oxygen should be greater than the simple addition of their separate effects. In that case the right hand side of the previous equation would look like this:

= Expected Mortality + Temperature Effect + Oxygen Effect

+ (Temperature x Oxygen) Effect

It is reasonable to expect that such an interactive effect does occur. However, ignoring the interaction in this model will be useful. Since a specific mathematical form for this interaction will not have to be specified, the model will be simplified. In addition, the deletion of the interaction term can be expected to produce a minimum estimate of the deleterious effects of these two factors.

This model of mortality will also ignore the effects of fluctuating temperatures. Both field measurements and temperature model predictions indicate that daily temperature fluctuations in this stretch of stream are commonly on the order of 5°F. Diurnal fluctuations of 10°F are also found at times. These temperature changes reduce the ability of the trout to resist high temperatures. This would provide an additional stress on the trout reducing their ability to thrive in this section of stream.

The item called "Expected Mortality" is defined to include the effects of numerous factors other than oxygen and temperature. For this example, "Expected Mortality" has been estimated roughly from fish collection data from the Au Sable River.[33]

A specific mathematical form which computes the separate effects of oxygen and temperature on the rate of fish loss in a small section of stream, must now be defined. With little knowledge of these effects, except at extreme conditions, it is perhaps most reasonable to define a model which assumes virtually no effect on "Mortality and Emigration" except at these extremes. The following formulae are used to simulate these effects:

$$\text{Temperature Effect} = a \times (\text{Actual Temperature} - \text{Desired Temperature})^b$$

$$\text{Oxygen Effect} = c \times (\text{Actual Oxygen} - \text{Desired Oxygen})^d$$

The values for the exponents b and d were chosen to give the equation the proper form: high values for extreme deviations from the desired condition and virtually zero effects for small deviations. The coefficients a and c were chosen to convert the calculated values into the effect on the fishes specific daily survival. For this example it was decided that each factor could independently force the emigration of 5% of the fish in a section per day if the factor concerned reached its extreme. The oxygen extreme is 5 ppm and the temperature extreme is 80°F. There are no field observations to support the 5% per day figure. Although it may be totally inappropriate, it does not seem to be unreasonably high considering that these same temperature and oxygen levels could cause death under laboratory conditions.

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[33] Alexander, G. R. Fisheries Biologist in Charge, Hunt Creek Fish Research Station, Michigan. 1972. Personal communication.

Simulation of environmental values. The temperature model was used to simulate the river's daily temperature fluctuations for a typical day of each summer month, May through September. This simulation was carried out for the river with the Grayling impoundments, and as it might be without the impoundments. These values could then be used to provide the environment for running the fish model. The predictions to be used are for the stream section from the low-head dam at US-27 to the mouth of the East Branch.

Due to problems encountered in developing the separate oxygen model, the oxygen values used in this example are close to saturation levels. Slight, reasonable depressions are incorporated in the set of values for the river with impoundments. These values represent the daily maximum temperature and the daily minimum oxygen level.

The temperature predictions for the river were made under very low wind and clear skies and thus are probably higher than everyday temperatures. To compensate, it was decided that these warmer temperatures would occur about five times per month. This figure was arrived at after a qualitative examination of the temperature records. It was reasoned that warmer days occur more than two or three times per month, but certainly less than ten times per month. The remaining days were adjusted to have no additional effect on the trout population. The predicted maximum daily temperatures for May through September (with the Grayling impoundments) were 73, 77, 76, 75, and 71°F, respectively. The corresponding minimum oxygen levels were 6.0, 5.7, 5.7, 5.9, and 6.2 ppm. Without the impoundments, the maximum daily temperatures for this river section were 60, 66, 66, 66, and 64°F, respectively, for the months May through September. Oxygen levels were all above 7 ppm.

Essentially, the fish model will examine the effect on the trout population when the impoundments are causing five days of elevated stream temperatures per month during the summer. This will be contrasted with an identical trout population subject to the summer temperatures resulting from the removal of both Grayling impoundments. In order to make the comparison easier to understand, a standard recruitment of 1,000 age-class-0 fish has been assumed for both cases (with and without the impoundments). Temperature and oxygen will certainly have an effect on recruitments, but the effect would magnify differences which will appear in any case.

Figure 70 compares the monthly population figures for the last year of two 12-year simulations, one with the impoundments in place, one with the impoundments removed. By examining the end point of an extended simulation under constant environmental conditions, it is possible to approximate the long-run equilibrium population without concern for the initial population levels. Comparing the two situations for both the total fish remaining and for the number of older fish remaining, it is evident that the trout fare much better after the impoundments are removed. The exact numbers are meaningless, but the relative sizes of the two populations imply that the trout population is subjected to a severe stress by the thermal effluent from the impoundments. Recalling that the model should be a conservative estimate of the temperature and oxygen effects on the trout, it is not difficult to see that the impoundments are capable of producing a major stress on any trout immediately downstream.

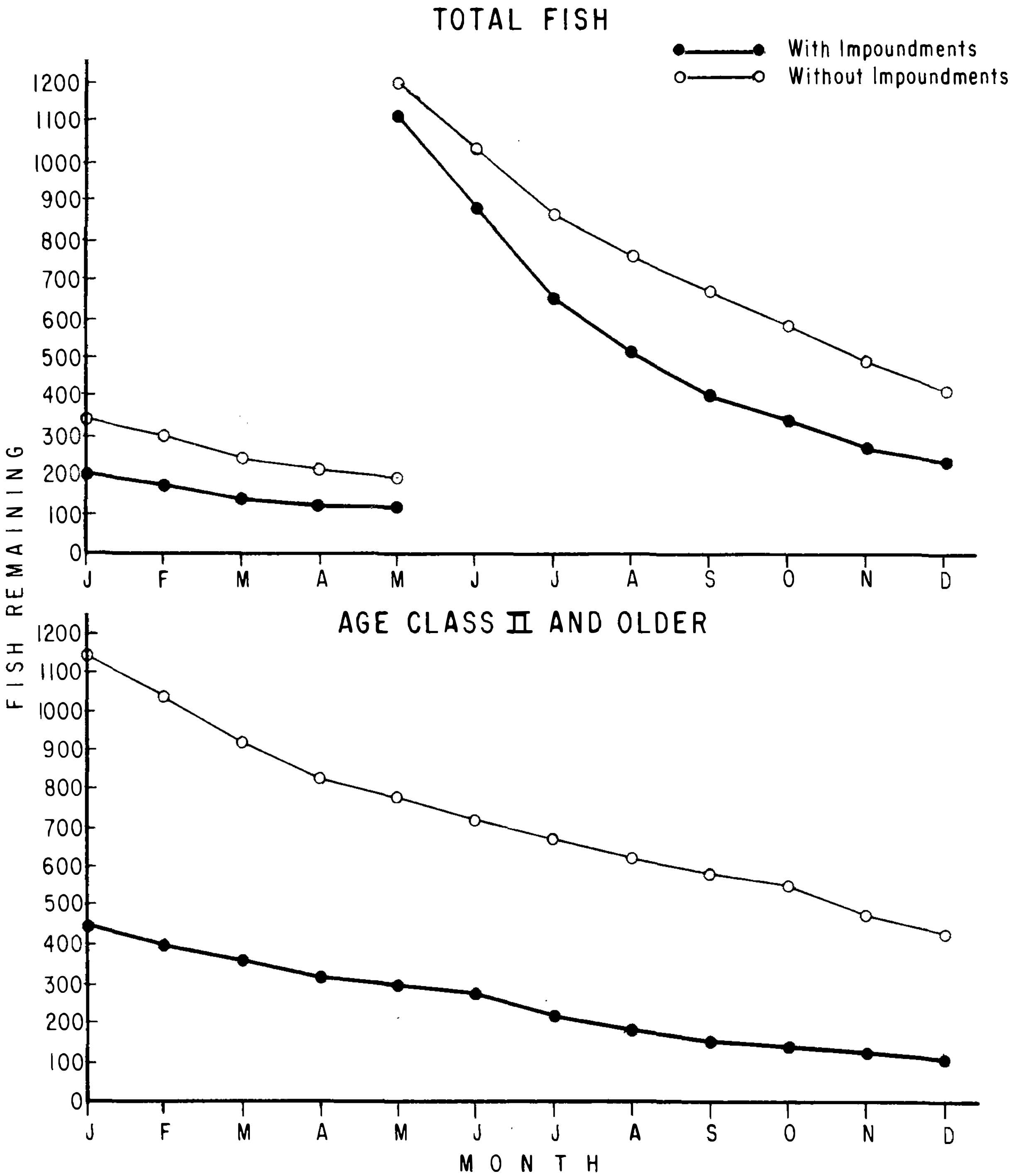

Figure 70. Predicted numbers of trout in the Au Sable River at Grayling, based on effects of temperature and D.O. regimes with and without these impoundments.

Thus, with only a crude model predicting the effects of temperature and oxygen on trout mortality, it is possible to illustrate the controlling factors in the present real world situation. It might have been hypothesized that the removal of the waste treatment effluent would allow the trout to become reestablished in the section of stream in Grayling. However, the model suggests that the major stress in this stream segment is the heated water from the impoundments. Although the exact numerical predictions are meaningless, the trends should be real. Other effects, such as fluctuating temperatures and inhibited recruitment, would further emphasize the difference between the populations with and without the impoundments.

Groundwater added to the stream, eventually cools it to more favorable temperatures. However, the thermal effects of the impoundments reach well downstream (see Temperature, Figure 65, page 193). If the impoundments were removed, this would certainly improve the thermal regime in the stream section now occupied by the impoundments. It would also make the river downstream assume summer temperatures more favorable for trout.

Oxygen (B.O.D. and D.O.) Model. It was expected that a model of biological oxygen demand and dissolved oxygen would be completed at this time. However, the Au Sable River presents some problems for modeling that have not been fully treated in the literature. One particular problem is that the river is just too clean.[34] Its B.O.D. levels are very low, probably on the order of measurement error and certainly on the same order as expected model error. This problem could be ignored, since the real problems in the river will only arise when it is receiving much larger inputs of waste. The present models of B.O.D. and D.O. are designed for these heavily loaded (polluted) situations.

The second problem appears to be much more difficult to handle. Existing models are formulated for rivers in which there is little diurnal variation in the water temperature, preferably less than a couple of degrees F. However, the section of stream near Grayling has temperature fluctuations of as much as 10°F. This forces a great change in B.O.D. breakdown rates and other related reaction rates. In addition, the temperature is a major factor in determining how much oxygen the water can hold. A model, which can account for variable temperatures, is now being developed. This model should prove to be quite useful for the application of dissolved oxygen models to similar streams in other parts of Michigan, and the United States.

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[34] McCracken, W. E. In Charge, Monitoring and Surveys Unit, Michigan Water Resources Commission. 1972. Personal communication.

Analysis: Effect of a "No-Kill" Regulation on Numbers of Legal Brown Trout in the River

Problem: Predict the effect of "no-kill" regulations on the legal-sized brown trout present throughout a season.

Factors to be considered:

Normal exploitation or capture rate
Natural mortality
Hooking mortality

The current discussion regarding the possible effects of "no-kill" regulations, prompted an attempt to quantitatively evaluate this topic. A rather simple model of fishing was developed. With this model, it was hoped that we could estimate the change in effective harvest resulting from "no-kill" regulations. Other research indicates that by stockpiling fish, there could be an increase in the number of captures during a season. However, over-winter mortality appears to be compensatory. That is, the mortality acts in such a way that the number of spring survivors is almost the same regardless of the number of fish which enter the winter. Thus the model need only be concerned with the changes in the fish population over the summer, since fish accumulated in the fall will affect little increase in the subsequent spring population.

We will start each fishing season with 1,000 legal fish (Fig. 71). The fishing pressure will act only on the survivors of these fish over the 20-week season. With normal regulations it can be assumed that every fish that is caught is kept. Under "no-kill" regulations it is assumed that every fish caught is returned to the water although some of these will die of hooking mortality. Those that live, remain just as likely to be captured a second time. For each experimental season we will define an "equivalent exploitation." This can be described as the fraction of the population which would be removed over the 20-week season (for this fishing pressure) under normal regulations. This "equivalent exploitation" will define the specific rate at which fish are being captured under either regulation. As a final approximation for the initial analysis, it can be assumed that the fishing pressure is distributed evenly throughout the season.

Table 23 shows the number of captures from the initial 1,000 fish population after a season at various fishing intensities. For example, the 5% "equivalent exploitation" means that the fishing pressure is such that 5% or 50 of the 1,000 fish would be captured over the season under normal regulations. This table also gives the computed captures for "no-kill" regulations with an equivalent fishing pressure. All of these captures are computed under ideal conditions to show the maximum benefit one might expect from special regulations. These ideal conditions assume no hooking mortality, no natural mortality, and no learning. While these assumptions are not realistic, they are used to show the most favorable results that could be expected. In the table, regulations are compared over a range from very low to very high fishing pressures. Notice that the benefit to be gained from "no-kill" regulations, increases as the fishing pressure increases. This is to be expected. The value of this

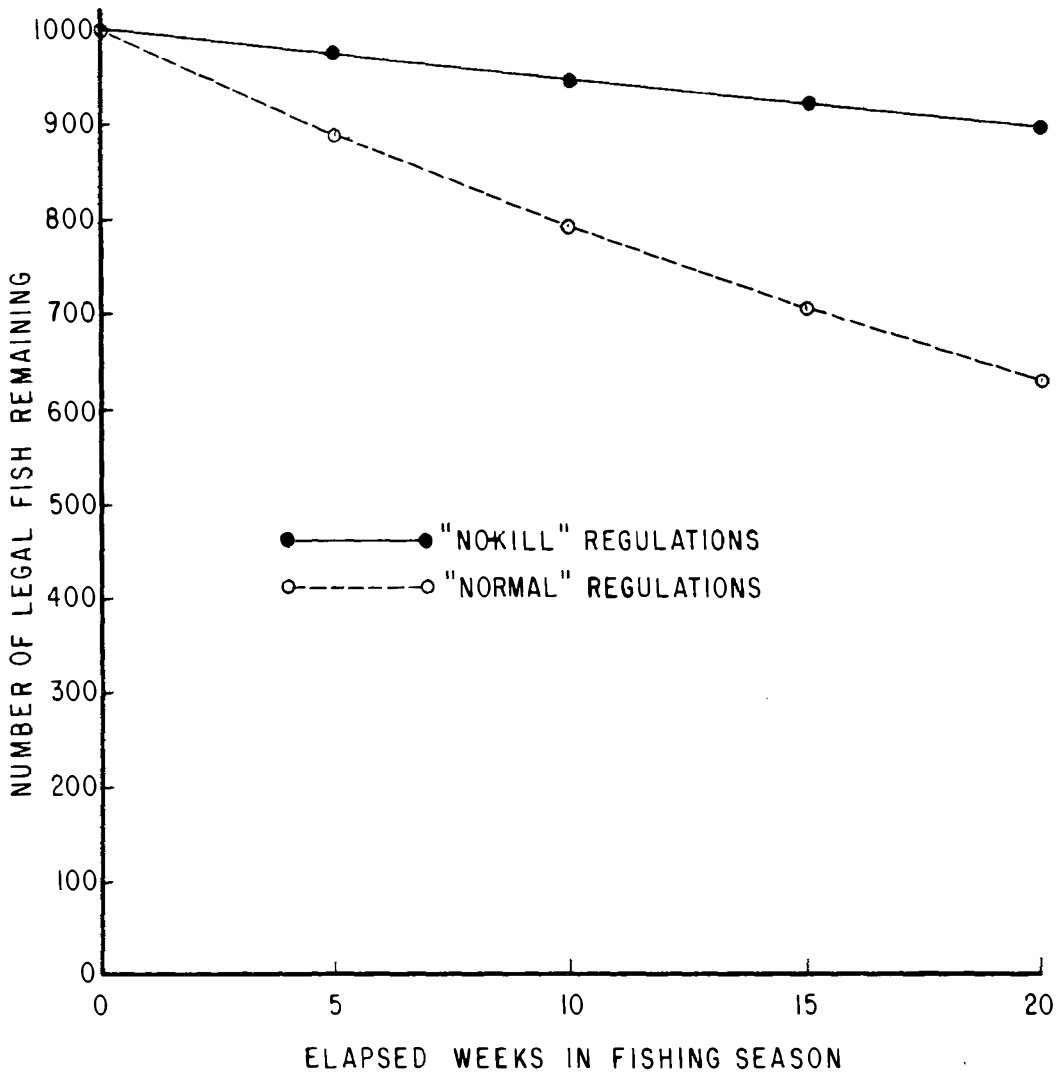

Figure 71. Comparison of the numbers of legal brown trout available during a fishing season, updated by five week periods, under "no-kill" and normal regulations. "Normal" regulations refers to the flies-only waters of the Au Sable River.

Table 23. Theoretical comparison of brown trout captures over fishing season

Conditions: 1,000 legal fish make up the original population. No natural mortality, and no hooking mortality are considered. Exploitation is constant throughout the 20-week season

Equivalent seasonal exploitation (%)	Number of Captures		Ratio
	Normal regulations a	"No-kill" regulations b	b/a
5	50	52	1.04
10	100	106	1.06
15	150	161	1.07
20	200	221	1.11
25	250	286	1.14
30	300	353	1.18
40	400	504	1.26
50	500	680	1.36
60	600	895	1.49
70	700	1,169	1.67
80	800	1,555	1.94

table is that it shows the order of magnitude of benefit which might be gained. Informal discussions around the state had suggested that fishermen might see a four- to six-fold increase in the number of captures under "no-kill" regulations. Our analysis indicates that for reasonable fishing pressures, this would not be the case.

Discussions with fisheries biologists [35] suggest that brown trout populations are probably subject to fishing pressures which harvest 15 to 30 percent of the population in a season. For the higher value of a 30% equivalent season exploitation, the model indicates that we might expect about an 18% increase in the number of captures by switching to "no-kill" regulations. Even if fishing pressure were high enough to remove 40% of the population over a year, the increase in captures under special regulations would only be about 26%.

Thus, there is not a ballooning increase in the number of captures to be expected under "no-kill" conditions. However Figure 71 does show that the difference is more dramatic in the residual population. Here we have imposed natural mortality and hooking mortality to make the example more realistic. Under normal regulations only 634 fish are left at the end of the season. Under the "no-kill" regulations, 899 fish are left. The major effect is increasing the late season captures, since more fish are left to be fished over. Figure 72 shows the number of captures by quarter for this same example. Notice that although the first quarter for each scheme is almost identical, later in the season the difference becomes pronounced. In addition, predictions were made for the situation where fishing pressure had been adjusted so that 75 percent of the catch came in the first half of the season. Again, the model predicted approximately an 18 percent increase in the total number of captures over the season.

Of course, all of this assumes that the fishing pressure stays the same when special regulations are imposed. Preliminary observations by the DNR indicate that the fishing pressure on some streams may drop significantly when special regulations are imposed. Hence this figure also displays the capture by quarters when special regulations are in effect, but the fishing pressure drops. Here, the equivalent seasonal exploitation drops to about half its original 30% value. Notice that there could be a major reduction in the numbers of captures rather than an increase.

These results are certainly preliminary, meant only to indicate the magnitude of change which might be expected. Even if these results were precise, they would be subject to alternative interpretation. However it appears that the increase in captures which might result from imposing "no-kill" regulations, must be less than the proponents of the plan have predicted. It seems that an increase in the number of captures may not be sufficient reason for imposing "no-kill" regulations. The real justification for special regulations would instead have to come from fishermen's preferences for a certain total experience which has at times been referred to as "quality fishing."

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[35] Latta, Dr. C. W. Biologist in Charge, Institute for Fisheries Research,
Alexander, G. R. Biologist in Charge, Hunt Creek Research Station. 1972.

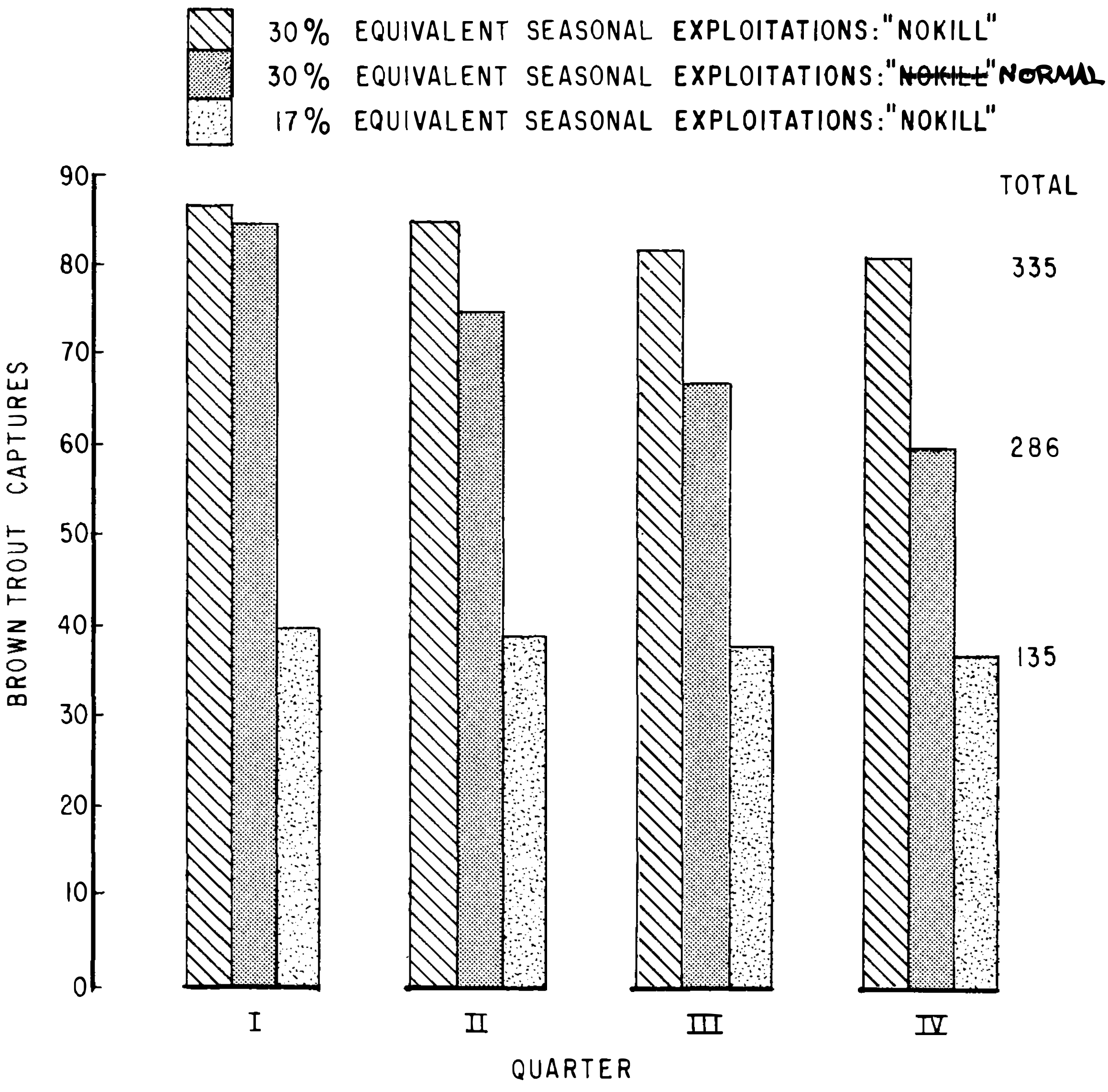

Figure 72. Number of brown trout caught, by quarters, under different regulations and exploitation rates. "Normal" regulations refer to present flies-only waters of the Au Sable.

As a final comment on fishing, it should be pointed out that the fisherman is only contributing a small amount to the fish's mortality throughout its life history. Only a very small portion of trout reproduction eventually becomes available for harvest. Table 24 shows typical proportions of surviving brown trout for different age classes, broken down into summer and winter components in addition to yearly survival. Figure 73 shows the effect of these survival rates on the relative numbers of successive age classes. Figure 74 shows the subsequent relative seasonal abundance. Notice that each of these figures points out the heavy mortality during the first year of a fish's life. In addition, Table 25 illustrates the relative contribution of various factors to total mortality. These weighted factors should be appropriate for parts of the Au Sable River.[36] The losses listed under "natural and hooking mortality" are primarily due to undefined natural causes during age classes 0 to I. Notice that only about 1% (13/1,000) of the spring population is really available to the fisherman. Different types of "natural" mortality account for most of the other losses.

NOTE: The doctoral dissertation of George Burgoyne, when it is completed, will be available from the University of Michigan graduate school, on an inter-library loan basis.

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[36] Alexander, G. R. Fisheries Biologist, In Charge, Hunt Creek Fisheries Research Station, Michigan Department of Natural Resources. 1973. Personal communication.

Table 24. Typical proportion of surviving brown trout, by season and age class, over a one-year period beginning and ending in spring

Age class	Proportion of brown trout surviving: Spring to fall	Fall to spring	For the year
0	0.10	0.30	0.03
I	0.60	0.50	0.30
II	0.60	0.50	0.30
III	0.60	0.50	0.30
IV	0.60	0.50	0.30

Table 25. Expected fate of a fish population consisting of 1,000 brown trout over a period of one year beginning and ending in spring

Age class	Spring population	Annual losses due to: Predation: Adult brown trout	Merganser	Undefined natural & hooking mortality	Angler harvest
0	958	465	93	371	...
I	29	10	2	8	...
II	9	...	1	2	3
III	3	...	...	1	1
IV	1	...	...	...(?)	1(?)
Total	1,000	475	96	382	5

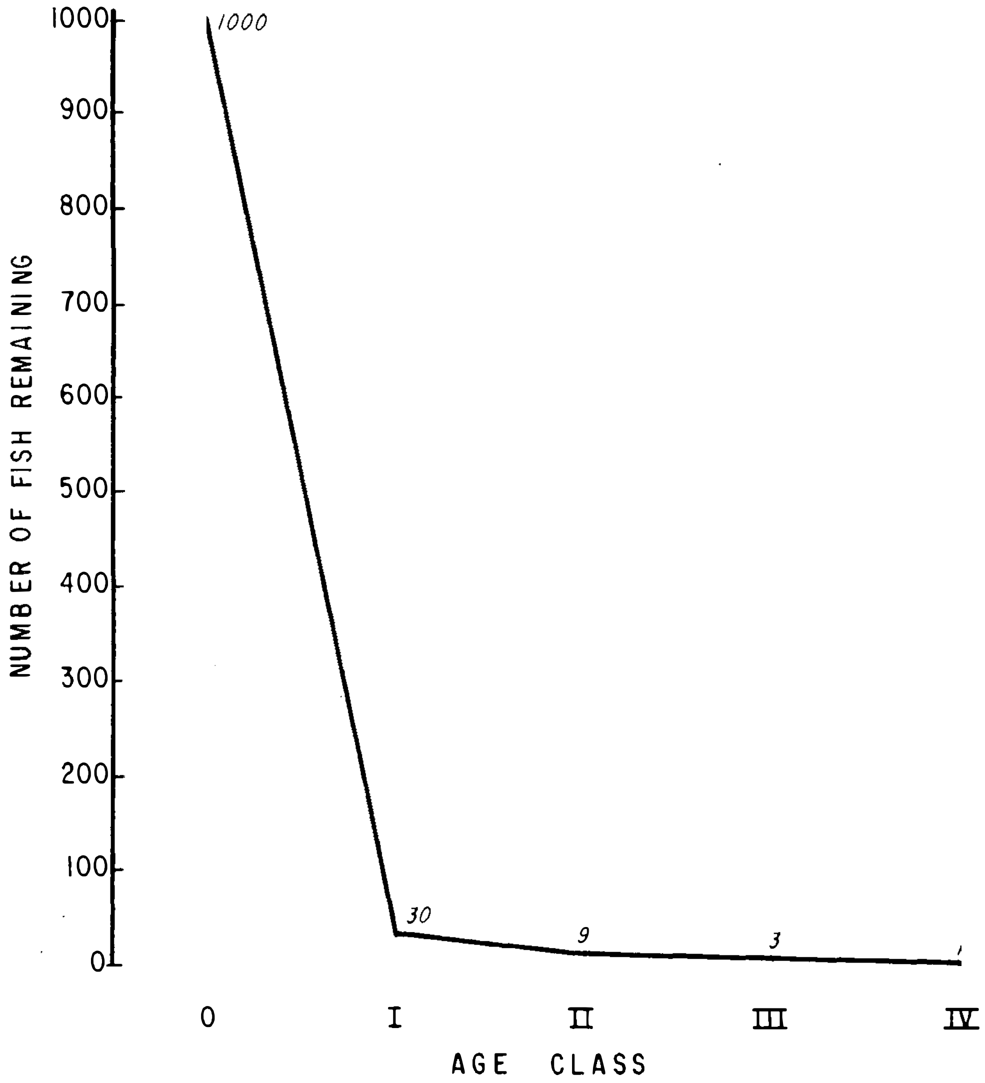

Figure 73. Typical pattern of survival for Au Sable River brown trout, beginning with 1,000 fry and entering the number remaining in the spring of each subsequent year over a four-year period. Note that when dealing with a larger initial population, some individuals will survive past age-class IV.

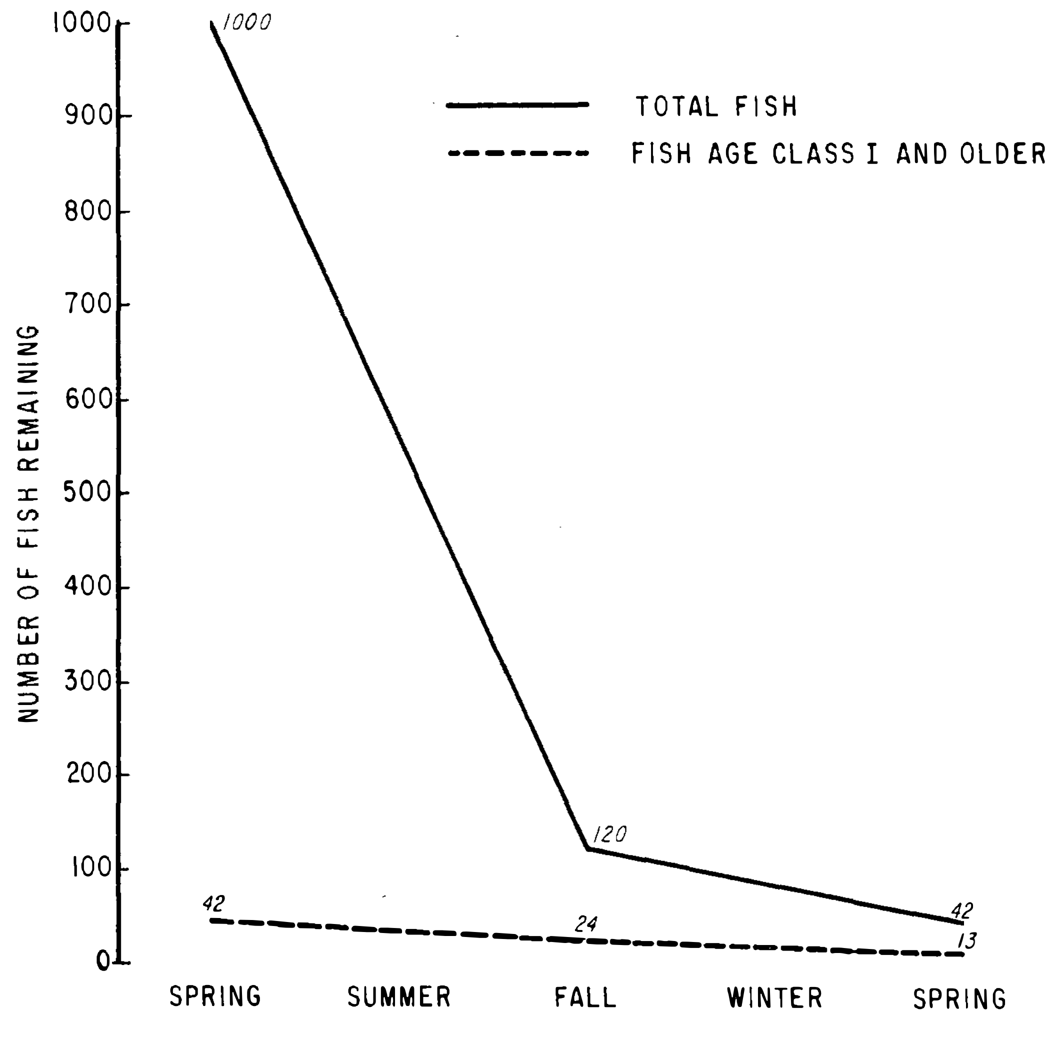

Figure 74. Typical pattern of survival for Au Sable River brown trout beginning with 1,000 trout and computing mortality, from all causes, for a single year beginning and ending in spring.

SECTION V. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Unique Characteristics

The Au Sable River is a recreational river system of high quality because of the geology and topography of the basin. These characteristics include: the gentle slope of the terrain, the sandy porous soil type that encourages infiltration of the precipitation delivered to the basin, and the resultant high groundwater yield that insures cool water temperatures in all seasons.

Historical Change

Pre-logging Period

Before significant human impact reached the area, the Au Sable Watershed uplands had a mature coniferous forest with some hardwoods. The predominant fish species was the grayling, a relative of the trout family. Habitat change and over-exploitation brought about its demise.

Post-logging Period

The stream had become more productive due to temperature increases and nutrient release, both caused by removal of forest cover. The resultant erosion of soils also provided nutrient enrichment. Ponds, built to store logs, further warmed the surface waters and disrupted plant and animal communities.

The effect of clear cutting would have resulted in increased streamflow, both from groundwater contribution and overland runoff, because much of the water loss due to transpiration was eliminated. A dense forest cover retards rapid snow melt in the spring. Therefore, the loss of this cover would result in more overland runoff and higher spring discharge. The scouring of the stream bed by release of water and logs from holding ponds, accompanied by an increase in sediment movement from logs, roadends, and bridge crossings, would also exact their toll on resident plant and animal communities.

Fires in the early decades of this century (Mich. Dept. of Cons., 1933) delayed the re-stablization of the system by renewed forest cover. The construction of hydro-electric dams permanently blocked spawning migrations of salmonids (introduced to Michigan), and brought about changes that favored the encroachment of less desirable warmwater fish species.

Present Status

While it is true that the Au Sable River has managed to "cover its scars," some of the activities that caused the scars have resulted in permanent change. There has been considerable change since man's arrival in the watershed, and change is continuing to take place today. Cottages and homesites are being developed along the river channels, and around the lakes in the headwaters. Because most of the upper watershed (above Mio) is in private ownership, uncontrolled development could easily result in serious enrichment of the system from septic tank seepage. Building along the river is also aesthetically displeasing to most recreational users that are seeking a wilderness experience.

Whereas the human population at Grayling has decreased in the last 50 years, the impervious surface area within the city (buildings, blacktop) has increased, because of service needs by an expanding population in the township and county and by tourists and weekend users. This increase of impervious cover results in a higher percentage of surface runoff (storm water) directly overland to the stream, carrying with it high levels of nutrients, impurities, and B.O.D. load. Roads leading to the river and to bridge crossings may have decreased over the years, but use of access sites has definitely increased. This use causes erosion problems, litter, and overuse of sanitary facilities.

There are now over 60 dams in the watershed in addition to power dams. Forty-four of these are on small feeder streams and have a lesser effect than those on the Mainstream and major tributaries. Nevertheless, these small ponds impound streamflow, increase water temperatures, and in most cases block fish movement.

Some improvements have also taken place in recent times. Many of the old lumber storage dams have been removed, second growth forest cover has stabilized stream banks and added shade to small streams, stream modification structures have improved habitat, and there has been a positive response of trout which is well documented. The diversion of sewage effluents from the river at Grayling and Roscommon will improve conditions for communities of sensitive coldwater animals in the degraded zones immediately downstream that have been subjected to the direct adverse effects. However, the long-term effects on trout in the "quality trout-fishing waters" several miles downstream from Grayling must be carefully evaluated. Trout populations in this area have demonstrated a notably high standing crop in terms of pounds of trout per acre of stream. It is possible that these fish have, to some degree, benefited from the additional nutrients available at a point where other environmental conditions (adversely affected in closer proximity to Grayling) have totally recovered. Greenbelt ordinances along stream frontage will help preserve the wilderness character of the Au Sable.

Existing Environmental Quality

Due to Natural Conditions

Lakes and wetlands in the headwater areas of most Au Sable tributaries exact a high rate of evapo-transpiration, and create conditions that are not suitable for coldwater species. This situation exists in all feeder streams with the exception of Big Creek (south). There are other low-lying areas of low velocity and little groundwater input, such as the South Branch above Roscommon, and the Shellenbarger swamp below Grayling, that also constitute poor trout habitat.

Nitrate-nitrogen levels are high in the upper Mainstream and East Branch, because of local groundwater recharge from marshy areas. High phosphate readings are found in swampy areas as well as in surface runoff. Chloride levels are relatively high in the upper South Branch below Lake St. Helen, due to the geology of the area, although salt water escaping from transmission lines in the Lake St. Helen Oil Field have reached the river on occasion.

Due to Human-Induced Changes

Water treatment facilities. Nutrient increases from sewage effluent inputs at Grayling and Roscommon have stimulated aquatic weed growths downstream, resulting in a depression of dissolved oxygen. Effects of the Grayling treatment plant were the more pronounced because of a larger volume input, lower groundwater dilution, and the physical character of the river channel. The Grayling sewage effluent has now been diverted to off-river disposal, and the Roscommon lagoon, spray-irrigation complex is scheduled for completion by the fall of 1973.

Storm water runoff. Urban runoff during the first hour of intense storms can have an impact on the river equal in magnitude to sewage effluent. Phosphates and chlorides were at high concentrations in all storm drain samples. Samples of river water, above and below storm drain inputs, have demonstrated increases in these constituents. Gas and oil residues are prominent constituents of surface runoff along with other impurities that threaten the aquatic life of the river.

Response of aquatic communities to sewage effluent. This stimulus has increased rooted aquatics (weed beds) and algae, and has altered insect and fish communities in favor of more tolerant species. Periphyton analysis shows that growth increases many times below the village of Roscommon due to the effluent. Periphyton growth increases from above, to below Grayling as well, but not as dramatically without the sewage effluent input. In the absence of sewage, *Sphaerotilus* (commonly miscalled sewage fungus) has disappeared, and insect communities have begun to recover.

Impoundments. Between fish and insect data there is good agreement that the impounded waters along the river have effected major species changes that reach some distance above and below the ponded areas as well as within them. Periphyton samples below the Mio Dam showed that primary productivity had increased relative to a station above the pond. In every case, investigations showed that animal communities had suffered a decrease in diversity and a decrease of intolerant forms below dams. Surveys conducted within the major basins along the Mainstream also demonstrate major changes in fish communities. Coldwater fish species (trout) are rare in occurrence, and warmwater game fish are slowly giving way to rough fish species.

Sediment movement. The movement of sand that resulted from the I-75 bridge and pipe line crossings below Grayling, disrupted all forms of aquatic life in the river below. The sand so displaced has now at least partially filled in dredged areas in the river channel below Shellenbarger. The dredging was done to provide fill for building sites. Insect communities in the affected area have a low diversity, and the abundance of trout appears to be down from preceding years. The heavy sand load is only one of many adverse effects on this area, but one that is known to have a serious impact on a stream's plant and animal communities.

The lower East Branch was also subjected to a heavy sand input from the I-75 crossing, and that stream has a very low insect diversity above North Down River Road. A seined fish collection, made in 1972, to compare with a similar collection in 1924, revealed a 65 percent reduction in the number of fish species present (largest such reduction in the watershed).

Cottage construction. There were no inputs of nutrient matter or coliform bacteria directly traceable to individual cottages or to groups of cottages. However, preliminary results from a detailed study of Houghton Lake[37] demonstrate that nutrients in significant concentration can move more than ten feet vertically to the water table (especially in sandy soils), and over 100 feet laterally within the water table. Dorance Brege (1968) attempted to trace movement of waste water through septic systems along the upper Au Sable; he reported contamination of river water in at least four situations; although this represented only two percent of the systems tested, many were not in continuous use. Brege's results certainly do indicate that poor placement of individual septic systems can result in significant contamination of surface waters.

The heaviest concentrations of cottages coincide with the best areas of the stream where there are: fast current velocities, gravel-riffle substrate, and good groundwater contribution. Consequently, any changes in water quality that could affect insect and fish communities would be largely compensated for by the physical character of the stream (aeration), and by groundwater dilution.

Recreational use of the stream. Recreational use of the river causes erosion problems at access points including campgrounds, roadends, bridges, and public access sites. The litter associated with this use, in and along the river, is also increasing. Both of the above can be confirmed by a visual inspection of the river. Physical disturbance of aquatic communities and fish cover is more discreet, but still a very real problem. There is no reason why man cannot work out a compatible plan that would allow continued recreational use of the river without undue confrontation and degradation. Preservation of the natural character of the river system is paramount to this end. If water and habitat quality are allowed to deteriorate, as they have on many other rivers in Michigan, there will be no great demand for recreational use. Therefore, all interests must insure that use of the river is well designed and controlled.

Trout Management Information

Because of the necessity of limiting the scope of this report to the identification of the effects of continuing human use and development on the aquatic ecosystem, aspects of fishing quality could not be properly covered. Therefore, persons interested in information on angler surveys,

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[37] Novi, J. R. 1972. Demonstration of Water Quality Protection at Houghton Lake. Progress Report July 1 to September 30. Water Quality Appraisal Section - Biology Unit, Michigan Bureau of Water Management.

trout population levels, trout tagging programs, fishing regulations, and other related questions should contact:

Michigan Department of Natural Resources
District 7 Headquarters
Box 146
Mio, Michigan 48647

and,

Michigan Department of Natural Resources
Hunt Creek Fisheries Research Station
Star Route 1
Lewiston, Michigan 49756

Recommendations

The Au Sable River should be designated as a coldwater recreational system, so that the anticipated impact of future activities in the watershed can be evaluated and controlled on this premise.

Nutrient Enrichment

No domestic, industrial, or agricultural waste products should be discharged directly to recreational streams such as the Au Sable. Even treated effluents should not be so disposed of, unless processed to such a degree that the quality of receiving waters is not lowered, and chlorination is not required as a disinfectant. An accidental discharge of chlorine water into the Au Sable at Grayling, in the summer of 1969, resulted in a substantial kill of trout (Mich. Dept. of Nat. Res., 1972). Chlorine forms compounds with ammonia, which is a readily available component of sewage effluent. These compounds are called chloramines and they persist longer in receiving waters than does chlorine alone (McKee and Wolf, 1963). The high toxicity of these compounds to fish, even in very low concentrations, has been well demonstrated. The more likely result below waste outfalls, where effluents are chlorinated, is the absence of normal numbers and species of fish.

An engineering recommendation (Rich Svendory Engineering Firm, Traverse City) for sewering needs for the area west of Grayling and the lower East Branch calls for an expenditure of 5.5 million dollars. There is a need at both state and federal levels for support of projects that would upgrade sewage disposal methods for areas not presently discharging wastes directly to waterways. Such assistance in funding these projects could preclude serious problems in the future. However, such a plan should not be interpreted as encouraging additional building in areas along the river where requirements for private septic systems could not presently be met, as outlined in the following paragraph.

The Crawford County Greenbelt zoning laws should read "six feet to water table - and no fill," as stipulated by the Otsego County ordinance, unless it can be demonstrated by field studies that a lesser depth of soil is adequate to prevent contamination from reaching the river. Based on preliminary findings of the Houghton Lake Study, some of the nitrates and phosphates could still reach waterways, but uptake by vegetation should utilize much of the input. The movement of nitrates, phosphates, and chlorides is governed primarily by soil types, degree of loading of the system, and the groundwater hydraulics. These factors should all be investigated and evaluated for a given area before zoning requirements are stipulated. Preliminary inspection of proposed building sites by zoning officials would allow better specification of the type of waste disposal system employed, and better location of drain fields with reference to groundwater, to surface waters, and to spring seeps. The sandy soils of the upper Au Sable Basin have a very low capacity for nutrient removal and stringent controls are needed. It is essential that all building on flood plain and lowlands be prevented to protect the river from almost certain contamination.

Test wells are in place to monitor the Grayling lagoon and sanitary landfill site, and a sampling program should be initiated forthright to gather baseline data for existing groundwater quality. Robert Larson, USGS hydrologist at Grayling, stresses the need to detect the presence of, to test the potability of, and to discover the combined effects on humans of, various chemicals reaching groundwater as a result of seepage from waste disposal sites.

A test well and a sampling program are also needed for the Bear Mountain sewage lagoon, which now serves a trailer park and stables in addition to the recreational complex.

There will be a total of 14 test wells associated with the Roscommon lagoon and spray-irrigation sewage disposal system. A sampling program for these wells should be initiated immediately. It is highly desirable to gain baseline data on background levels of groundwater parameters in the region, in order to monitor the effectiveness of the system in removing the key waste water constituents.

A more intensive study is needed for the individual septic system in areas such as Karen Woods (just above Grayling), and the subdivision below Shellenbarger (built over a fill of river bottom spoil). Septic systems in permanent use, in these low-lying areas, should be highly suspect of providing seepage to the river. Such a need for further study was suggested by Dorance Brege in his thesis (1968). Ellis and Erickson (1969) showed that most soil types can recover their ability to absorb phosphorus, if not in continuous use. Therefore a follow-up study on Au Sable private septic systems should be directed at homesites that are occupied year around.

Brege (1968) also commented on the need for close inspection by county officials of septic system placement. He cited the need to study a soil's ability to absorb nutrients, in addition to its permeability. Dean Urie, USFS at Cadillac (personal communication), feels that some soils can become charged with nutrients from continuous use, and thereafter be less effective in further adsorption of these nutrients.

The village of Mio should be encouraged to build a community sewage disposal facility (off-river) to solve the problem of a contaminated water supply, rather than to bring in "safe" water from a new supply as has been proposed.

According to the 1966 WRC report, Oscoda has periodic failure associated with private septic systems. A study should be undertaken to determine the need for a community collection and disposal system.

Surface Runoff

Contamination of the Au Sable watercourse from urban type surface runoff is becoming increasingly more serious. This is, of course, brought about by the increase of impervious cover type (roots, concrete, packed soils) that results in overland flow of rains and melt waters to the river. The amount of contaminating material reaching the river can be reduced by frequent sweeping of streets and gutters, including hard-surfaced parking lots, and especially gasoline service stations and auto garages (Sandoski, 1972). Grayling and Roscommon conduct sweeping operations as necessary.

Intercept basins have been designed for new communities to collect surface runoff, treat it, and even process it for community use (Mallory, 1973). Because Grayling and Roscommon are built right on the river channel, there is little opportunity to intercept surface runoff before it reaches the river. It would, therefore, appear more practical to minimize the adverse effects by periodic cleaning of village streets. However, an engineering feasibility study should be conducted in regard to the construction of intercept-recharge ponds, or catch basins, for the retention of surface runoff in all villages in the basin that are located on the river channel. Small catch basins can be more of a detriment than the direct drain system, unless they are frequently cleaned (Sandoski, 1972).

If at all possible the open areas, that still remain near the river channel, should be kept in an undeveloped state (Hendrickson, 1972). In Grayling this would include the school recreation field, the city athletic field, the fish hatchery grounds, the river park, and the golf course. The exposed uplands below M-72 west of town (should the "stump" pond be removed) would also be included. This would help balance the area covered by pavement and roof tops, by providing recharge areas. Legislation is pending that would require adequate headwall to prevent siltation where storm drains are incorporated in bridge abutments. However, legislation is needed that would govern the quality of surface runoff that could be diverted into public waterways through storm drains.

Because of these inherent problems in "river front" communities (water use, solid and liquid waste disposal, surface runoff, sea walls, and aesthetics), and because such waterways are no longer needed for transportation, commerce (excepting canoeing), water supply, and waste disposal - communities should be built elsewhere. They should be designed and located in areas where the building complex, along with its associated service needs (water supply and waste disposal), would be the least disruptive of natural resources. A tax preferential system, for encouraging building in less sensitive areas (environmentally) or for leaving lands in an undeveloped state, should be adopted.

By locating new communities away from rivers, surface runoff and waste water could be contained, filtered, treated, and allowed to infiltrate to groundwater storage, or be processed for various water supply uses.

Oil Wells

The transmission line failures, that have occurred in the Lake St. Helen oil field on the upper South Branch, have resulted in oil and salt-water spills that have reached the river. Although changes in the location of these lines have made such contamination less likely, a regular sampling program of surface and groundwater at certain sites would be desirable for the early detection of such failures; the Sherman Bridge site is a case in point.

Water Use

The most important consideration for recreational streams is to maintain high drought flow, and consequently low summer temperatures where trout are present (Hendrickson, 1972). The planned use of water on a regional basis is necessary to assure maximum streamflow during dry seasons.

When the groundwater aquifers that supply the upper Au Sable River Basin are delineated by geological survey agencies, it will be possible to determine the amount of water available to users in the basin. It should then also be possible to interpret the effect of flowing wells, plus withdrawals for lawn irrigation and other consumptive uses in the hydrologic cycle. Although it appears that only a small amount of the available water supply is presently being utilized, placement of new wells should be carefully evaluated for possible effect on streamflow. Syd Dyer, the regional geologist (State of Michigan) at Roscommon, is gathering information from oil exploration activities to map locations of the groundwater table. This will constitute the first water table maps for northern Michigan. This information will be essential for land use planning, as new community development should not be located in areas where the water supply is limited or critical in maintaining summer base levels in streams and wetlands. The direction of groundwater movement is of great importance in selecting waste disposal sites. Dyer also recommends locating and capping abandoned wells (flowing wells) to help conserve the groundwater supply.

Construction of a pond in the stream channel, or connected to it, should not be allowed in coldwater systems. These ponds serve as nutrient banks, and provide warmer water downstream during production seasons, resulting in accelerated eutrophication.

The location of wells and the timing of withdrawals are also of prime importance in maintaining high drought flow (Hendrickson, 1972). Wells located at some distance from the river channel would not be as likely to affect groundwater contribution to streams during low-flow periods. It is evident that regulation of both surface and groundwater withdrawals will be necessary in order to maintain the integrity of these coldwater, recreational stream systems.

Impoundments

The case against impounding waters on trout streams, including feeder systems, is well documented by data that demonstrate the resultant changes in plant and animal communities. Nearly every quantitative or qualitative collection in the Au Sable basin, relative to impoundments, demonstrates their degrading effects on the environment.

The dams above Grayling should be removed, on the basis that they no longer support significant populations of coldwater or warmwater game fish or waterfowl, and that they warm surface waters to temperatures unsuitable for trout. The removal of the "stump" pond would lower the water table and thereby improve septic tank operation in the Karen Woods Subdivision. The dam removal should be preceded by installation of a coffer dam and settling basin downstream to trap sediment until the channel has cut down (by stages) to the original grade. Once this is accomplished, the stream banks can be vegetated and stabilized. This pond is shallower, more productive, and provides more of a temperature increase than does the upper pond. Improvement in the temperature regime can then be measured and evaluated before the decision is made to remove the upper dam (the old power dam above M-72). This dam is in poor physical condition. If the dam is not removed in the near future, extensive repair work may be necessary to prevent a possible failure.

It is further recommended that when the six power dams from Mio downstream are no longer needed to produce power, they be removed. Mr. Gary Schnicke, fisheries supervisor at Mio, has informally proposed the following plan. He would leave a barrier at the present location of Foote Dam to prevent further upstream progress of lamprey. Another barrier would remain at Mio to block passage of all fish, and maintain the integrity of resident trout in the upper watershed. By this action, there would be 59 additional miles of river to be utilized for a burgeoning anadromous fishery, in place of the mediocre warmwater fishery that now exists. This action would also result in an increase of canoeable miles of river.

Dam 2 in the upper North Branch (Otsego County) is a holdover from the logging days; currently it has a head of two to three feet. The impounding of water at this point serves only to extend the warmwater character of this area further downstream. The dam should therefore be removed.

The removal of the old Blonde Dam on the lower part of Big Creek (north) since the 1920's has resulted in a substantial improvement in the trout population in this stretch of stream. The removal of small dams on many other streams has resulted in restoration of temperature regimes favorable for trout.

There are three wildlife floodings in the basin. Two of them - the middle branch of Big Creek (north) and Conner's Flats flooding on a small tributary above McMasters Bridge - have good groundwater coming in downstream to offset warming effects. The third - Robinson Creek flooding in the upper South Branch - is in a low-lying area in the swampy headwaters of this creek. Robinson Lake also feeds these headwaters, so it is unlikely that there is any increased effect on maximum temperatures.

Beaver dams, found to be creating temperature problems in coldwater feeder streams, should be removed as well. These ponds eventually result in an increase of rooted aquatics, and decomposition of organic material leading to wider fluctuations of dissolved oxygen and lower nighttime concentrations of oxygen, that are detrimental to trout (Adams, 1953).

Under authority of the new Lake and Streams Act (346, PA of 1972) the DNR should oppose the construction of any more dams along the Au Sable, its major tributaries, or designated coldwater feeder streams. Under the WRC water quality standards of 1968, nearly all of the Au Sable is to be protected for intolerant fish, coldwater species. Accordingly, any damming of stream sections so designated would be in violation of these standards. Of the 67 dams in the basin, only 15 are located in waters designated for warmwater species.

However, removal of dams should be carefully considered as to the total advantage to the local stream ecology. Removal of dams must be accomplished in such a manner that stored sediment and oxygen-demanding matter do not create problems downstream. All dams, especially abandoned ones, should be inspected to anticipate possible failures. In the final analysis, it is desirable to prevent the installation of dams that will result in obviously adverse conditions for trout, rather than to deal with complex problems in effecting their removal after they are in.

Erosion

There are many eroding banks along the Mainstream and major tributaries that contribute significant amounts of sediment to the river. This problem is presently being addressed on the Au Sable and other streams by an on-going stream improvement program by the Michigan Department of Natural Resources. Primary emphasis so far has been on major problems between Grayling and Burtons Landing.

In most cases, bridges constitute legal access points to streams. To prevent erosion from this use, three corners of the bridge could be fenced off, while the remaining corner could then be stabilized (riprapped) to prevent erosion at the single access point.

Sand banks, the typical type in the Au Sable River drainage, are particularly susceptible to erosion. It is difficult to maintain a vegetative cover on sand banks used for access to the stream. Accordingly, rails and steps must be installed in these areas so that access can be controlled. Rules for campground and access sites should be prominently posted to advise the users of necessary restrictions.

The removal of trees, brush, or other cover on the uplands along the stream margins, or the removal or placement of in-stream cover (logs, rubble, sweepers, structures, etc.) by other than the designated resource agency, should require a permit from the proper authority. Controls, authority, and enforcement to regulate this activity should be clearly spelled out in a Greenbelt ordinance.

Stream improvement devices are designed both to stabilize banks and to provide additional cover for trout where workable. Also, where possible, consenting riparians are having docks rebuilt that will comply with Greenbelt codes, as well as afford bank protection. These activities should be continued, as part of an overall plan for the watershed.

All roadends should be blocked off at least 50 feet back from the water's edge, and the "buffer" area planted with a hardy form of vegetation.

Canoe landings and other high-use areas should be sand-bagged with cement below and just above the water's edge (as the lower part of the Au Sable canoe campground above Burtons Landing) to withstand heavy traffic.

A canal, that enters the Mainstream 3/10 of a mile below the Shellenbarger outlet, was dredged in the late 1950's. A bridge of land now separates the upper end of the canal from the Mainstream just below beaver island. If connected, this canal would cut off about a mile of river including the Shellenbarger outlet. The canal is silt laden and likely contributes some nutrient matter to the river during storms. The canal, in effect, provides access to the Mainstream and riparian privileges where they did not previously exist. In the future, providing additional access in this way can be prevented under Act 346, PA 1972. Presently, only one of several lots along the canal has a cottage. It is recommended that no further cottage development be permitted along this canal, or along the Mainstream between the canal and Mud Creek, to preclude the possibility of septic seepage to the river.

The construction of bridge and pipeline crossings should be subjected to continued close supervision. Coffer dams and settling basins should first be constructed downstream to prevent any unavoidable sedimentation from eroding banks. All raw earth cuts during construction should be quickly covered and protected to prevent erosion. Pipeline crossings should be tunneled under the stream if at all possible, with proper precautions taken in case of a cave in. Proper procedures and protective measures, in regard to such stream crossings, are detailed in a DNR handbook of specifications. These specifications are included in the required permit, along with other stipulations that are deemed necessary in regard to a particular crossing, and are legally binding upon the contractor.

Recreation

Because of the unique value of the Au Sable River system to all of the people of Michigan, there is no real point in indicting any single interest group for problems associated with its use. Continued use of the stream must be well designed and managed in order to preserve desirable habitat and water quality, necessary for the maintenance of endemic plant and animal communities.

Existing campgrounds and access sites should be improved before any new ones are developed, including:

Adequate set-back of camp sites from the river (100 feet).
Streambank frontage stabilized and protected (rip-rapped, stepped, railed off, graded, and seeded).

Adequate sanitary facilities and maintenance, with all users required to carry litter bags.

All users should be required to finance associated services.

Canoeing could be encouraged on other systems, as well as during late fall and winter on the Au Sable, to relieve the summertime pressure on the Au Sable.

River use rules should be implemented, that will restrict the number of canoes on portions of the river that are now overcrowded. Such rules would require that watercraft be identified and have suitable containers for food, beverages and litter. Most importantly, the river user must be exposed to the concept of the river system as a fragile, irreplaceable natural resource. Until river users can be so oriented, rules and regulations will be directed toward the symptoms and not the cause of habitat destruction.

Recreational vehicles (all-terrain vehicles, motorbikes, snowmobiles, etc.) must be prevented from destroying vegetative cover on streambanks and uplands. This can be accomplished only by limiting their use to marked trails.

In order to keep the river scene in as natural a state as possible, Greenbelt ordinances could be revised to require a minimum building set-back of 50 feet where there is over 10 feet of elevation and an adequate vegetation screen, and a 100-foot set-back where there is not. The Betsie River plan, under the Natural Rivers Program, calls for a 200-foot set-back and allows the building site to be moved 5 feet closer to the river for every 5 feet of elevation above 5 feet, but not closer than 150 feet.[38] Such a plan could prove adequate along the Au Sable, modified to a 100-foot set-back but no closer than 50 feet.

In the final analysis, if the Au Sable system is to be maintained as a top-quality recreational river, a concerted effort must be made at all levels of government with the full cooperation of riparians. This may require state-wide land use zoning because so much frontage of the upper river is in private ownership and otherwise under the control of various governmental units. As noted by Gerth Hendrickson (1966), the status of most of the remaining undeveloped wilderness areas that adjoin the Au Sable are owned by Consumers Power Company. The retention of the wilderness character of this frontage for the enjoyment of future generations depends upon it remaining in its present state. At such future time that the river frontage is of no further use to Consumers Power Company, some suitable plan should be worked out between the public and the power company to preserve the wild areas of the river. This unique river system is needed by the people of Michigan for recreational enjoyment, and all other uses should be subordinate to this need.

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[38] Vollmar, Bruce. Rivers and Shorelands Specialist, Mich. Dept. of Nat. Res. Office of Planning Services. 1973. Personal communication.

Models

Computer models, programmed with mathematical expressions of various biological, chemical and physical interactions, can be of considerable value where a number of variables need to be considered (simultaneously) in dealing with complex aquatic ecosystems. In this way, the probable impact of any one of several management options can be predicted before a final decision is made. This is especially important in bringing to light possible adverse results that may not otherwise have been anticipated

The modeling procedure has also proved to be a useful tool in evaluating existing habitat and water quality conditions, that are a result of natural causes as well as human-induced impact. In this report we have been greatly aided by modeling techniques in two areas of interest: the definition of problems with temperature regimes and response of trout populations, stream stability and surface runoff; and the effects of proposed fishing regulations on the availability of large brown trout to anglers. The models have been kept quite basic in their approach to these problems, because of limitations of time and manpower. Field data and field observations were used for model verification.

Other subject areas that affect river systems, such as hydrology, land use patterns, and the impact of political power groups, will also be examined by models now being designed and utilized in the University of Michigan Sea Grant Program. The modeling procedure not only facilitates the examination of complex natural systems, but delineates areas of insufficient data where further research efforts are needed.

As additional ecological relationships are defined, and output information is tested against "real world" conditions, broader application in dealing with environmental problems will be possible. Universities and governmental agencies at all levels should work together in developing the use of models, as part of the decision making process, so that the intelligent use of natural resources can best be served.

SECTION VI. APPENDIX TABLES

Appendix Table I-A. List of survey stations and their locations on the Au Sable River and tributaries

County and Station	Location	T.	R.	Sec.	Miles above mouth
Crawford					
1	Frederic Co. 612	28N	4W	35	127.1
1A	Kolka Creek	28N	4W	11	131.4
1B	Bradford Creek	28N	4W	12	131.2
Otsego					
1C	Kolka Creek	29N	4W	23	137.9
Crawford					
1D	Bradford Creek	28N	3W	6	133.2
1E	Cameron Bridge	28N	4W	26	127.7
2	Pollack Bridge	27N	4W	36	118.1
3	M-72 (west of Grayling)	26N	3W	7	115.2
4	Maple St. (Grayling)	26N	3W	8	113.7
4A	Sewer pipe (Maple St. Br.)	26N	3W	8	113.7
5	I-75 (east of Grayling)	26N	3W	8	112.7
6	Burton's Landing	26N	3W	11	108.7
7	Stephan's Bridge	26N	2W	5	104.6
8	Wakeley Bridge	26N	2W	12	100.3
9	McMasters Bridge	26N	1W	11	93.2
Oscoda					
10	Parmalee Bridge	26N	1E	2	85.1
11	P.A.S. Co. 606	26N	2E	6	80.8
12	Mio M-72	26N	3E	7	73.0
13	Comin's Landing	26N	3E	11	65.0
Alcona					
14	Alcona Dam	25N	5E	14	46.5
Iosco					
15	5-Channels Dam	24N	6E	23	29.9
16	Foote Dam	24N	8E	35	13.7
17	Oscoda US-23	23N	9E	10	0.2
Crawford					
18	Co. 612 (E. Branch)	28N	2W	30	13.3
18A	Jones Lake outlet (below) (Robinson's Dam)	28N	2W	30	12.6
18B	"Cabin"(E.Br.) (CCC Bridge)	28N	3W	36SW1/4	10.8
18C	Hartwick Pines (E.Br.) (Military Road)	27N	3W	12SE1/4	9.9
18D	Lewiston Grade Rd. (E.Br.) (above Meadows)	27N	3W	14	8.1

Appendix Table I-A. (concluded)

County and Station	Location	T.	R.	Sec.	Miles above mouth
Crawford					
18E	Karen Lk. Rd. (E.Br.) (below "Burnt Dam")	27N	3W	23NW1/4	7.5
18F	Wilcox Rd. (E. Br.)	27N	3W	28SW1/4	3.7
18G	Milliken Rd. (E.Br.)	26N	3W	5NW1/4	1.4
18H	N.Down River Rd. (E.Br.)	26N	3W	5SW1/4	0.4
19	Hosp. Br. (E.Br.)	26N	3W	8NW1/4	0.2
Roscommon					
20	Roscommon M-144 (S.Br.)	24N	2W	5	19.5
Crawford					
20A	P.A.S. below WWTP (S.Br.)	25N	2W	31	17.5
Roscommon					
20B	Sherman Br. (S.Br.)	24N	1W	9	31.1
Crawford					
21	Steckert Br. (S.Br.)	25N	2W	29	16.7
22	Chase Br. (S.Br.)	25N	2W	22	14.3
23	Smith's Br. (S.Br.)	26N	1W	29	4.6
24	Lovells (N.Br.)	28N	1W	19	16.0
25	Red Dog (N.Br.)	26N	1W	1	0.1
Oscoda					
26	Co. 487 (Big Ck.-So.)	26N	1E	13	1.6
Crawford					
27	Shellenbarger Lk. outlet	26N	3W	11SW1/4	113.3
28	Mud Creek	26N	3W	11N1/2	110.7
29	Big Creek(N) Co. 608	27N	1W	23	1.0
Iosco					
30	Cooke Impoundment	24N	6E	26	22.1
Oscoda					
31	Mio Impoundment	26N	2E	12	73.4
32	Big Creek (S) (E.Br.)	26N	1E	25	4.6
33	Pond trib. to E.Branch	26N	1E	25	4.7
Crawford					
34	Jones Lake (E.Br.)	28N	2W	30	14.0
Roscommon					
35	Co. 602 Bridge (S.Br.)	24N	1W	21	33.5
36	McCrea Bridge (S.Br.)	24N	1W	29	36.9
37	St. Helen Dam (S.Br.)	23N	1W	8	40.5
38	Swamp (S.Br.)	24N	1W	20	--

Appendix Table I-B. Key to environmental factors covered by monthly data surveys--see Appendix Table I-C

Temp	Water temperature in ° C
D.O.	Dissolved oxygen in parts per million
pH	Normal scale
Alk	Total alkalinity in parts per million
BOD	Five-day BOD in parts per million
Cond	Conductance in μmhos/cm
$NO_{2,3}$	Nitrate + nitrite nitrogen in parts per billion
PO_4	Phosphate phosphorus in parts per billion
CHL	Chlorides in parts per million
T-COL	Total coliform bacteria in organisms per 100 milliliters
F-COL	Fecal coliform bacteria in organisms per 100 milliliters
NH_4	Ammonia as nitrogen in parts per billion

Appendix Table I-C. Water analysis data for numerous stations on Au Sable River and tributaries from monthly sampling from December 7, 1971 to October 25, 1972, with supplemental data for January 16, 1973

December 7, 1971

Sta.	Time	Temp	D.O.	pH	Alk	BOD	Cond	$NO_{2,3}$	PO_4	CHL	T-COL	F-COL
1	12:30p	4	10.5	8.1	142	0.8	348	151	76	2.5	300	10
2	11:45a	3	11.6	7.8	140	1.1	368	154	27	3.9	1900	<10
3	11:28a	3	10.7	7.8	130	1.1	353	149	34	4.0	<100	<10
4	11:07a	2	11.0	7.8	129	1.0	338	122	39	5.6	400	<10
5	12:10p	3	11.0	7.8	135	0.8	330	159	23	5.8	700	<10
6	10:20a	2.5	11.4	7.8	126	1.2	-	169	24	4.9	100	<10
7	10:03a	3	10.9	7.9	127	1.1	-	146	38	5.0	200	<10
8	9:45a	4.2	10.3	8.0	124	0.8	-	130	34	5.0	600	<10
9	1:47p	4	10.8	7.9	118	0.8	337	122	35	5.6	300	<10
10	9:00a	3.2	11.1	8.0	127	0.9	-	108	45	8.2	500	10
11	8:45a	4	10.4	8.1	102	-	-	103	36	5.0	400	<10
12	7:45a	3	11.1	8.1	132	1.2	-	98	25	4.6	100	<10
13	8:00a	3	11.1	8.1	127	0.8	-	113	38	7.5	100	<10
18	12:00p	4	9.4	7.6	134	0.5	359	35	27	0.0	100	<10
19	10:50a	3.5	10.9	8.0	147	0.9	340	207	37	6.9	200	<10
20B	2:10p	2	10.7	7.8	92	-	278	67	49	12.3	700	<10
21	2:48p	2.5	10.7	7.8	103	1.3	280	103	60	9.0	1100	10
22	2:30p	3	10.6	7.7	104	1.2	253	111	60	9.0	1000	<10
23	9:30a	3	11.2	7.9	102	1.2	-	133	54	7.5	400	<10
24	1:07p	4.5	10.7	8.3	121	0.6	318	51	38	0.9	<100	<10
25	1:35p	4.2	11.0	7.6	145	0.9	339	60	38	1.7	300	<10
26	9:10a	4.2	10.7	7.9	135	0.9	-	95	40	3.1	100	10

Appendix Table I-C. (continued)

January 4, 1972

Sta.	Time	Temp	D.O.	pH	Alk	BOD	Cond	$NO_{2,3}$	PO_4	CHL	T-COL	F-COL
1	1:55p	2	13.1	8.3	136	1.5	340	145	62	4.3	<100	<10
2	12:45p	1	13.3	8.2	130	1.6	322	125	35	5.0	<100	<10
3	12:35p	1	12.8	8.1	129	1.5	350	121	27	4.9	<100	<10
4	1:00p	1	13.3	7.9	130	1.1	335	107	56	6.9	<100	<10
5	1:35p	2	12.6	8.1	120	1.1	341	127	56	6.9	<100	<10
6	12:20p	1.5	12.4	7.9	126	1.0	318	145	37	6.1	<100	<10
7	12:08p	2	13.1	8.2	119	1.1	303	128	40	5.1	100	<10
8	11:50a	2	12.7	8.1	121	0.9	301	135	32	4.9	100	<10
9	11:20a	2	14.3	8.2	104	1.5	292	85	52	5.9	100	10
10	11:00a	1	13.1	7.8	118	1.3	288	120	42	4.7	300	<10
11	10:45a	2	11.9	8.0	120	1.3	300	91	36	4.9	300	<10
12	9:50a	2	11.2	8.3	121	0.8	307	93	41	6.3	<100	<10
13	9:30a	2	10.7	7.8	120	1.0	280	89	62	5.6	200	<10
14	8:45a	1	10.9	8.1	118	1.3	327	114	63	7.3	200	<10
15	8:20a	0	11.8	8.3	123	1.1	-	99	63	6.4	<100	<10
16	7:45a	1.5	11.1	8.1	112	1.6	275	108	261	5.8	<100	<10
17	7:00a	4.0	11.2	8.2	136	2.0	315	119	91	5.9	50	10
18	2:15p	2.5	12.2	8.1	126	1.3	331	39	32	2.2	<100	<10
19	1:10p	0.8	13.8	7.7	136	0.8	353	181	30	5.6	<100	<10
20	4:00p	1.5	10.0	8.0	82	1.8	240	75	50	8.5	100	<10
21	4:50p	1.5	11.2	7.7	89	2.0	258	108	91	8.2	100	<10
22	3:40p	2.0	11.5	8.2	90	1.4	279	87	84	8.3	300	<10
23	11:30a	2	12.0	7.8	99	1.0	290	114	94	7.1	500	<10
24	2:25p	2	13.3	8.0	132	1.0	332	76	60	3.4	<100	<10
25	2:50p	1	14.5	8.1	124	0.9	324	63	51	3.2	<100	<10
26	11:10a	1	14.0	8.1	129	1.1	321	94	26	2.5	<100	<10

Appendix Table I-C. (continued)

February 1, 1972

Sta.	Time	Temp	D.O.	pH	Alk	BOD	Cond	$NO_{2,3}$	PO_4	CHL	T-COL	F-COL
1	11:30a	1	13.8	8.0	139	1.3	389	207	61	5.6	5500	<10
2	10:45a	1	13.8	7.9	132	1.4	-	174	35	4.3	<100	<10
3	10:05a	1	13.5	7.9	133	1.1	-	174	64	5.7	100	<10
4	10:30a	0	15.0	7.9	132	1.7	325	159	49	4.7	500	<10
5	11:05a	0.5	14.9	7.9	135	1.3	368	211	48	5.7	300	10
6	9:52a	0	14.7	8.0	133	0.8	-	184	57	5.6	200	<10
7	9:40a	1	15.2	8.0	127	1.4	-	156	46	5.8	<100	<10
8	9:20a	0	16.3	8.0	124	1.2	-	183	50	5.0	100	<10
9	12:45p	0.5	15.1	8.0	115	1.3	326	130	41	5.5	<100	10
10	8:20a	0	15.3	8.0	120	1.4	346	164	38	4.7	<100	<10
11	8:03a	0	15.8	-	-	-	346	-	-	-	100	<10
12	7:20a	1	14.6	7.9	125	1.2	311	157	87	11.1	<100	<10
13	7:38a	1.5	15.7	7.9	130	1.2	322	130	45	4.9	<100	<10
18	11:50a	0.5	13.0	7.8	128	0.8	344	68	61	6.1	<100	<10
19	10:40a	0	16.2	7.9	138	1.7	379	222	37	5.3	400	10
20	1:10p	1	10.2	7.7	107	0.8	310	139	61	10.5	100	<10
21	1:30p	0.5	12.4	7.7	106	1.2	315	120	95	10.5	<100	<10
22	12:45p	1	11.5	7.6	102	0.7	316	109	42	9.9	<100	<10
23	9:00a	-1	14.2	7.9	109	1.8	325	125	70	7.0	100	<10
24	12:05p	0.5	14.9	8.1	134	1.4	329	105	59	4.6	<100	<10
25	12:35p	0	16.9	8.1	123	1.7	333	92	30	3.8	<100	<10
26	8:30a	0	17.1	8.1	127	1.3	338	110	27	2.4	<100	<10

Appendix Table I-C. (continued)

March 7, 1972

Sta.	Time	Temp	D.O.	pH	Alk	BOD	Cond	$NO_{2,3}$	PO_4	CHL	T-COL	F-COL
1	12:25p	0.5	11.5	8.0	148	1.3	335	195	33	3.5	<100	<10
2	1:50p	0.5	11.1	8.0	152	1.2	375	168	32	6.6	<100	<10
3	1:40p	0.5	11.5	7.9	165	0.8	378	186	43	5.7	100	<10
4	1:20p	0.5	11.3	7.9	144	1.3	375	170	32	5.7	200	<10
4A	1:25p	0.5	11.0	8.0	148	2.6	-	40	71	3.6	-	-
5	12:45p	0.5	12.0	7.8	154	1.3	378	180	29	8.0	400	<10
6	1:15p	0.5	12.1	7.9	144	0.9	374	192	47	5.3	100	<10
7	12:45p	0.5	12.9	8.1	140	1.2	378	146	42	6.7	100	<10
8	12:30p	0.5	12.7	8.1	136	0.8	350	171	44	4.8	<100	<10
9	11:50a	0.5	12.9	8.1	126	1.0	370	132	50	5.6	<100	<10
10	11:20a	0.5	13.5	8.1	140	1.6	300	124	53	4.7	<100	<10
11	11:05a	1.0	12.9	8.0	140	0.8	359	136	48	4.2	100	<10
12	9:50a	1.0	12.1	8.0	138	0.7	360	109	44	4.5	<100	<10
13	9:35a	0.5	12.8	8.1	138	0.8	352	116	41	6.6	<100	<10
14	8:45a	0.5	12.3	8.1	148	1.1	372	113	41	5.1	100	<10
15	8:10a	0.5	10.0	8.1	148	0.9	381	117	50	5.8	<100	<10
16	7:25a	0.5	11.3	8.1	146	0.7	372	109	42	7.4	<100	<10
17	6:50a	0.5	11.8	8.0	152	1.2	358	123	51	6.8	<100	<10
18	12:10p	0.5	10.5	8.1	152	0.7	356	87	36	0.9	<100	<10
18H	1:00p	0.5	12.2	8.0	162	1.5	378	194	45	5.7	<100	<10
19	1:10p	0.5	12.2	8.1	150	0.5	389	181	51	7.3	100	<10
20	2:00p	0.5	8.7	7.8	122	1.0	-	88	51	11.2	<100	<10
21	2:20p	0.5	10.2	7.8	126	1.4	-	107	59	11.5	<100	<10
22	2:45p	0.5	10.2	7.8	130	1.6	-	105	84	8.4	<100	<10
23	12:10p	0.5	12.5	7.9	128	0.9	-	112	69	6.9	400	10
24	11:55a	0.5	12.4	8.2	158	1.1	350	76	50	5.0	800	<10
25	3:00p	0.5	13.1	8.1	148	1.9	351	92	47	3.0	100	<10
26	11:30a	0.5	12.7	8.1	144	1.4	-	64	34	3.6	<100	<10

Appendix Table I-C. (continued)

April 4, 1972

Sta	Time	Temp	D.O.	pH	Alk	BOD	Cond	$NO_{2,3}$	PO_4	CHL	T-COL	F-COL
1	11:12a	1	11.4	8.1	160	0.5	390	125	35	2.8	<100	<10
1A	10:57a	1	11.6	8.0	144	1.4	-	145	88	1.5	<100	10
1B	10:50a	2	10.9	8.0	182	1.0	435	119	42	0.0	1200	<10
2	12:25p	1	11.5	8.1	164	1.8	365	106	62	3.6	<100	10
3	12:15p	1	11.2	8.0	160	1.5	385	117	122	4.9	100	<10
4	6:30a	1	11.2	8.0	156	1.4	349	105	59	4.2	100	<10
5	11:30a	1	12.0	8.2	162	1.6	372	106	43	5.7	2100	10
6	6:50a	1	11.4	8.1	160	1.9	240	114	63	5.2	100	10
7	7:05a	1	11.4	8.2	154	2.2	320	87	69	5.0	200	<10
8	7:18a	1	10.9	8.2	146	1.6	352	85	56	4.3	400	<10
9	8:30a	1	11.1	8.1	140	1.3	330	89	190	6.6	200	<10
10	9:35a	1	11.4	8.0	144	1.5	305	72	81	5.4	100	20
11	9:25a	1	11.4	8.1	144	2.0	-	52	141	4.8	<100	<10
12	9:10a	1	11.0	8.1	146	1.2	340	78	61	5.7	100	<10
18	10:30a	1	10.8	7.9	150	1.5	348	55	61	0.7	<100	<10
18E	11:20a	1	11.2	-	-	-	-	186	65	1.8	-	-
18F	11:35a	1	11.4	-	-	-	-	128	39	3.1	-	-
18G	11:55a	1	11.4	8.1	162	1.6	365	267	95	11.6	200	<10
20	7:40a	1	10.9	7.9	116	1.5	283	92	52	10.4	200	<10
21	7:50a	1	10.6	7.8	116	1.6	298	99	59	10.6	200	<10
22	7:58a	1	10.8	7.8	120	1.6	312	110	69	10.0	<100	<10
23	8:15a	1	11.0	7.8	126	1.5	295	90	63	7.8	100	<10
24	10:15a	1	11.2	8.2	152	1.5	338	86	65	2.6	<100	<10
25	8:40a	1	11.5	8.2	152	3.3	-	58	87	3.3	400	10
26	9:48	1	11.5	8.0	148	1.3	340	81	117	2.8	200	<10

Appendix Table I-C. (continued)

May 2, 1972

Sta	Time	Temp	D.O.	pH	Alk	BOD	Cond	$NO_{2,3}$	PO_4	CHL	T-COL	F-COL
1	7:25a	9.5	10.3	7.8	136	1.8	262	130	36	3.2	5500	<10
1A	7:46a	9.5	10.3	7.6	108	1.2	208	93	66	0.0	2700	<10
1B	7:39a	9.0	7.4	7.8	158	1.0	319	59	43	0.0	8400	40
2	12:10p	9.5	-	7.8	138	1.3	-	108	63	4.0	34000	<10
3	12:00p	11.0	8.3	7.9	146	1.4	258	64	32	4.6	32000	<10
4	12:20p	10.0	-	7.8	148	1.4	-	48	47	5.1	5300	<10
5	6:50a	10.0	10.5	7.7	136	2.2	262	74	32	5.6	5100	<10
6	11:26a	10.0	9.7	7.8	134	1.4	275	74	45	4.7	5000	<10
7	11:10a	10.0	10.4	7.8	126	1.5	267	72	35	4.3	2400	<10
8	10:57a	10.0	10.0	7.8	126	1.2	267	82	44	3.8	3300	<10
9	9:26a	11.0	10.2	7.9	110	1.1	228	51	77	5.5	3300	20
10	9:57a	10.0	10.9	7.8	116	1.2	239	56	74	4.3	3800	20
11	10:08a	10.0	10.8	7.8	118	1.5	242	56	69	4.7	7100	10
12	10:18a	11.8	10.7	7.8	120	1.5	252	39	103	6.9	1400	<10
18	8:15a	10.0	9.7	7.8	132	1.6	278	2	60	2.3	1500	<10
18C	8:20a	9.1	9.3	7.7	124	1.2	242	82	51	1.9	3700	20
18F	7:05a	9.5	10.3	7.7	124	1.2	210	87	52	2.0	2900	20
19	12:30a	9.5	-	7.8	124	0.4	-	107	60	7.6	6400	60
20	12:21p	12.0	8.4	7.4	76	1.1	164	3	55	7.0	1400	<10
21	12:32p	12.0	8.4	7.4	81	1.2	168	27	54	8.1	6800	10
22	12:45p	12.0	8.9	7.4	84	1.0	166	28	66	8.0	3200	<10
23	10:40a	11.5	9.8	7.4	88	1.5	184	40	76	7.0	4600	<10
24	8:55a	9.5	10.7	7.9	128	2.2	262	63	70	11.7	5300	60
25	9:14a	9.5	11.7	7.9	136	1.6	250	61	65	10.9	7200	70
26	9:48a	10.0	10.2	7.9	137	1.2	282	57	63	2.4	2200	10

Appendix Table I-C. (continued)

June 5, 1972

Sta	Time	Temp	D.O.	pH	Alk	BOD	Cond	$NO_{2,3}$	PO_4	CHL	T-COL	F-COL
1	9:45a	14	8.3	8.2	186	2.5	305	77	38	2.3	2900	<10
2	9:15a	14	8.1	8.2	170	1.7	-	58	57	3.5	3800	10
3	9:30a	17.5	7.9	8.3	162	2.3	-	28	58	4.0	10400	<10
4	9:45a	18	7.7	8.2	172	-	319	17	45	5.3	4700	<10
5	8:50a	16	7.7	8.2	166	2.0	-	51	52	5.1	7000	30
6	10:25a	18	7.9	8.4	160	1.0	311	39	87	5.3	3300	<10
7	10:40a	16	8.2	8.3	170	1.5	-	34	50	5.6	3600	<10
8	11:00a	16	8.3	8.4	152	0.9	-	12	57	5.0	3800	10
9	10:35a	15	8.1	8.3	152	1.4	305	14	57	5.1	4200	<10
10	2:40p	17	8.0	8.2	156	1.1	299	21	52	4.8	3500	<10
11	1:55p	17	8.3	8.2	150	1.4	300	9	64	9.1	3600	<10
12	2:15p	17	8.1	8.4	152	1.4	295	8	48	4.4	4500	10
13	3:05p	17	8.3	8.4	156	2.0	268	6	47	4.6	4400	<10
14	4:00p	18	7.6	8.3	160	-	-	7	69	5.4	2900	<10
15	4:15p	18	7.0	8.1	142	-	302	10	63	5.8	3500	<10
16	4:40p	20	7.1	8.0	142	0.8	270	4	55	5.0	1900	<10
17	5:10p	20	7.1	8.0	144	1.1	287	10	48	5.2	4200	<10
18	9:10a	14.5	8.1	8.1	162	1.6	324	7	44	0.0	2900	<10
18B	9:25a	14.5	8.1	8.1	152	1.0	326	73	77	0.0	4100	<10
18H	3:10p	20	-	-	-	2.9	-	70	49	4.9	-	-
19	9:50a	15	7.9	8.1	170	0.8	343	77	40	4.4	9500	30
20	12:00p	20	7.7	7.9	134	0.8	298	35	50	10.8	14800	40
21	11:40a	19	7.7	7.9	136	1.2	300	34	80	9.6	16600	20
22	11:25a	19.5	8.2	8.0	144	-	302	42	64	9.4	9000	<10
23	12:15p	18	8.2	8.1	146	0.5	298	30	79	9.0	6000	<10
24	8:40a	15	8.2	8.1	166	0.8	344	11	77	1.7	4600	20
25	8:10a	15	8.2	8.1	166	0.7	324	8	49	2.9	11900	20
26	1:25p	14	8.1	8.2	156	0.7	310	20	32	2.0	9200	<10
30	4:30p	20	-	-	-	-	-	14	63	6.2	-	-
31	2:30p	23	-	-	-	7.1	-	13	73	4.4	-	-
34	10:15a	20.5	8.1	8.1	152	1.0	285	58	44	4.0	8300	10

Appendix Table I-C. (continued)

July 10, 1972

Sta	Time	Temp	D.O.	pH	Alk	BOD	Cond	$NO_{2,3}$	PO_4	CHL	T-COL	F-COL
1	12:20p	18	9.7	8.1	166	1.5	324	63	24	4.8	7300	20
2	1:30p	20	9.3	8.1	165	1.2	289	31	68	10.2	3200	<10
3	1:20p	19.5	8.5	8.1	158	1.2	297	31	41	6.5	5800	10
4	1:04p	20	7.6	8.1	160	1.0	291	29	49	6.2	5200	10
5	12:45p	18.5	7.8	8.0	160	1.0	284	70	55	8.7	4200	<10
6	1:48p	20	9.0	8.2	154	1.1	292	18	26	8.0	2300	<10
7	2:00p	18	9.2	8.3	146	1.3	293	27	51	6.4	1800	<10
8	2:10p	20	9.2	8.3	144	0.8	281	23	38	6.2	2800	<10
9	4:40p	19	9.0	8.2	150	0.7	277	10	70	8.0	4700	10
10	3:00p	19	9.9	8.2	148	0.9	291	0	47	6.5	20000	<10
11	2:35p	19	9.4	8.2	148	0.8	294	4	46	5.5	4300	<10
12	2:10p	19	9.2	8.1	150	0.8	290	0	39	6.2	2200	<10
13	1:40p	19	9.8	8.3	148	0.6	-	2	59	6.6	4100	<10
14	12:20p	20	8.3	8.1	148	0.9	-	3	48	7.3	24000	<10
15	11:50a	23	8.5	8.0	152	0.9	-	0	38	6.7	6800	<10
16	11:15a	20	8.0	8.0	152	0.6	-	2	38	7.6	11000	<10
17	11:00a	20	7.5	8.0	148	0.9	-	7	30	7.5	42000	10
18	12:20p	19	8.5	7.9	152	1.2	286	7	32	4.3	3600	<10
19	12:55p	18	9.2	8.1	160	0.9	261	108	33	7.8	3800	<10
20	2:50p	21	9.0	8.0	136	1.2	286	16	50	13.7	4200	<10
21	2:40p	20	10.4	8.2	140	1.8	298	33	56	11.9	33000	480
22	2:30p	19.5	11.4	8.3	138	1.6	304	18	72	12.4	4500	10
23	3:15p	19.5	9.0	8.2	144	2.3	293	10	78	7.2	3000	<10
24	12:05p	18	9.6	8.2	156	1.0	299	4	31	6.4	3300	<10
25	11:40a	17	9.6	8.1	160	1.5	-	8	42	3.4	4900	10
26	3:55p	17	9.9	8.2	152	1.1	315	0	22	2.9	7100	<10

Appendix Table I-C. (continued)

August 7, 1972

Sta	Time	Temp	D.O.	pH	Alk	BOD	Cond	$NO_{2,3}$	PO_4	CHL	T-COL	F-COL
1	11:10a	19	9.5	8.1	170	1.4	-	120	26	4.1	6400	30
2	12:37a	21	9.1	8.1	170	0.9	-	72	29	4.5	5100	40
3	1:02p	20.5	7.9	8.0	158	1.1	-	39	30	3.7	4300	20
4	1:00p	21	7.5	8.0	160	1.5	-	26	36	4.3	6000	<10
5	1:47p	19.5	8.2	8.0	158	1.0	-	53	28	5.7	8800	40
6	2:34p	21	8.5	8.1	154	1.4	-	51	35	5.3	8500	90
7	2:56p	19	8.9	8.1	150	1.4	-	40	41	5.0	4000	10
8	3:07p	21	9.2	8.1	148	1.9	-	29	33	4.4	5900	40
9	1:20p	20.5	10.0	8.0	148	1.3	-	16	109	8.2	2800	<10
10	10:00a	17	9.8	8.1	150	1.2	-	5	44	4.6	5800	10
11	10:00a	18.5	9.3	8.4	150	0.9	-	3	45	3.4	5800	30
12	9:40a	18.5	8.3	8.3	146	0.9	-	22	40	5.5	5800	30
18	10:55a	15	7.4	8.0	152	0.9	-	10	45	2.0	4900	<10
18A	4:40p	18.5	6.7	8.1	156	1.7	303	-	55	2.7	7600	10
19	12:01p	18	8.7	8.1	170	0.6	-	100	46	5.0	4600	80
20	11:35a	17	8.5	8.0	142	1.4	351	42	42	10.9	4500	80
21	12:00p	18	9.1	8.0	144	1.7	340	81	57	11.8	5900	70
22	12:20p	18	9.2	8.1	146	1.3	335	52	59	8.9	5100	50
23	12:50p	17	10.1	8.2	148	1.8	320	46	40	6.7	6100	30
24	10:40a	14	8.7	8.1	156	2.1	283	18	47	1.4	15000	100
25	1:10p	17	10.4	8.2	157	1.2	327	3	34	2.9	6000	60
26	10:25a	18	10.3	8.1	157	1.3	261	18	21	1.8	7300	40
28	1:59p	14.5	-	-	-	-	340	-	-	-	-	-
32	3:10p	12	10.9	-	-	-	346	-	-	-	-	-
33	1:59p	14.5	5.3	8.0	166	3.0	358	11	49	-	-	-

Appendix Table I-C. (continued)

September 11, 1972

Sta	Time	Temp	D.O.	pH	Alk	BOD	Cond	$NO_{2,3}$	PO_4	CHL	T-COL	F-COL
1	11:10a	15.5	10.1	7.9	160	0.6	363	95	18	3.7	560000	210
2	11:30a	16.5	10.1	7.9	158	0.7	335	37	25	3.7	2200	<10
3	5:05p	14	9.8	8.0	158	1.2	342	10	37	3.2	12000	10
4	4:55p	15	9.2	7.9	160	1.3	344	12	41	4.3	5300	20
5	4:40p	14	9.3	8.0	160	1.1	373	88	25	6.2	7000	50
6	3:50p	15	10.5	8.1	158	1.3	357	41	28	5.0	3700	<10
7	3:10p	14	11.5	8.1	150	1.4	338	26	34	4.3	2500	20
8	2:20p	13	11.2	8.2	146	1.4	303	12	30	4.0	3500	<10
9	12:00p	12.7	10.5	8.0	144	1.1	308	0	34	4.4	14000	<10
10	12:40p	13	10.5	8.0	148	1.4	329	0	36	3.3	4000	10
12	1:20p	16.5	8.7	8.0	148	1.1	318	0	54	3.9	5700	<10
18	9:00a	14.5	7.7	7.8	-	1.5	327	60	60	0.0	2600	10
18A	9:15a	15	8.0	7.8	156	0.9	330	?	70	0.0	1500	<10
18B	9:40a	14.5	8.9	7.9	158	1.0	340	48	42	0.0	1900	20
18C	9:50a	14.5	9.0	7.8	164	0.7	345	106	43	0.0	28000	10
18D	10:05a	14	9.7	7.8	165	0.4	357	144	34	0.0	1000	<10
18F	10:25a	15	9.5	7.9	166	0.8	361	109	35	0.0	700	10
18H	10:35a	14.5	9.7	7.9	162	0.8	363	103	70	0.0	1500	<10
19	10:50a	15	9.7	8.0	160	0.7	368	71	33	0.0	2000	10
20	10:45a	14	9.0	7.8	126	1.3	-	11	60	9.9	15000	30
20A	11:00a	14	8.9	7.7	127	1.6	321	62	140	10.3	40000	950
21	11:10a	13.5	9.6	7.8	128	1.3	315	66	75	9.1	4800	20
23	11:35a	12.5	10.6	7.9	135	1.0	309	22	49	6.0	2200	10
24	8:45a	14.5	9.0	7.8	-	1.9	311	2	55	0.0	1800	10
25	2:45p	16	10.2	8.0	152	0.8	319	0	34	0.0	440000	310
26	12:50p	11.5	11.1	8.0	150	0.8	348	5	31	0.8	6000	<10
27	5:15p	19	9.8	8.0	120	0.8	262	0	46	2.9	6000	10
28	12:45p	16.5	8.4	7.9	122	1.0	324	9	42	4.3	37000	<10
29	12:15p	12.5	10.8	7.9	144	0.7	318	0	76	1.2	2600	10

Appendix Table I-C. (continued)

October 25, 1972 (Nov)

Sta	Time	Temp	D.O.	pH	Alk	BOD	Cond	NO_{23}	PO_4	CHL	T-COL	F-COL
*1	11:30a	5	12.5	8.1	178	1.5	310	197	8	4.7	900	<10
2	4:15p	5	12.4	7.8	132	1.5	-	153	15	3.2	2600	<10
*3	11:20a	5.5	12.2	8.2	162	1.6	330	99	6	4.6	1600	<10
*4	11:52a	5.5	11.9	7.9	168	1.7	291	112	13	5.1	800	<10
5	3:45p	6.0	11.4	7.8	134	1.8	-	160	18	8.8	4500	60
6	3:25p	7.5	10.9	7.8	128	3.2	274	121	38	7.3	3900	70
7	2:55p	6.5	11.7	7.8	132	1.9	268	112	43	7.3	2400	70
8	2:30p	7.5	11.3	7.8	124	1.6	271	116	21	7.7	2800	20
9	1:52p	6.5	11.4	8.0	110	1.7	246	92	27	7.5	1700	<10
10	1:02p	7.0	10.2	8.0	108	2.2	255	87	29	7.1	3400	30
12	11:53a	7.5	10.6	8.1	136	1.6	282	83	35	5.2	3900	60
13	11:40a	7	11.6	8.0	140	1.5	302	82	34	5.6	6700	40
14	10:58a	7	10.4	8.0	154	1.5	299	32	38	4.3	1400	<10
16	10:20a	10	9.2	8.1	160	1.0	282	19	20	5.2	400	<10
17	10:00a	11	8.9	8.0	162	1.4	314	33	22	5.4	4400	70
*18	11:53a	5.5	11.0	8.1	164	2.1	325	42	32	1.1	800	<10
*19	10:55a	5	10.3	8.1	171	2.7	-	219	21	5.2	700	20
*20	2:08p	4.5	10.8	8.0	104	1.3	205	23	19	8.5	2000	<10
*20A	2:02p	5	10.8	7.9	104	2.2	216	42	30	9.2	1500	<10
*21	1:50p	5	10.8	7.9	104	2.8	215	46	29	9.2	2800	<10
23	2:20p	5.5	11.3	7.4	96	2.7	233	67	32	8.5	2700	110
*24	12:07p	5	13.1	8.0	164	1.0	298	16	16	1.5	400	<10
25	1:35p	5	12.6	8.0	110	1.8	261	32	22	3.0	900	10
26	12:35p	6.5	11.7	8.0	134	1.4	284	103	17	3.6	2200	10

* Collected Oct. 31

Appendix Table I-C. (concluded)

January 16, 1973 (Supplemental Water Chemistries)

Sta.	Time	Temp	D.O.	pH	Alk	$NO_{2,3}$	NH_4	PO_4	CHL	T-COL	F-COL
1A	2:10p	0.0	-	8.5	140	201	11	7	0	100	<10
1B	2:20p	5.0	-	8.5	174	214	4	3	0	400	<10
1C	1:30p	0.0	-	7.8	112	73	15	18	0	300	<10
1D	2:00p	2.0	15.5	8.0	140	70	12	15	2	<100	<10
1E	2:20p	2.0	-	8.2	142	233	4	6	3	-	-
18	2:45p	4.0	10.7	8.0	128	72	3	-	-	-	-
18A	3:25p	2.0	-	8.1	134	82	8	-	-	-	-
18B	3:50p	2.0	-	8.2	138	214	10	-	-	-	-
18E	4:15p	2.0	-	8.2	140	324	1.4	-	-	-	-
18F	4:30p	2.0	-	8.2	138	287	3	-	-	-	-
18H	4:45p	2.0	-	8.2	141	274	6	-	-	-	-
19	5:10p	2.0	-	8.2	140	300	4	-	-	-	-
20A	11:45a	2.0	-	7.8	106	131	-	22	10	200	<10
20B	11:30a	2.0	-	7.7	104	126	-	11	29	-	-
21	12:05p	2.0	-	7.7	110	156	-	20	10	700	<10
35	11:20a	2.0	-	7.7	104	106	-	10	10	-	-
36	11:01a	2.0	-	7.8	94	94	-	16	7	-	-
37	10:40a	2.0	-	7.8	96	81	-	13	9	100	<10
38	11:15a	3.0	-	5.7	20	109	7	540	13	9200	<10

Appendix Table I-D

Winter and summer means of monthly values for dissolved oxygen

Station	Winter		Summer	
	$\bar{x}$	$\pm$ (t.05;N-1)($S\bar{x}$)	$\bar{x}$	$\pm$ (t.05;N-1)($S\bar{x}$)
1	11.6	2.0	9.5	2.3
2	12.3	2.3	9.1	2.4
3	11.9	2.2	8.5	2.6
4	12.4	3.3	8.1	2.8
5	12.5	2.8	8.4	3.0
6	12.4	2.6	9.0	3.7
7	12.7	3.2	9.5	4.2
8	12.6	4.5	9.6	3.6
9	12.8	3.6	9.5	3.0
10	12.9	3.3	9.4	3.1
11	12.5	3.9	8.8	3.2
12	12.0	2.9	8.2	1.2
13	12.6	4.1	---	---
14	11.6	2.0	---	---
15	10.9	2.6	---	---
16	11.2	0.3	---	---
17	11.5	0.9	---	---
18	11.2	3.4	7.7	0.8
19	13.3	4.6	8.8	2.1
20	10.1	1.7	8.4	1.4
21	11.0	1.6	8.6	1.8
22	10.9	2.6	8.7	3.2
23	12.2	2.4	9.6	3.0
24	12.9	3.3	8.6	1.0
25	13.4	4.6	9.6	2.9
26	13.2	4.8	9.8	3.7

Appendix Table I-D. continued

Winter and summer means of monthly values for pH, with probable errors

Station	Winter		Summer	
	$\bar{x}$	$\pm$ (t.05;N-1)(S$\bar{x}$)	$\bar{x}$	$\pm$ (t.05;N-1) (S$\bar{x}$)
1	8.1	0.2	8.1	0.3
2	8.0	0.3	8.1	0.3
3	7.9	0.1	8.1	0.3
4	7.9	0.1	8.1	0.3
5	8.0	0.3	8.1	0.2
6	7.9	0.2	8.2	0.3
7	8.0	0.3	8.2	0.2
8	8.0	0.2	8.3	0.3
9	8.1	0.2	8.1	0.3
10	8.0	0.2	8.1	0.2
11	8.1	0.1	8.3	0.3
12	8.1	0.3	8.2	0.4
13	8.0	0.3	8.4	0.5
14	8.1	0.0	8.2	0.6
15	8.2	0.6	8.1	0.0
16	8.1	0.0	8.0	0.0
17	8.1	0.6	8.0	0.0
18	7.9	0.4	7.9	0.4
19	7.9	0.3	8.1	0.1
20	7.8	0.2	7.9	0.2
21	7.8	0.1	8.1	0.4
22	7.8	0.4	8.1	0.4
23	7.9	0.1	8.1	0.3
24	8.2	0.2	8.1	0.4
25	8.0	0.5	8.1	0.2
26	8.0	0.2	8.1	0.2

 Appendix Table I-D. continued

Winter and summer means of monthly values for alkalinity

Station	Winter $\bar{x}$	Winter $\pm$ (t.05;N-1)(S$\bar{x}$)	Summer $\bar{x}$	Summer $\pm$ (t.05;N-1)(S$\bar{x}$)
1	145	18.1	171	22.7
2	144	27.3	166	11.6
3	143	33.5	159	4.1
4	138	22.2	163	8.4
5	141	31.9	162	13.4
6	138	27.5	157	6.2
7	133	26.2	154	22.0
8	130	20.1	148	7.1
9	121	25.6	149	5.4
10	130	22.3	151	8.2
11	127	35.8	147	7.4
12	132	19.1	149	5.3
13	129	11.4	152	25.2
14	133	94.4	154	37.9
15	136	78.9	148	37.9
16	129	107.3	147	11.3
17	144	50.5	146	12.6
18	138	23.3	155	22.3
19	143	13.9	162	13.8
20	104	31.7	135	13.5
21	108	26.6	137	13.9
22	109	30.1	143	10.0
23	113	25.7	143	11.7
24	140	28.5	159	13.8
25	138	26.4	159	11.9
26	137	17.5	154	6.8

Appendix Table I-D. continued

Winter and summer means of monthly values for BOD_5

Station	Winter $\bar{x}$	Winter $\pm$ (t.05;N-1)($S\bar{x}$)	Summer $\bar{x}$	Summer $\pm$ (t.05;N-1)($S\bar{x}$)
1	1.3	1.1	1.5	1.6
2	1.4	0.5	1.1	0.9
3	1.2	0.6	1.5	1.2
4	1.3	0.5	1.4	0.6
5	1.2	0.6	1.3	1.0
6	1.2	0.8	1.2	0.3
7	1.4	0.9	1.4	0.2
8	1.1	0.6	1.3	1.0
9	1.2	0.5	1.1	0.6
10	1.3	0.5	1.2	0.4
11	1.3	0.9	1.1	0.6
12	1.0	0.5	1.2	0.6
13	0.8	0.5	1.3	4.4
14	1.2	0.6	0.9	---
15	1.0	0.6	0.9	---
16	1.1	2.8	0.7	0.6
17	1.6	2.5	1.0	0.6
18	1.0	0.8	1.3	0.6
19	1.0	0.7	0.8	0.3
20	1.3	0.9	1.2	0.5
21	1.5	0.6	1.5	0.6
22	1.3	0.4	1.5	1.0
23	1.3	0.8	1.4	1.6
24	1.1	0.7	1.5	1.1
25	1.7	1.9	1.1	0.8
26	1.2	0.4	1.0	0.6

 Appendix Table I-D. continued

Winter and summer means of monthly values for conductivity

Station	Winter		Summer	
	$\bar{x}$	$\pm$ (t.05;N-1)($S\bar{x}$)	$\bar{x}$	$\pm$ (t.05;N-1)($S\bar{x}$)
1	360	51.4	331	70.5
2	356	44.5	312	145.1
3	367	35.8	320	142.0
4	344	36.5	318	63.2
5	358	40.1	329	280.8
6	346	176.7	325	82.4
7	334	93.8	316	142.0
8	334	50.7	292	69.4
9	331	53.2	297	40.8
10	310	51.3	306	48.6
11	330	186.2	297	19.0
12	330	51.1	301	35.6
13	318	86.2	---	-----
14	350	142.1	---	-----
15	---	-----	---	-----
16	324	306.1	---	-----
17	337	135.7	---	-----
18	348	21.1	312	55.8
19	365	46.1	324	106.9
20	278	58.7	312	54.0
21	288	49.8	313	39.5
22	290	60.5	320	97.9
23	303	45.1	305	24.5
24	333	22.5	309	51.3
25	337	23.1	323	91.3
26	333	24.9	309	73.0

Appendix Table I -D. continued

Winter and summer means of monthly values for nitrate-nitrogen in ppb

Station	Winter		Summer	
	$\bar{x}$	± (t.05;N-1)($S\bar{x}$)	$\bar{x}$	± (t.05;N-1)($S\bar{x}$)
1	165	66.5	89	50.1
2	146	55.5	50	38.6
3	149	59.0	27	24.9
4	133	57.4	21	16.0
5	156	47.6	66	35.1
6	161	60.5	37	28.2
7	133	52.1	29	14.8
8	141	62.5	19	17.2
9	111	44.3	10	14.5
10	118	101.9	7	20.3
11	96	70.7	4	7.6
12	107	57.4	8	21.2
13	112	34.4	4	12.6
14	114	6.0	5	12.6
15	108	79.0	5	31.6
16	109	4.0	3	-----
17	121	13.9	9	----
18	57	40.6	21	53.0
19	198	41.5	89	36.2
20	92	53.5	26	30.2
21	107	16.8	54	48.7
22	104	19.3	37	43.3
23	115	31.0	27	30.7
24	79	37.5	9	14.4
25	71	36.6	5	8.1
26	89	32.9	11	19.9

 Appendix Table I-D. continued

Winter and summer means of monthly values for phosphate phosphorus in ppb

Station	Winter		Summer	
	$\bar{x}$	$\pm$ (t.05;N-1)(S$\bar{x}$)	$\bar{x}$	$\pm$ (t.05;N-1)(S$\bar{x}$)
1	54	40.0	27	17.1
2	38	26.3	45	42.8
3	58	72.3	42	24.3
4	47	21.7	43	11.3
5	40	25.9	40	32.0
6	46	24.9	44	58.9
7	47	28.0	33	30.6
8	43	20.2	40	24.7
9	74	124.7	68	64.0
10	52	32.2	45	13.7
11	65	127.0	52	25.5
12	52	44.9	45	14.3
13	47	21.9	53	37.9
14	52	85.0	59	66.3
15	57	41.1	51	27.4
16	152	691.0	47	53.7
17	71	126.2	39	56.8
18	43	31.2	45	23.4
19	39	17.9	38	13.4
20	53	9.2	51	21.2
21	73	35.2	67	25.0
22	76	38.0	65	12.6
23	70	28.3	61	41.1
24	54	20.3	53	39.0
25	51	41.8	40	14.7
26	49	80.3	27	11.9

Appendix Table I -D. continued

Winter and summer means of monthly values for nitrate-nitrogen in ppb

Station	Winter $\bar{x}$	Winter $\pm$ (t.05;N-1)($S\bar{x}$)	Summer $\bar{x}$	Summer $\pm$ (t.05;N-1)($S\bar{x}$)
1	165	66.5	89	50.1
2	146	55.5	50	38.6
3	149	59.0	27	24.9
4	133	57.4	21	16.0
5	156	47.6	66	35.1
6	161	60.5	37	28.2
7	133	52.1	29	14.8
8	141	62.5	19	17.2
9	111	44.3	10	14.5
10	118	101.9	7	20.3
11	96	70.7	4	7.6
12	107	57.4	8	21.2
13	112	34.4	4	12.6
14	114	6.0	5	12.6
15	108	79.0	5	31.6
16	109	4.0	3	-----
17	121	13.9	9	----
18	57	40.6	21	53.0
19	198	41.5	89	36.2
20	92	53.5	26	30.2
21	107	16.8	54	48.7
22	104	19.3	37	43.3
23	115	31.0	27	30.7
24	79	37.5	9	14.4
25	71	36.6	5	8.1
26	89	32.9	11	19.9

Appendix Table II. Location of Au Sable River storm water sampling stations, conditions, and results listed by the dates of collection

Station No.	Storm Drain - Collecting sites
1	Grayling, US-27 Bridge, North side
2	Grayling, Maple Street, North side
3	Grayling, Maple Street, South side
4	Roscommon, M-144 Bridge, South-East side
5	Roscommon, ditch-tributary to Tank Cr. at Main St.
6	Grayling, US-27 Bridge, South side
7	Grayling, US-27 Bridge, East side
8	Grayling, railroad bridge, above US-27
9	Grayling, elementary school below WWTP
10	McMaster's Bridge, North-East side

Date and station	Time A=AM P=PM	Temperature (F)		Weather conditions	Turbidity
		Air	Water		
March 23, 1972					
1	2:50P	50	35	Thaw,	Mod. turbid
2	2:30P	50	34	light	"
6	2:55P	50	35	rain	"
7	3:00P	50	35		Lightly turbid
8	2:45P	50	35		Mod. turbid
March 28, 1972					
1	3:20P	34	39	Thaw,	Mod. turbid
2	3:05P	34	38	moder-	Very turbid
3	3:10P	34	38	ate	"
6	3:25P	34	38	rain	Mod. turbid
7	3:30P	34	38		Lightly turbid
8	3:35P	34	39		Very turbid
9	3:00P	34	37		Lightly turbid
March 29, 1972					
3	3:45P	36	38	Thaw, mod-	Very turbid
9	3:00P	36	38	erate rain	Lightly turbid
April 11, 1972					
2	2:30P	40	38	Thaw,	Very turbid
4	3:00P	40	39	light-mod.	"
5	3:15P	40	39	rain	"
6	2:00P	39	38		Mod. turbid
10	10:00A	40	39		Lightly turbid

Appendix Table II, cont.

Date and station	pH	T-alk (ppm)	5-day B.O.D. (ppm)	Cond. (mhos /cm)	$NO_3 + NO_2$ (ppb)	PO_4 (ppb)	CHL (ppm)	T-Col (orgs/100 ml)	F-Col (orgs/100 ml)
March 23 1972									
1	7.8	96	5.8	652	---	---	--	6,500	110
2	7.9	69	3.8	222	---	---	--	152,000	8,600
6	7.8	88	5.3	592	---	---	--	500	10
7	7.9	83	5.9	360	---	---	--	<100	<10
8	7.7	78	4.3	260	---	---	--	3,700	<10
March 28 1972									
1	8.1	118	8.0	---	396	767	95	11,500	130
2	7.7	82	6.3	---	161	2,217	54	1,300	<10
3	8.1	136	3.2	---	184	1,459	67	1,440,000	8,000
6	8.2	80	8.9	---	408	735	95	1,200	<10
7	8.1	193	1.8	---	396	810	84	<100	<10
8	8.1	114	5.2	---	342	959	63	400	<10
9	8.2	84	5.4	---	183	1,270	79	1,100	<10
March 29 1972									
3	---	---	---	---	---	---	--	58,000	2,890
9	---	---	---	---	---	---	--	5,100	10
April 11 1972									
2	9.0	52	---	180	---	---	--	92,200	6,090
4	9.4	36	---	588	215	491	36	16,500	20
5	9.4	36	---	289	244	328	39	52,700	520
6	9.0	32	---	131	---	---	--	1,200	<10
10	9.4	58	---	358	154	104	45	3,500	<10

T-alk = Total alkalinity
B.O.D. = Biological oxygen demand
Cond. = Conductivity
$NO_3 + NO_2$ = Nitrate-nitrite nitrogen
PO_4 = Phosphate phosphorus
CHL = Chlorides
T-Col = Total coliforms
F-Col = Fecal coliforms

Appendix Table II. continued

Date and station	Time (am)	Temperature (°F) Air	Water	Weather conditions	Turbidity
Aug. 8, 1972					
1*	10:10	65	67	Heavy rain	Very turbid
2	9:40	64	63	Heavy rain	Mod. turbid
3	9:50	64	63	Heavy rain	Mod. turbid
4	10:50	65	65.5	Heavy rain	Mod. turbid
5	11:24	67	68	Heavy rain	Very turbid

* Strong odor of gasoline and oil.

Date and station	pH	T-alk (ppm)	5-day B.O.D. (ppm)	Cond. (mhos /cm)	$NO_3 + NO_2$ (ppb)	PO_4 (ppb)	CHL (ppm)	T-Col (orgs/100 ml)	F-Col
August 8 1972									
1	7.5	82	14.0	321	415	2,085	43	310,000	1,100
2	7.6	102	7.0	678	243	483	101	350,000	1,200
3	7.8	106	3.8	577	196	142	76	60,000	<10
4	7.6	62	4.3	260	125	174	34	310,000	270
5	7.5	74	4.4	208	169	375	21	460,000	920

Appendix Table II. continued

Date and station	Time (pm)	Temperature (°F) Air	Water	Weather conditions	Turbidity
Sept. 29 1972					
1	8:10	52	50	Very heavy rain	Mod. turbid
2	8:30	52	50	Very heavy rain	Very turbid
3	8:55	52	50	Very heavy rain	Lightly turbid
4	9:30	52	50	Very heavy rain	Very turbid
5	9:40	52	50	Very heavy rain	Mod. turbid

Date and station	pH	T-alk (ppm)	5-day B.O.D. (ppm)	Cond.*	NO_3 $+NO_2$ (ppb)	PO_4 (ppb)	CHL (ppm)	T-Col** (orgs/100 ml)	F-Col (orgs/100 ml)
Sept. 29 1972									
1	7.6	50	4.5	--	563	404	20.4	990	980
2	8.5	98	4.7	--	319	151	40.1	35	70
3	8.3	44	6.5	--	389	246	3.1	64	370
4	7.6	65	7.1	--	408	437	8.7	650	4,800
5	7.6	138	5.2	--	335	41	15.9	1,260	320

* No tests were made.

** In thousands, add ,000.

Appendix Table II. concluded

Analysis	Robin-son Creek (3/5/73)	Tank Creek (3/5/73)	Swamp in upper So. Br. drainage (1/16/73)	Swamp in Shellen-barger drainage (3/6/73)
Total PO_4-P (ppb)	<20	140	540	640
NO_3-N (ppb)	110	620	109	340
NH_3-N (ppb)	60	60	7	40
Chlorides (ppm)	4	7	13	4
T-COL orgs/100 ml	1,600	7,100	9,200	7,300
F-COL orgs/100 ml	<10	50	-10	20

Appendix Table III. List of fish species captured, by percent, for the four major habitat types in the Au Sable River basin for seine collections in the 1920's and in 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

Appendix Table IV. List of fish species captured, for the Au Sable River Mainstream seine collections in the 1920's and in 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	--	6	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	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Rainbow darter	--	--	--	--	1	1	--	--	--	--	--	--	--	--
Least darter	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Johnny darter	--	--	--	2	41	--	2	--	4	--	--	--	--	--
Yellow perch	--	--	--	--	--	1	--	2	--	--	--	--	1	--
Logperch	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Channel darter	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Blackside darter	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Walleye	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Appendix Table IV. continued

MAIN STREAM																			
STILLWATERS		MOUTH OF BIG CREEK		MIO POND		MIO DAM		COMINS LANDING		MOUTH OF LOWER SOUTH BRANCH RIVER		FIVE CHANNELS DAM		COOKE DAM		FOOTE DAM		BETWEEN FOOTE DAM AND OSCODA	
8A		10A		11A		12		13		13A		14		15		16		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	--	--	--	--	--	--

Appendix Table V. List of fish species captured, for the Au Sable River tributaries seine collections, in the 1920's and in 1972

	EAST BRANCH						SOUTH BRANCH									
	COUNTY ROAD 612		HARTWICK PINES		HATCHERY		MUD LAKE		SHERMAN BRIDGE		ROSCOMMON		CHASE BRIDGE		SMITH BRIDGE	
SPECIES Station No.	18		18A		18H		37		20B		20		22		23	
Year	1920's	1972	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	9	30
Rainbow trout	--	--	--	--	21	2	--	--	--	--	--	--	--	--	28	--
Brown trout	--	--	--	1	1	5	--	--	--	--	--	--	3	2	4	17
Round whitefish	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Mottled sculpin	3	2	26	18	14	7	--	--	7	1	31	15	54	11	80	3
Slimy sculpin	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	8
Lamprey larvae	10	--	--	--	9	--	--	--	2	--	22	--	14	--	17	--
Central mudminnow	--	7	--	--	1	--	--	--	29	17	13	--	6	--	2	--
Northern pike	--	--	--	--	--	--	--	10	8	2	--	--	--	--	3	--
Horneyhead chub	--	12	1	--	--	--	--	--	1	--	--	3	--	--	--	--
River chub	2	--	--	--	--	--	--	--	--	--	3	--	1	--	2	--
Golden shiner	2	--	--	--	--	--	--	4	2	--	--	--	--	--	--	--
Lake emerald shiner	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Common shiner	25	43	5	1	21	--	--	1	2	--	2	100	3	33	2	5
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	--	--	10	--
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	41	--
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	--	--	1
Pumpkinseed	--	--	--	--	--	--	2	--	5	--	--	--	--	--	--	--
Bluegill	--	--	--	--	--	--	1	46	--	1	--	--	--	--	--	--
Smallmouth bass	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Largemouth bass	--	--	--	1	--	--	1	77	--	--	--	--	2	--	2	--
Black crappie	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Rainbow darter	--	--	--	--	--	--	--	--	--	--	--	4	5	--	1	--
Least darter	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Johnny darter	13	27	9	9	--	--	--	10	63	32	32	38	18	9	10	3
Yellow perch	25	16	--	--	--	--	--	49	14	--	--	--	--	--	--	--
Logperch	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Channel darter	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Blackside darter	--	--	--	--	--	--	--	1	4	4	1	2	--	--	--	--
Walleye	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Appendix Table V. continued

NORTH BRANCH								BIG CREEK Crawford Co.						BIG CREEK Oscoda Co.			
DAM 1		DAM 4		CAMPGROUND BETWEEN DAM 4 AND KELLOGG'S		KELLOGG'S BRIDGE		MIDDLE BRANCH		EAST BRANCH		NORTH DOWN RIVER ROAD		25N, 1E, SEC. 26		COUNTY ROAD 487	
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
3	--	5	34	2	1	--	3	5	33	25	15	--	--	5	5	--	--
--	--	7	--	5	--	--	--	--	--	--	--	--	--	--	--	--	--
--	1	10	17	--	18	1	3	--	2	9	5	--	6	--	--	--	2
--	--	--	--	--	--	--	2	--	--	--	--	--	--	--	--	--	--
5	3	34	15	50	18	12	10	3	3	3	15	11	14	3	2	--	9
--	--	--	--	--	9	--	1	--	8	--	5	--	1	--	--	--	5
--	--	2	1	--	1	--	--	1	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--
--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	1	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
6	29	13	--	2	--	5	--	3	--	2	--	6	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	1	--	--	--	--	--	--	1	1	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
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--	--	--	--	--	--	--	--	--	--	2	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
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18	19	151	63	252	34	15	252	30	--	--	7	53	23	17	85	--	--
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[illegible]	36	55	26	5	10	18	14	3	1	3	--	3	3	--	12	--	--
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4	8	20	1	39	28	52	9	--	--	--	--	4	3	--	2	--	1
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Appendix Table VI-A. Physical data and analysis of intolerant and facultative benthic insects at stations on the Mainstream Au Sable River in June of 1972

Under bottom type, S = sand, G = gravel, Slt = silt, and Cl = clay

Location	Station No.	Date (June 1972)	Depth[1] (inches)	Bottom type	Miles from mouth	Insects per square foot				
						Intolerant		Facultative		Total number
						Number	%	Number	%	
Frederic	1	28	6	S,G	127	20	42	28	58	48
	1	28	12	S,G	127	17	11	134	89	151
	1	28	24	S,G	127	9	11	71	89	80
Bradford Cr.										
Upper	1B	8	12	G	131	88	44	111	56	199
Lower	1B	8	12	G	131	61	50	62	50	123
Pollack Bridge	2	26	6	G	118	18	35	33	65	51
	2	26	12	G	118	25	39	39	61	64
	2	26	24	G	118	60	44	76	56	136
M-72, W. of Grayling	3	26	12	Slt, G	115	49	38	81	62	130
Maple St.	4	28	6	G	114	23	38	38	62	61
	4	28	24	G	114	59	28	149	72	208
Mouth of E. Br.										
Upper	-	8	12	G	-	17	53	15	47	32
Middle	-	8	12	G	-	12	40	18	60	30
I-75	5	28	6	G, S	113	93	55	75	45	168
	5	28	12	G, S	113	87	58	62	42	149
	5	28	24	G, S	113	19	29	46	71	65
Burton Landing	6	29	12	G	109	38	49	39	51	77
Stephan Br.	7	29	6	G	105	92	41	133	59	225
Wakeley Br.	8	27	12	G	100	69	53	62	47	131
McMaster Br.	9	29	12	G,Cl	93	20	26	56	74	76
Parmalee Br.	10	27	24	G	85	71	49	73	51	144
Mouth Big Cr.(S)	-	15	-	-	-	27	20	107	80	134
P.A.S.	11	30	6	G	81	57	45	70	55	127
Mio	12	9	12	G	73	12	15	67	85	79
Comins	13	30	12	G	65	19	7	246	93	265
Alcona Dam	14	6	12	G	47	2	4	48	96	50
Schannels Dam	15	19	24	S,G,Slt	31	13	46	15	54	28
Cooke Dam	-	19	12	-	23	0	0	9	100	9
Foote Dam	16	30	6	S	14	0	0	2	100	2

[1] At each listed depth, a one-square-foot sample was taken.

Appendix Table VI-B. Identification of aquatic insects in bottom samples from Mainstream Au Sable River in June 1972, classified as facultative or intolerant species. For data on stations, and number of samples at each station, see Appendix Table VI-A.

Order and family	Tol-er-ance	Station									
		1	1B	2	3	4	E.Br	5	6	7	8
Coleoptera											
Elmidae	F	53	33	42	2	33	4	3	2	6	3
Other[1]	F	--	--	--	--	--	--	1	--	--	--
Diptera											
Chironomidae	F	132	63	78	24	16	18	125	14	49	40
Empididae	F	--	--	1	--	1	--	1	--	--	--
Rhagionidae	F	3	7	1	--	--	1	1	--	--	5
Simuliidae	F	8	30	6	--	3	--	5	2	71	12
Tabanidae	F	2	11	7	--	--	--	1	--	3	--
Tipulidae[2]	F	22	4	1	--	--	3	3	--	1	--
Ephemeroptera											
Baetidae[3]	I	16	36	1	--	13	2	59	1	34	12
Baetiscidae	I	--	--	--	1	--	--	--	--	--	--
Caenidae	F	1	--	2	53	1	--	--	1	--	--
Ephemerellidae[4]	I	6	23	40	--	--	2	11	1	17	23
Ephemeridae[5]	I	5	1	--	40	1	--	--	--	--	--
Heptageniidae[6]	I	1	--	3	--	2	--	--	2	--	--
Leptophlebiidae	I	4	16	1	--	--	--	--	--	--	--
Siphlonuridae	I	--	--	9	--	2	--	--	3	--	--
Tricorythidae	I	2	--	35	3	59	14	104	23	17	--
Rare forms[7]	-	1	6	1	1	--	--	1	--	--	--
Trichoptera											
Brachycentridae[8]	I	2	32	2	--	--	3	1	--	12	14
Glossosomatidae	I	4	28	2	--	3	8	11	--	6	16
Goeridae	I	--	6	--	--	1	--	--	4	--	--
Helicopsychidae	I	2	3	2	--	1	--	6	4	--	--
Hydropsychidae	F	12	18	15	1	133	6	40	20	3	2
Lepidostomatidae	I	--	2	--	--	--	--	--	--	5	1
Rare forms[9]	-	3	3	2	5	--	1	9	--	1	3
Total organisms	-	279	322	251	130	269	62	382	77	225	131

[1] Other includes 1 Gyrinidae, 1 Haliplidae. [2] Genera are Antocha, Limnophila and Tipula.

[3] Genera: Baetis, Centroptilum and Pseudocloeon.

[4] Genus Ephemerella. [5] Genera: Ephemera and Hexagenia.

[6] Other genera of Ephemeroptera: Stenonema, Paraleptophlebia, Isonychia and Tricorythodes.

Appendix Table VI-B. (concluded)

Order and family	Tol- er- ance	Station									
		9	10	B.Cr	11	12	13	14	15	C.D.	16
Coleoptera											
Elmidae	F	4	15	8	2	5	2	1	--	--	--
Other[1]	F	--	--	--	--	--	--	--	--	1	--
Diptera											
Chironomidae	F	50	34	88	53	51	241	47	6	6	2
Empididae	F	--	--	1	--	--	--	--	--	--	--
Rhagionidae	F	--	6	1	--	--	--	--	--	--	--
Simuliidae	F	--	5	--	--	--	1	--	--	--	--
Tabanidae	F	--	1	7	--	--	--	--	2	--	--
Tipulidae[2]	F	--	--	1	5	--	--	--	--	1	--
Ephemeroptera											
Baetidae[3]	I	7	2	2	7	4	6	1	--	--	--
Baetiscidae	I	--	--	--	--	--	--	--	--	--	--
Caenidae	F	--	--	--	--	4	--	--	5	1	--
Ephemerellidae[4]	I	7	43	12	17	--	8	--	--	--	--
Ephemeridae[5]	I	--	2	--	3	1	1	--	13	--	--
Heptageniidae[6]	I	--	--	--	14	1	--	--	--	--	--
Leptophlebiidae	I	--	--	1	--	--	--	--	--	--	--
Siphlonuridae	I	--	--	--	--	--	--	--	--	--	--
Tricorythidae	I	2	1	--	--	--	1	--	--	--	--
Rare forms[7]	-	--	--	--	3	1	--	--	2	--	--
Trichoptera											
Brachycentridae[8]	I	1	12	5	1	--	--	1	--	--	--
Glossosomatidae	I	1	2	--	6	1	--	--	--	--	--
Goeridae	I	--	--	--	--	--	--	--	--	--	--
Helicopsychidae	I	--	7	--	5	--	1	--	--	--	--
Hydropsychidae	F	2	12	1	10	6	2	--	--	--	--
Lepidostomatidae	I	2	2	5	--	--	--	--	--	--	--
Rare forms[9]	-	--	--	2	1	5	2	--	--	--	--
Total organisms	-	76	144	134	127	79	265	50	28	9	2

[7] Rare forms: Lepidoptera (Elophila) 1 animal; Megaloptera (Nigronia) 5 animals; Odonata (Anax, Gomphus, Ophiogomphus and Agrion), 7 animals; Plecoptera (Isoperla, Acroneuria and Phasganophora), 3 animals.

[8] Among the families of Trichoptera, the families Brachycentridae and Hydrosychidae were each represented by 2 genera. For all families in this table, unless indicated otherwise, a single genus was represented.

[9] Rare forms under Trichoptera: Hydroptilidae (Agraylea), 2 animals; Leptoceridae (Decetis), 5 animals; Limnephilidae (Limnephilus and Pycnopsyche), 13 animals; Molannidae (Molanna), 4 animals; Philopotamidae and Psychomyiidae (3 genera each), 13 animals.

Appendix Table VII-A. Aquatic insects in bottom samples at stations on tributaries of the Au Sable River in 1972, analyzed for intolerant and facultative species

Bottom soil types: G = gravel, S = sand, V = vegetation

Stream and location	Station No.	Date 1972	Depth of water (inches)	Bottom soil type	Insects per square foot: Intolerant Number	Intolerant %	Facultative Number	Facultative %	Total number
East Branch									
County 612	18	June 2	12	G	6	5	126	95	132
Lewiston Gr.Rd.	18d	July 7	6	SGV	63	20	254	80	317
N.D.River Rd.	18h	June 9	12	S	10	56	8	44	18
Hosp. Br.	19	June 29	12	SGV	87	25	255	75	342
North Branch									
Lovells	24	July 5	12	G	251	57	190	43	441
Red Dog	25	July 6	6	-	153	43	201	57	354
South Branch									
M-144, Rosc.	20	June 22	12	G	56	16	303	84	359
Steckert Br.	21	June 22	6	G	41	84	8	16	49
Chase Br.	22	June 22	24	G	105	28	267	72	372
Smith Br.	23	June 14	12	G	310	69	141	31	451
Big Creek (No.)									
Hut-Sut (M)	-	--	--	-	46	79	12	21	58
Hut-Sut (E)	-	--	--	-	32	58	22	42	54
No. D.R.Rd.	29	July 6	6	GS	148	65	280	35	428
Big Creek (So.)									
Co. 487	26	July 6	24	G	40	30	92	70	132

Appendix Table VII-B. Identification of aquatic insects in bottom samples from tributaries of the Au Sable River in 1972, classified as facultative or intolerant species. For data on stations and number of samples at each station, see Appendix Table VII-A

Order and family	Tol-er-ance	Stations							
		East Branch				N. Br.		So. Br.	
		18	18d	18h	19	24	25	20	21
Coleoptera									
Elmidae	F	25	13	--	93	9	27	112	2
Diptera									
Chironomidae	F	73	205	8	146	13	135	106	--
Rhagionidae	F	1	9	--	2	2	5	12	--
Simuliidae	F	--	3	--	5	20	2	6	--
Tabanidae	F	1	1	--	2	--	--	1	--
Tipulidae[1]	F	1	17	--	--	--	--	15	--
Ephemeroptera									
Baetidae[2]	I	4	16	--	--	20	3	24	32
Caenidae[3]	F	22	--	--	--	--	1	--	--
Ephemerellidae	I	--	19	--	52	112	60	11	--
Ephemeridae	I	--	1	--	--	--	3	--	2
Heptageniidae[4]	I	--	3	--	--	15	2	1	--
Leptophlebiidae	I	--	11	--	1	4	2	--	--
Siphlonuridae	I	--	--	--	--	--	4	--	--
Tricorythidae	I	--	2	--	--	1	9	1	4
Rare forms[5]	-	--	2	--	--	4	12	10	--
Trichoptera									
Brachycentridae	I	--	--	--	16	14	28	--	2
Glossosomatidae[6]	I	--	--	--	13	53	2	--	--
Helicopsychidae	I	--	--	10	--	--	24	4	1
Hydropsychidae[7]	F	3	6	--	7	145	32	51	6
Hydroptilidae[8]	I	--	--	--	2	--	3	1	--
Lepidostomatidae	I	--	2	--	1	5	--	--	--
Philopotamidae[9]	I	--	7	--	1	23	--	--	--
Rare forms[10]	I	2	--	--	1	1	1	4	--
Total organisms	-	132	317	18	342	441	355	359	49

1/ Two genera: Antocha and Hexatoma.

2/ Three genera: Baetis, Centroptilum, and Pseudocloeon.

3/ Genera: Brachycercus and Caenis.

4/ Genera: Heptagenia and Stenonema.

5/ Includes: Lepidoptera(F), genus Elophila, 1 animal at Sta. 24; Megaloptera(I) genus Nigronia, 1 at Sta. 18d, 12 at 25, 1 at 20; Odonata(F), genus Ophiogomphus, 1 at 23, 1 at Hut-Sut(M), 1 at 29; Plecoptera, genera Paragnetina, Phasganophora and Taeniopteryx, 1 at 18d, 3 at 24, 9 at 20, 1 at 22, 3 at 29.

6/ Two genera: Agapetus and Glossosoma.

Appendix Table VII-B (concluded)

Order and family	Tol-er-ance	So. Br. 22	So. Br. 23	Big Cr. (N) Hut-Sut (M)	Big Cr. (N) Hut-Sut (E)	Big Cr. (N) 29	Big Cr. (S) 26
Coleoptera							
Elmidae	F	10	13	4	2	62	17
Diptera							
Chironomidae	F	233	123	3	16	160	52
Rhagionidae	F	--	2	--	--	1	2
Simuliidae	F	3	4	--	--	47	--
Tabanidae	F	11	4	3	4	3	15
Tipulidae[1]	F	--	--	--	--	--	2
Ephemeroptera							
Baetidae[2]	I	11	36	1	3	6	9
Caenidae[3]	F	--	--	2	20	--	--
Ephemerellidae	I	16	29	27	5	69	22
Ephemeridae	I	--	1	--	--	1	--
Heptageniidae[4]	I	--	--	--	--	--	--
Leptophlebiidae	I	--	4	3	--	1	--
Siphlonuridae	I	--	--	--	--	--	--
Tricorythidae	I	3	--	7	3	15	--
Rare forms[5]	-	1	1	1	--	4	--
Trichoptera							
Brachycentridae	I	14	--	--	--	39	--
Glossosomatidae[6]	I	42	76	6	--	4	10
Helicopsychidae	I	3	130	--	--	1	--
Hydropsychidae[7]	F	10	3	1	--	6	2
Hydroptilidae[8]	I	--	--	--	1	--	1
Lepidostomatidae	I	14	21	--	--	9	--
Philopotamidae[9]	I	--	2	--	--	--	--
Rare forms[10]	I	1	1	--	--	--	--
Total organisms	-	372	450	58	54	428	132

[7] Genera: Hydropsyche and Cheumatopsyche.

[8] Genera: Agraylea and Neotrichia.

[9] Genera: Chimarra and Dolophilodes.

[10] Rare forms include: Goeridae (Goera), 1 animal at 24; Leptoceridae (Oecetis), 4 at 20; Limnephilidae (Pycnopsyche), 1 at 18, 1 at 23; Psychomyiidae (Lype, Polycentropus and Psychomyia), 1 at 18, 1 at 19, 1 at 25, 1 at 22.

Appendix Table VIII-A. Aquatic insects in bottom samples at six stations on the Mainstream Au Sable River, collected by three agencies from 1966 to 1972 (see title to Appendix VIII-B for further information). Here, samples are analyzed for intolerant and facultative species

Bottom soil types: G = gravel, S = sand, V = vegetation

Location and date	Depth (inches)	Bottom soil type	Insects per square foot				
			Intolerant		Facultative		Total number
			Number	%	Number	%	
Pollack Bridge							
June 14-16, 1966	16	SG	104	70	45	30	149
June 28, 1972	6, 12, 24	SG	34	42	48	58	82
Aug. 11, 1972	16(3)	SG	14	16	75	84	89
Sept. 27-28, 1968	15	S	23	21	85	79	108
Above Grayling Sewage Plant							
June 14-16, 1966	16	SG	31	27	83	73	114
June 28, 1972	6, 12, 24	SG	27	30	62	70	89
Aug. 11, 1972	16(3)	SG	30	18	134	82	164
Sept. 27-28, 1968	15	G	12	14	77	86	89
Confluence East Branch							
June 14-16, 1966	14	SG	0	0	19	100	19
June 8, 1972	6, 12, 24	SG	16	50	16	50	32
Aug. 11, 1972	14(3)	SG	2	4	36	96	38
Sept. 27-28, 1968	14	G	3	11	24	89	27
I-75 Bridge							
June 14-16, 1966	16	SGV	40	16	207	84	247
June 28, 1972	6, 12, 24	SG	62	78	18	22	80
Aug. 11, 1972	16(3)	SGV	111	20	452	80	563
Sept. 27-28, 1968	18	G	38	35	69	65	107
Old Allison Residence							
June 14-16, 1966	15	SV	6	24	19	76	25
Aug. 8, 1972	15(3)	-	52	32	112	68	164
Canoe Campground							
June 14-16, 1966	15	SGV	30	10	283	90	313
Aug. 8, 1972	15(3)	SG	31	36	57	64	88
Sept. 27-28, 1968	19	G	12	5	221	95	233

Appendix Table VIII-B. Insects collected in the Grayling area of the Au Sable River by the Michigan Water Resources Commission in 1966, by Dorance Brege (then a graduate student at MSU) in 1968, and by Au Sable River Study personnel of the Michigan Department of Natural Resources in 1972. Tolerance status (intolerant or facultative) is indicated for each taxon. Tabled figures are numbers of insects per square foot of stream bottom

Appendix Table VIII-B. continued

Location and date	Baetidae	Baetis	Pseudocloeon	Centroptilum	Baetiscidae	Baetisca	Caenidae	Caenis	Brachycercus	Tricorythidae	Tricorythodes
	Ephemeroptera										
Tolerance level	I	I	I	I	I	I	F	F	F	I	I
Pollack Bridge											
6/14-16/66	-	1	-	-	-	-	-	-	-	-	-
6/28/72	-	-	-	0.3	-	-	-	1.0	-	-	12.7
8/11/72	-	1.3	1.0	-	-	2.0	-	15.5	-	-	0.7
9/27-28/68	-	-	-	-	2	-	3	-	-	6	-
Above Grayling sewage treatment plant											
6/14-16/66	-	4	-	-	-	-	-	-	-	-	1
6/28/72	-	0.3	2.3	1.7	-	-	-	0.3	-	-	19.5
8/11/72	-	1.7	-	-	-	-	-	0.3	-	-	6.0
9/27-28/68	-	-	-	-	-	-	-	-	-	-	-
Confluence, East Branch											
6/14-16/66	-	-	-	-	-	-	-	-	-	-	-
6/28/72	-	-	-	2.0	-	-	-	-	-	-	7.0
8/11/72	-	-	-	-	-	-	-	0.7	-	-	-
9/27-28/68	-	-	-	-	-	-	-	-	-	-	-
I-75 Bridge											
6/14-16/66	-	1	4	-	-	-	-	-	-	-	2
6/28/72	-	2.0	0.7	16.8	-	-	-	-	-	-	34.3
8/11/72	-	8.0	30.4	7.0	-	0.3	-	0.3	-	-	55.1
9/27-28/68	4	-	-	-	-	-	-	-	-	-	-
Old Allison residence											
6/14-16/66	-	3	-	-	-	-	-	-	-	-	-
8/8/72	-	0.3	33.3	4.6	-	-	-	-	-	-	10.2
Canoe campground											
6/14-16/66	-	3	-	-	-	-	-	-	-	-	-
8/8/72	-	0.3	0.7	0.7	-	-	-	-	0.3	-	-
9/27-28/68	4	-	-	-	-	-	-	-	-	1	-

Appendix Table VIII-B. continued

Location and date	Ephemeroptera											
	Heptageniidae	Stenonema	Ephemerellidae	Ephemerella	Siphlonuridae	Isonychia	Leptophlebiidae	Leptophlebia	Paraleptophlebia	Ephemeridae	Ephemera	Hexagenia
Tolerance level	I	I	I	I	I	I	I	I	I	I	I	I
Pollack Bridge												
6/14-16/66	-	11	-	31	-	-	-	-	8	-	-	-
6/28/72	-	1.0	-	13.5	-	3.0	-	0.3	-	-	-	-
8/11/72	-	5.3	-	-	-	2.0	-	-	-	-	0.3	-
9/27-28/68	8	-	2	-	2	-	-	-	-	-	-	-
Above Grayling sewage treatment plant												
6/14-16/66	-	1	-	-	-	-	-	-	-	-	-	-
6/28/72	-	0.7	-	-	-	0.7	-	-	-	-	0.3	-
8/11/72	-	3.3	-	-	-	-	-	-	-	-	-	-
9/27-28/68	8	-	-	-	-	-	-	-	-	-	-	-
Confluence, East Branch												
6/14-16/66	-	-	-	-	-	-	-	-	-	-	-	-
6/28/72	-	-	-	1.0	-	-	-	-	-	-	-	-
8/11/72	-	-	-	-	-	-	-	-	-	-	-	-
9/27-28/68	-	-	-	-	-	-	-	-	-	-	-	-
I-75 Bridge												
6/14-16/66	-	-	-	1	-	-	-	-	-	-	-	-
6/28/72	-	-	-	3.6	-	-	-	-	-	-	-	-
8/11/72	-	0.3	-	-	-	-	-	-	-	-	-	-
9/27-28/68	-	-	-	-	-	-	-	-	-	-	-	-
Old Allison residence												
6/14-16/66	-	-	-	-	-	-	-	-	-	-	1	-
8/8/72	-	0.3	-	-	-	-	-	-	-	-	-	2.0
Canoe campground												
6/14-16/66	-	6	-	1	-	-	-	-	1	-	-	-
8/8/72	-	0.7	-	-	-	-	-	-	-	-	0.7	-
9/27-28/68	-	-	-	-	-	-	-	-	-	-	-	-

Appendix Table VIII-B. continued

Location and date	Ephemeroptera: Ametropodidae	Ephemeroptera: Siphloplecton	Trichoptera: Hydropsychidae	Pupae	Hydropsyche	Cheumato-psyche	Helicopsychidae	Helicopsyche	Goeridae	Goera
Tolerance level	I	I	F	F	F	F	I	I	I	I
Pollack Bridge										
6/14-16/66	-	-	-	-	13	2	-	32	-	-
6/28/72	-	-	-	0.3	1.3	0.7	-	0.7	-	-
8/11/72	-	0.7	-	0.3	5.6	9.2	-	-	-	0.3
9/27-28/68	-	-	44	-	-	-	2	-	-	-
Above Grayling sewage treatment plant										
6/14-16/66	-	-	-	7	42	-	-	5	-	-
6/28/72	-	-	-	0.3	41.9	1.7	-	0.3	-	0.3
8/11/72	-	-	-	4.0	61.1	6.0	-	1.0	-	-
9/27-28/68	-	-	48	-	-	-	-	-	-	-
Confluence, East Branch										
6/14-16/66	-	-	-	-	1	-	-	-	-	-
6/28/72	-	-	-	1.0	1.5	0.5	-	-	-	-
8/11/72	-	-	-	0.3	16.2	4.0	-	-	-	-
9/27-28/68	-	-	3	-	-	-	-	-	-	-
I-75 Bridge										
6/14-16/66	-	-	-	2	-	-	-	-	-	-
6/28/72	-	-	-	1.7	7.3	4.0	-	2.0	-	-
8/11/72	-	-	-	0.3	97.4	31.0	-	2.3	-	-
9/27-28/68	-	-	48	-	-	-	-	-	-	-
Old Allison residence										
6/14-16/66	-	-	-	1	4	-	-	-	-	-
8/8/72	-	-	-	-	3.0	-	-	-	-	-
Canoe campground										
6/14-16/66	-	-	-	-	6	38	7	-	-	-
8/8/72	-	-	-	-	-	27.0	-	0.7	-	-
9/27-28/68	-	-	190	-	-	-	-	-	-	-

Appendix Table VIII-B. continued

Location and date	Trichoptera											
	Leptoceridae	Arthripsodes	Mysticides	Limnephilidae	Pycnopsyche	Glossosomatidae	Glossosoma	Protoptila	Agapetus	Psychomyiidae	Psychomyia	Lype
Tolerance level	I	I	I	I	I	I	I	I	I	I	I	I
Pollack Bridge												
6/14-16/66	-	2	-	-	-	-	15	-	-	-	-	-
6/28/72	-	-	-	-	0.7	-	0.7	-	-	-	-	-
8/11/72	-	-	-	-	-	-	-	-	-	-	0.3	-
9/27-28/68	-	-	-	-	-	-	-	-	-	-	-	-
Above Grayling sewage treatment plant												
6/14-16/66	-	-	-	-	-	-	5	-	-	-	13	-
6/28/72	-	-	-	-	-	-	1.0	-	-	-	-	-
8/11/72	-	-	-	-	-	-	2.3	-	-	-	15.5	-
9/27-28/68	-	-	-	-	-	-	-	-	-	-	1	-
Confluence, East Branch												
6/14-16/66	-	-	-	-	-	-	-	-	-	-	-	-
6/28/72	-	-	-	-	-	-	4.0	-	-	-	-	-
8/11/72	-	-	-	-	-	-	-	-	-	-	1.0	-
9/27-28/68	-	-	-	-	-	-	-	-	-	3	-	-
I-75 Bridge												
6/14-16/66	-	-	-	-	-	-	-	-	1	-	-	-
6/28/72	-	-	-	-	0.7	-	-	-	-	-	1.7	-
8/11/72	-	0.7	0.3	0.3	2.3	-	1.0	-	-	-	1.3	-
9/27-28/68	-	-	-	-	-	-	-	-	-	33	-	-
Old Allison residence												
6/14-16/66	-	-	-	-	-	-	-	-	1	-	-	-
8/8/72	-	-	-	-	-	-	-	-	-	-	0.7	-
Canoe campground												
6/14-16/66	-	-	-	-	-	-	-	-	-	-	12	-
8/8/72	-	-	-	-	-	-	-	-	-	-	0.7	-
9/27-28/68	-	-	-	-	-	-	-	-	-	7	-	-

Appendix Table VIII-B. continued

Location and date	Trichoptera										
	Hydroptilidae	Agraylea	Lepidostomatidae	Lepidostoma	Brachycentridae	Brachycentrus	Micrasema	Molannidae	Molanna	Philopotamidae	Chimarra
Tolerance level	I	I	I	I	I	I	I	I	I	I	I
Pollack Bridge											
6/14-16/66	-	-	-	-	-	1	3	-	-	-	-
6/28/72	-	0.7	-	-	-	0.7	-	-	-	-	-
8/11/72	-	-	-	-	-	-	-	-	-	-	-
9/27-28/68	-	-	-	-	1	-	-	-	-	-	-
Above Grayling sewage treatment plant											
6/14-16/66	-	1	-	-	-	-	-	-	-	-	1
6/28/72	-	-	-	-	-	-	-	-	-	-	-
8/11/72	-	-	-	0.7	-	-	-	-	-	-	-
9/27-28/68	-	-	-	-	1	-	-	-	-	2	-
Confluence, East Branch											
6/14-16/66	-	-	-	-	-	-	-	-	-	-	-
6/28/72	-	-	-	-	-	1.0	0.5	-	0.5	-	-
8/11/72	-	-	-	-	-	0.7	-	-	-	-	-
9/27-28/68	-	-	-	-	-	-	-	-	-	-	-
I-75 Bridge											
6/14-16/66	-	-	-	-	-	1	-	-	-	-	-
6/28/72	-	-	-	-	-	0.3	-	-	0.3	-	-
8/11/72	-	0.3	-	-	-	1.0	-	-	-	-	-
9/27-28/68	-	-	-	-	1	-	-	-	-	-	-
Old Allison residence											
6/14-16/66	-	-	-	-	-	1	-	-	-	-	-
8/8/72	-	-	-	-	-	-	-	-	-	-	-
Canoe campground											
6/14-16/66	-	-	-	-	-	-	-	-	-	-	-
8/8/72	-	-	-	-	-	-	-	-	-	-	-
9/27-28/68	-	-	-	-	-	-	-	-	-	-	-

Appendix Table VIII-B. continued

Location and date	Trichoptera		Coleoptera			Hemiptera	Diptera				
	Rhyacophilidae	Rhyacophila	Elmidae	Dytiscidae	Gyrinidae	Corixidae	Chironomidae	Rhagionidae	Atherix	Simuliidae	Empididae
Tolerance level	I	I	F	F	F	F	F	F	F	F	F
Pollack Bridge											
6/14-16/66	-	-	7	-	-	-	4	-	2	-	-
6/28/72	-	-	14.0	-	-	-	25.7	-	0.3	2.0	0.3
8/11/72	-	-	9.3	-	-	-	26.7	-	0.3	1.3	0.7
9/27-28/68	-	-	1	-	-	-	35	1	-	-	-
Above Grayling sewage treatment plant											
6/14-16/66	-	-	5	-	-	-	17	-	1	-	-
6/28/72	-	-	11.6	-	-	-	5.3	-	-	1.0	0.3
8/11/72	-	-	53.3	-	-	-	5.0	-	-	1.7	-
9/27-28/68	-	-	19	-	-	-	4	-	-	-	-
Confluence, East Branch											
6/14-16/66	-	-	-	-	-	-	16	-	-	-	-
6/28/72	-	-	2.0	-	-	-	9.0	-	0.5	-	-
8/11/72	-	-	11.0	-	-	-	4.0	-	-	-	-
9/27-28/68	-	-	2	-	-	-	18	-	-	-	1
I-75 Bridge											
6/14-16/66	-	30	-	-	-	-	189	-	-	4	-
6/28/72	-	-	1.0	-	0.3	-	-	-	0.3	1.0	0.3
8/11/72	-	-	3.0	-	-	0.3	278.5	-	-	36.3	-
9/27-28/68	-	-	4	-	-	-	13	-	-	2	-
Old Allison residence											
6/14-16/66	-	-	-	-	-	-	12	-	-	-	-
8/8/72	-	-	-	7.3	0.3	0.7	90.4	-	-	4.6	0.3
Canoe campground											
6/14-16/66	-	-	1	-	-	-	233	-	-	-	-
8/8/72	-	-	2.3	0.3	-	-	50.8	-	0.3	-	-
9/27-28/68	-	-	-	-	-	-	21	-	-	2	-

Appendix Table VIII-B. continued

Location and date	Diptera							Megaloptera			
	Tipulidae	Antocha	Tipula	Tabanidae	Chrysops	Anthomyiidae	Limnophora	Corydalidae	Nigronia	Sialidae	Sialis
Tolerance level	F	F	F	F	F	F	F	I	I	F	F
Pollack Bridge											
6/14-16/66	-	17	-	-	-	-	-	-	-	-	-
6/28/72	-	-	-	-	2.3	-	-	-	-	-	-
8/11/72	-	0.7	-	-	5.0	-	-	-	-	-	-
9/27-28/68	1	-	-	-	-	-	-	-	-	-	-
Above Grayling sewage treatment plant											
6/14-16/66	-	10	-	-	-	-	-	-	-	-	-
6/28/72	-	-	-	-	-	-	-	-	-	-	-
8/11/72	-	1.0	-	-	1.3	-	-	-	-	-	-
9/27-28/68	5	-	-	-	-	-	-	-	-	-	-
Confluence, East Branch											
6/14-16/66	-	-	-	-	-	-	-	-	-	-	-
6/28/72	-	1.0	0.5	-	-	-	-	-	-	-	-
8/11/72	-	-	-	-	-	-	-	-	-	-	-
9/27-28/68	-	-	-	-	-	-	-	-	-	-	-
I-75 Bridge											
6/14-16/66	-	12	-	-	-	-	-	-	-	-	-
6/28/72	-	0.7	0.3	-	0.3	-	-	-	0.3	-	-
8/11/72	-	4.3	-	-	-	-	0.3	-	0.7	-	-
9/27-28/68	2	-	-	-	-	-	-	-	-	-	-
Old Allison residence											
6/14-16/66	-	1	-	-	1	-	-	-	-	-	-
8/8/72	-	-	-	-	2.3	-	-	-	-	-	0.3
Canoe campground											
6/14-16/66	-	4	-	-	1	-	-	-	-	-	-
8/8/72	-	0.3	0.3	-	1.0	-	-	-	-	-	-
9/27-28/68	8	-	-	-	-	-	-	-	-	-	-

Appendix Table VIII-B. concluded

Location and date	Lepidoptera: Pyralidae	Lepidoptera: Elophila	Anisoptera: Gomphidae	Anisoptera: Gomphus	Anisoptera: Ophiogomphus	Zygoptera: Agrionidae	Zygoptera: Agrion	Zygoptera: Coenagrionidae	Zygoptera: Anomalagrion
Tolerance level	F	F	F	F	F	F	F	F	F
Pollack Bridge									
6/14-16/66	-	-	-	-	-	-	-	-	-
6/28/72	-	-	-	-	-	-	-	-	-
8/11/72	-	-	-	-	-	-	-	-	-
9/27-28/68	-	-	-	-	-	-	-	-	-
Above Grayling sewage treatment plant									
6/14-16/66	-	1	-	-	-	-	-	-	-
6/28/72	-	-	-	-	-	-	-	-	-
8/11/72	-	-	-	-	-	-	-	-	-
9/27-28/68	-	-	1	-	-	-	-	-	-
Confluence, East Branch									
6/14-16/66	-	2	-	-	-	-	-	-	-
6/28/72	-	-	-	-	-	-	-	-	-
8/11/72	-	-	-	-	0.3	-	-	-	-
9/27-28/68	-	-	-	-	-	-	-	-	-
I-75 Bridge									
6/14-16/66	-	-	-	-	-	-	-	-	-
6/28/72	-	-	-	-	-	-	-	-	-
8/11/72	-	-	-	-	-	-	-	-	-
9/27-28/68	-	-	-	-	-	-	-	-	-
Old Allison residence									
6/14-16/66	-	-	-	-	-	-	-	-	-
8/8/72	-	-	-	1.7	-	-	1.3	-	0.3
Canoe campground									
6/14-16/66	-	-	-	-	-	-	-	-	-
8/8/72	-	-	-	0.3	0.3	-	-	-	-
9/27-28/68	-	-	-	-	-	-	-	-	-

Appendix Table IX-A. Number and size of fish collected from hydroelectric impoundments on the Au Sable River in 1971 and 1972

The right-hand column is the percentage of each species which were of legal size or of a size usually kept by anglers

Impoundment Species	Number of fish (2-inch size groups) 2	4	6	8	10	12	14	16	18	20	22+	Total	Average size (inches)	Percent catchable
Foote Impoundment														
Northern pike	-	-	-	-	-	-	1	-	6	2	12	21	24	64
Smallmouth bass	-	-	-	-	-	2	4	2	1	-	-	9	15	100
Walleye	-	-	-	-	-	-	-	-	1	-	1	2	22	100
Yellow perch	1	2	2	2	2	-	-	-	-	-	-	9	6	50
Pumpkinseed	-	-	5	2	-	-	-	-	-	-	-	7	6	72
Rock bass	-	17	55	23	2	-	-	-	-	-	-	97	6	58
Bowfin	-	-	-	-	-	-	-	-	-	1	7	8	23	100
Brown bullhead	-	-	-	-	1	10	5	-	-	-	-	16	12	100
Black bullhead	-	-	-	-	-	-	1	-	-	-	-	1	13	100
White sucker	-	-	-	-	-	1	-	-	1	-	-	2	15	--
Carp	-	-	-	-	-	-	1	-	-	-	-	1	15	--
Golden shiner	-	-	1	-	-	-	-	-	-	-	-	1	6	--
Totals	1	19	63	27	5	13	12	2	9	3	20	174	--	--
Cooke Impoundment														
Northern pike	-	-	-	-	-	-	5	1	13	3	7	29	19	24
Smallmouth bass	-	-	-	-	-	-	1	-	-	-	-	1	13	100
Walleye	-	-	-	-	1	-	-	-	1	-	1	3	17	67
Yellow perch	16	25	23	20	5	2	2	-	-	-	-	93	6	31
Pumpkinseed	1	6	37	28	-	-	-	-	-	-	-	72	6	81
Rock bass	2	4	56	59	5	-	-	-	-	-	-	126	7	87
Bowfin	-	-	-	-	-	-	1	-	-	3	22	26	23	96
Brown bullhead	-	-	-	-	5	6	4	-	-	-	-	15	11	94
Black bullhead	-	-	-	1	1	13	15	-	1	-	-	31	13	94
White sucker	1	4	-	-	-	-	-	2	5	1	1	14	13	--
Redhorse	-	-	-	-	-	-	-	-	-	1	-	1	19	--
Brook trout	-	-	-	-	-	1	-	-	-	-	-	1	11	--
Black crappie	-	-	-	-	-	1	-	-	-	-	-	1	11	--
Totals	20	39	116	108	17	23	28	3	20	8	31	413	--	--

Appendix Table IX-A. continued

Impoundment Species	Number of fish (2-inch size groups) 2	4	6	8	10	12	14	16	18	20	22+	To-tal	Aver-age size (inches)	Per-cent catch-able
Alcona Impoundment														
Northern pike	-	-	-	-	-	-	-	-	-	-	8	8	25	100
Smallmouth bass	-	3	2	2	2	2	-	-	-	1	-	12	9	33
Walleye	-	-	10	2	2	1	-	-	5	1	5	26	12	42
Yellow perch	6	26	48	18	10	4	-	-	-	-	-	112	6	29
Pumpkinseed	-	1	2	3	-	-	-	-	-	-	-	6	7	80
Rock bass	1	2	26	18	1	-	-	-	-	-	-	48	7	71
Bowfin	-	-	-	-	-	-	-	-	-	1	19	20	24	100
Brown bullhead	-	-	-	-	2	1	1	-	-	-	-	4	11	100
Black bullhead	-	-	-	-	1	8	-	-	-	-	-	9	12	100
White sucker	1	5	30	12	6	7	7	5	9	22	3	107	12	--
Redhorse	-	-	-	-	-	-	-	2	-	1	13	16	26	--
Carp	-	-	-	-	-	2	1	1	-	-	-	4	13	--
Northern log perch	8	2	-	-	-	-	-	-	-	-	-	10	3	--
Golden shiner	-	-	2	-	-	-	-	-	-	-	-	2	5	--
Totals	16	39	120	55	24	25	9	8	14	26	48	384	--	--
Grayling Pond														
Brook trout	-	-	3	4	-	-	-	-	-	-	-	7	7	60
Brown trout	-	-	-	-	-	3	-	-	2	-	-	5	15	100
Golden shiner	9	3	-	-	-	-	-	-	-	-	-	12	2	--
Creek chub	-	4	-	-	-	-	-	-	-	-	-	4	5	--
White sucker	90	85	42	29	7	2	3	-	-	-	-	258	5	--
W. C. shiner	-	1	2	-	-	-	-	-	-	-	-	3	4	--
Rock bass	-	-	1	-	-	-	-	-	-	-	-	1	5	--
Totals	99	93	48	33	7	5	3	-	2	-	-	290	--	--

Appendix Table IX-A. concluded

Impoundment Species	Number of fish (2-inch size groups) 2	4	6	8	10	12	14	16	18	20	22+	Total	Average size (inches)	Percent catchable
Mio Pond														
Suckers	142	9	4	2	9	15	27	103	126	93	2	532	17	--
Yellow perch	38	2	25	31	45	23	4	-	-	-	-	168	8	62
Brown bullhead	-	-	2	5	69	31	-	-	-	-	-	107	10	--
Pumpkinseed	12	41	23	4	-	-	-	-	-	-	-	80	5	33
Rock bass	-	8	46	9	-	-	-	-	-	-	-	63	6	--
Largemouth bass	45	1	-	-	-	2	1	-	-	-	-	49	3	6
Walleye	3	11	-	4	7	14	2	3	-	2	2	48	10	8
Northern pike	-	2	1	-	2	2	8	12	7	4	8	46	17	2
Johnny darter	38	2	-	-	-	-	-	-	-	-	-	40	2	--
Bluntnose minnow	27	-	-	-	-	-	-	-	-	-	-	27	2	--
Carp	22	-	-	-	-	-	1	-	1	2	12	38	25	--
Bowfin	-	-	-	-	-	-	-	-	-	1	13	14	22	--
Black crappie	15	1	-	-	-	1	-	-	-	-	-	17	1	5
Smallmouth bass	4	-	-	-	-	-	-	1	-	-	-	5	6	20
Shiners	19	22	1	-	-	-	-	-	-	-	-	42	3	--
Golden shiners	1	4	-	1	-	-	-	-	-	-	-	6	4	--
Longear sunfish	-	-	-	-	-	-	-	-	-	-	-	3	--	--
Bluegill	-	-	-	-	1	-	-	-	-	-	-	1	10	--
Rainbow trout	-	-	-	-	-	-	-	-	-	-	1	1	22	--
Brown trout	-	-	1	-	-	-	-	-	-	-	-	1	6	--
Sculpins	-	-	-	-	-	-	-	-	-	-	-	3	3	--
Dace	-	-	-	-	-	-	-	-	-	-	-	2	2	--
Northern creek chub	-	1	-	-	-	-	-	-	-	-	-	1	4	--
Totals	366	104	103	56	133	88	43	119	134	102	38	1286	--	--

Appendix Table IX-B. Age and growth analysis for game fish species[1] captured in Au Sable River hydroelectric basins surveyed in 1972

Data are in two columns: M = mean length (inches) for the age group
D = deviation from State average

Impoundment	Pumpkinseed		Yellow perch		Northern pike		Smallmouth bass		Walleye		Rock bass	
Foote												
Number of fish	7		9		21		9		2		96	
Age group	M	D	M	D	M	D	M	D	M	D	M	D
I	---	---	3.1	-1.1	13.2	-2.3	---	---	---	---	---	---
II	---	---	5.2	-0.6	17.8	-1.6	---	---	---	---	---	---
III	6.2	+1.3	6.4	-0.4	20.1	-2.1	---	---	18.1	+2.9	4.4	-1.2
IV	---	---	7.3	-0.6	23.9	+0.5	13.1	-0.2	---	---	4.6	-1.9
V	6.5	+0.3	9.5	+0.7	26.1	+0.7	13.8	-1.1	---	---	5.8	-1.6
VI	8.0	+1.2	---	---	27.8	-5.1	15.8	+0.1	---	---	6.9	-1.3
VII	---	---	---	---	32.9	+0.4	---	---	---	---	7.9	-1.0
VIII	---	---	---	---	---	---	---	---	25.5	+3.9	---	---
IX	---	---	---	---	---	---	---	---	---	---	9.7	-0.2
X	---	---	---	---	---	---	---	---	---	---	---	---
Cooke												
Number of fish	70		70		29		1		3		75	
Age group	M	D	M	D	M	D	M	D	M	D	M	D
I	---	---	3.1	-1.1	13.9	-1.6	---	---	---	---	---	---
II	3.9	-0.2	4.6	-1.2	17.1	-2.3	---	---	9.9	-3.4	---	---
III	5.6	+0.7	5.9	-0.9	20.2	-2.0	---	---	---	---	4.4	-1.2
IV	6.8	+1.1	7.9	0.0	23.7	+0.3	---	---	17.2	0.0	5.6	-0.9
V	6.7	+0.5	9.4	+0.6	25.0	-0.4	13.2	-1.7	22.7	+4.1	6.2	-1.2
VI	8.0	+1.2	10.7	+0.9	---	---	---	---	---	---	7.3	-0.9
VII	8.0	+0.7	11.1	+0.7	---	---	---	---	---	---	8.6	-0.3
VIII	---	---	---	---	---	---	---	---	---	---	9.3	-0.3
IX	---	---	12.8	+1.4	---	---	---	---	---	---	9.7	-0.2
X	---	---	13.4	+1.2	---	---	---	---	---	---	---	---

[1] Additional fish from Cooke Pond: 1 black crappie, age V, 11.1 inches; and 1 brook trout, age III, 11.4 inches.

Appendix Table IX-B. concluded

Impound-ment	Pumpkin-seed		Yellow perch		Northern pike		Small-mouth bass		Walleye		Rock bass	
Alcona												
Number of fish	6		54		8		14		26		45	
Age group	M	D	M	D	M	D	M	D	M	D	M	D
I	---	---	2.8	-1.4	---	---	4.4	-1.7	6.2	-3.3	---	---
II	4.4	+0.3	5.0	-0.8	---	---	6.8	-2.4	11.1	-2.2	3.7	-0.8
III	5.9	+1.0	6.5	-0.3	---	---	9.4	-1.9	---	---	5.5	-0.1
IV	6.7	+1.0	8.3	+0.4	22.9	-0.5	12.0	-1.3	17.4	+0.2	6.5	0.0
V	7.1	+0.9	9.6	+0.8	26.6	+1.2	---	---	18.0	-0.6	6.8	-0.6
VI	7.7	+0.9	10.3	+0.5	---	---	---	---	---	---	7.5	-0.7
VII	---	---	11.7	+1.3	28.0	-4.5	19.0	+2.2	22.5	+2.9	8.1	-0.8
VIII	---	---	---	---	---	---	---	---	---	---	9.1	-0.5
IX	---	---	---	---	---	---	---	---	27.5	+6.1	---	---
X	---	---	---	---	---	---	---	---	27.3	+2.1	---	---

[1] Additional fish from Alcona Pond: 1 black crappie, age III, length 8.7 inches.

Appendix Table X. Comparison of streamflow levels and water temperatures at Au Sable River USGS gauging and recording stations during diurnal dissolved oxygen surveys in 1966, 1971 and 1972

Investigators	Date	Mainstream (at Grayling)		E. Branch (at Grayling)		S. Branch (at Smith Br.)		Mainstream (at Mio)	
		Avg. discharge (cfs)	Max. water temp (°F)	Avg. discharge (cfs)	Max. water temp (°F)	Avg. discharge (cfs)	Max. water temp (°F)	Avg. discharge (cfs)	Max. water temp (°F)
Mich. WRC 1966	Aug 17	47	73	26	68	No records	66	748	68
	Aug 18	46	72	25	69		67	712	67
	Aug 19	45	70	25	69		67	701	67
Mich. WRC 1971	July 13	70	72	49	66	139	No record	886	No Records
	July 14	73	67	50	61	137		883	
Au Sable Study 1972	Aug 3	80	69	48	63	142	64	888	
	Aug 4	80	67	45	61	138	63	906	
Au Sable Study 1972	Sept 6	69	68	47	No record	158	58	930	
	Sept 7	69	67	46		157	58	886	

SECTION VII. APPENDIX GLOSSARY

Aquifer - A formation, or formations, that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

Baseline (data) - Referring to data or information collected to establish a reference with which other data can be compared.

Bayou - A backwater or sluggish area along the margin of a stream channel which does not receive the main current of the stream.

Bedload - Referring to heavy or sand-sized particles that are in continuous contact with the stream bottom.

Benthos - Organisms that live on or in the stream bottom.

Bloom - Referring to a peak growth phase of aquatic plants - usually algae.

BOD (Biological oxygen demand) - A measure of the amount of organic material in the water that can be oxidized by microorganisms, over a given period of time (here five days at 20 C).

Boom shocker - A wide stable work boat, capable of carrying a crew of four or five, and outfitted with booms rigged with electrodes that hang into the water and create an electrical field in front of the boat. Fish passing through the field are momentarily stunned to facilitate collection.

Bulkhead - A structure placed at the water's edge to prevent erosion of uplands.

Capsule - A very brief condensation of information.

cfs (cubic feet per second) - Refers to the number of cubic feet of water flowing past a given point in one second.

Chloride - Generally referring to sodium and calcium chlorides, reaching the stream from human use and road salting, and occasionally from deep wells.

Coliform bacteria - All aerobic and facultative anaerobic gram-negative, non-spore-forming bacilli which ferment lactose with gas formation.

Community - Refers to an interacting population of various kinds of plant and animal species.

Concentration - Refers to the weight of a constituent in water per unit volume of solution.

Conductance - Referring to the ability of water to transmit an electric current in direct proportion to the amount of dissolved particles contained.

Confidence limits (90%) - Provides a method of stating the precision of an estimate. (Here the limits within which an observation will fall 90% of the time.)

Confluence - The flowing together of two or more streams or the place of meeting of two streams.

Consumptive - Refers to the consumptive use of water or water that is lost to the system as a result of evaporation or transpiration.

Creel census - A canvassing of the numbers of fishermen using a given stream segment and information as to the size and numbers of fish species caught, time expended, and type of bait used.

Discharge (streamflow) - Refers to the volume of water flowing past a given point in a specified unit of time.

Dissolved oxygen - The amount of oxygen dissolved in water, usually stated in ppm (parts per million).

Dissolved solids - The particles dissolved in water that are left behind when the water is evaporated away.

Dredging - Referring to the removal of soils and other materials from waterways below the ordinary high water mark.

Ecology - The interrelationships between living organisms and their environment.

Effluent - The liquid portion of sewage after the floating and settleable solids have been removed.

Electrofishing - A survey conducted to capture fish using a generator and hand-held electrodes carrying about three to five amps, in order to "stun" fish long enough to effect their capture.

Enrichment - Matter contributed to the stream that supplies nutrients which in most cases results in an increase in productivity.

Environment - The climatic, soil related, and biotic factors that act upon an organism or a community of organisms to determine its form and survival.

EPA - Environmental Protection Agency.

Erosion - A washing or wearing away of a stream bank by water action which may or may not be influenced by man's activity.

Evapo-transpiration - A term expressing the combined loss of water to the atmosphere from water and plant surfaces.

Eutrophication - Referring to the intentional or unintentional enrichment of water which results in increased biological production.

Evenness - Referring to a quantitative concept used in conjunction with species diversity analysis to describe the degree to which the total number of individuals in a collection are equally apportioned among all species.

Exploitation rate - Referring to the percentage of legal sized trout in a population that are caught over a fishing season.

Fecal coliform - Those coliform organisms present in the gut and feces of warm-blooded animals and which produce gas at 45.5 C ± 0.2 C.

Flow duration - Referring to the percentage of time a given flow is equalled or exceeded.

FWPCA - Federal Water Pollution Control Agency.

Filling - Referring to the placing of materials into waterways below the ordinary high water mark.

Gaging station - A particular location on the stream, or reservoir, where systematic observations of gage height or discharge are recorded.

Game fish - A desired target fish species sought by sports fishermen (for this report).

Glacial drift - All the material (including picked up, mixed, disintegrated), transported and deposited through the action of glaciers.

Greenbelt zoning - Zoning ordinances that limit lot size, size and location of buildings, placement of septic systems, and restricts removal of streamfront vegetation, and the filling and dredging on river uplands.

Gradient - The upward or downward slope of the streambed, usually expressed in feet, or feet per mile.

Groundwater - Water within the earth that supplies wells and springs and runoff from the zone of saturation.

Habitat - Type of surroundings (or characteristics of a land and/or water area) where a particular species of plant or animal is found.

Hatch - Refers to the emergence of various insect species that compose an important part of the diet for fish species.

Hydrograph - A graph showing stage, flow, velocity or other property of water with respect to time.

Hydrology - Science dealing with the properties, distribution and circulation of water on surface of land, in the soil and bedrock formations, and in the atmosphere.

Infiltration rate - Referring to the time necessary for water to pass through pores in the soil.

Impoundment - A body of water formed by a man-made obstruction on a stream, usually a dam (reservoir).

Index - Refers to a ratio or other number derived from a series of observations and used as an indicator or measure.

Jaccard Index - Used in biology to mathematically measure the degree of similarity of two species lists; one of the faunal resemblance indices.

Lagoon - A large open holding reservoir where waste water is introduced for stabilization by plant and animal communities.

Loading - Referring to an input of a material that results in a higher concentration than is normally present.

Marginal - Referring to the lower limit of qualification or acceptability for a given plant or animal species.

Model - Referring to mathematical expressions used to define some aspect of the physical, chemical, and biological make-up of the river environment.

Nutrients - Substances (chiefly nitrate and phosphate compounds) that provide nourishment for aquatic organisms.

Parameter - A consistent attribute of a system, or characteristic of a population.

Periphyton - Referring to primary producers in an aquatic system, chiefly algal organisms that attach to surfaces (rocks, stems, leaves) and convert dissolved nutrients into food matter by photosynthesis.

Population estimate - Referring to a fish survey using a mark-and-recapture technique in order to determine the number of a given species of fish in a measured stream segment.

Pool-riffle ratio - Referring to the relative abundance of deeper areas of a stream (pools, holes) that provide resting places for trout and of shallow areas of gravel substrate (riffles) where production of trout food organisms is generally high. According to P. R. Needham (1940), "The better type of trout stream, both as shelter for fish and for angling, has about 50 percent of its area made up of pools and 50 percent of its area made up of riffles."

Primary sewage treatment - Removal of most floating and settleable solids by mechanical means.

Production - Referring to the increase in biomass produced in a stream segment (generally controlled by the amount of nutrient matter available, temperature and sunlight) in a given period of time.

Regime - Referring to a regular pattern or occurrence of a streamflow or a water component or components.

Riffle - A shallow, usually gravel, stream bottom causing a broken-water type flow.

Rubble - Rough or water-worn stones of various sizes, but generally large enough to cause some turbulence in streamflow, especially in shallow areas.

Sea wall - A wall or embankment to protect a shoreline from erosion.

Secondary sewage treatment - Removal of colloidal and dissolved organic matter, usually under aerobic conditions by biological-oxidation-decomposition, in addition to primary treatment.

Sediment - Inorganic material, transported by, suspended in, or deposited from water, usually under aerobic conditions.

Seine - A net with sinkers on the bottom edge and floats on the top edge, used to enclose fish when its ends are brought together or drawn ashore.

Shoal - Referring to the shallow marginal area, generally less than six feet deep, along the shoreline of the river impoundments.

Sill plate - Two-inch lumber placed on edge and protruding about three inches above the stream bottom across its width and perpendicular to its flow, in order to force the "bed load" up into the sampling zone.

Species diversity - A numerical approach used in quantitative ecology to evaluate the community structure of a group of organisms, incorporating the number of species and their relative abundance.

Stage - The height of the water surface above an established datum plane.

Standard - Referring to the allowable maximum levels or concentrations (of parameters), or water quality conditions, resultant of various uses, according to the designated protection afforded a waterway or body of water.

Stability - Referring to the property of streamflow.

Stocking - Refers to the "planting" of hatchery-reared fish in public waters.

Storm water runoff - The portion of precipitation that runs overland directly to a waterway or collecting system, particularly from impervious urban areas.

Stream improvement device - Referring to a man-made structure placed in a stream for the purpose of altering the physical features of a small segment, to create more favorable conditions for trout or trout food organisms.

Student's t test - A statistical procedure to test whether the observed samples could have reasonably been drawn from identical populations.

Substrate (type) - Referring to the nature and composition of the stream bottom.

Taxon - A name applied to a group or entity in a formal system of nomenclature.

Temporal - Relating to time.

Trap net - A net that is set with a lead running from shore out to an entrapment so that fish moving along the shore are guided into the enclosure.

Transpiration - Emission of watery vapor from the surface of plant leaves, resulting in loss by evaporation.

Tributary - A stream feeding a larger stream or reservoir.

Turbidity - Relative state of muddiness or roilyness, with stirred-up sediment and/or particulate matter.

Turbulent flow - A flow in the velocity at a given point varies erratically in magnitude and direction.

Watershed - A region bounded peripherally by water draining ultimately to a particular watercourse or body of water.

WQI - Water quality index - A numerical representation of several parameters which combine to constitute a measurement of water quality.

WRC - Michigan Water Resources Commission.

WWTP - Waste water treatment plant.

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