

Measurement of the Effects of
Erosion Control on Aquatic
Life in the Nemadji River
and Its Tributaries

MEASUREMENT OF THE EFFECTS OF EROSION CONTROL ON AQUATIC LIFE
IN THE NEMADJI RIVER AND ITS TRIBUTARIES

William A. Swenson, Larry T. Brooke and Philip W. DeVore

A. INTRODUCTION

The influence of sedimentation and turbidity associated with erosion from the Nemadji River Basin is assumed to have deleterious effects on the aquatic biota. Studies in the past year have concentrated on identifying fish and macroinvertebrate populations which reside permanently or seasonally in the river system. Data on substrate type, turbidity and other stream parameters is being related to the distribution and population size indices of these organisms. This information will be necessary for evaluating the impacts of the proposed erosion control structures in relation to natural conditions in the basin.

Information provided from data analyses thus far has yielded baseline levels and provides a basis for a revised sampling plan which will yield more specific information on modes of action of erosion effects. Plans include elimination of stations yielding duplicate information and intensifying the invertebrate and vertebrate population studies in the vicinity of the erosion control construction sites.

B. PURPOSE

The present phase of study of aquatic life in the Nemadji River, Little Balsam Creek and Skunk Creek has been developed around the following objectives:

1. To collect sufficient pre-construction data to determine the effects and benefits of erosion control measures.

2. To determine the present and potential usage of the Nemadji River by migratory fish.
3. To determine the suitability of the Nemadji River and tributaries for spawning by resident and lake-run fish in relation to silt and clay sedimentation.
4. To determine the effects of red clay erosion, turbidity and sedimentation on the benthic community.

C. METHODS

Site Selection

Thirteen sampling sites were selected in the Nemadji River, Balsam Creek, Little Balsam Creek, Empire Creek, Skunk Creek and Elim Creek. These sites were chosen to represent the river and stream channel types which typify the Nemadji River and tributaries from headwaters to mouth and to provide answers to the research objectives. Sites were selected as follows:

Site 1: The Nemadji River one-half mile upstream from its mouth. The river channel is broad, fairly deep and of uniform shape. There is no bank erosion as the land is low on both sides of the river. The river bed is predominantly sand and fairly stable due to the slow-moving water.

Site 2: The Nemadji River at Woodlawn Road, Superior, approximately five river miles above the mouth. There is some bank erosion and the river is narrower but deep and slow-moving. This site and site 1 represent the mouth region of the river which has currents and water levels strongly influenced by Lake Superior.

Site 3: Nemadji River two miles above Highway 35. The river is fairly shallow (<1 m) with a higher gradient than the stations at the mouth. The substrate is still predominantly sand but is relatively unstable, providing poor habitat for benthic organisms. The uniform substrate provides little cover for fish populations. This area is just below the mouth of Balsam Creek.

Site 4: Nemadji River six miles above Highway 35. Physical features are similar to site 3. This site is above the mouth of Balsam Creek. Comparison of sites 3 and 4 should provide information on the influence of the Balsam drainage on stream life.

Site 5: Nemadji River at Douglas County Highway W. The character of the river is changed from previous sites. The river is still wide and relatively shallow but a pool-riffle pattern appears with rubble and gravel more prevalent. Influence of the presence of substrate suitable for attachment of benthic life and cover for fish under conditions of heavy siltation will be suggested by data collected at this location.

Site 6: North Branch of the Nemadji River at Minnesota Highway 103. This portion of the river has a typical pool-riffle configuration with rubble and boulders prevalent in the substrate. The shallow riffles and deep pools provide a diverse habitat which should increase diversity of the benthic and fish fauna.

Site 7: Balsam Creek. A site was chosen on Balsam Creek below the mouth of the Little Balsam to monitor possible fish movement into the system and to provide additional information on the Balsam drainage. All of Balsam Creek is classified as trout water (Surface Water Resources of Douglas County by

Sather and Johannes, 1973), but the lower reaches are marginal. Turbidity and siltation seem to be the major problems in this portion of the river. The effect of this condition will be measured through data collected at this site.

Site 8: Little Balsam Creek below Highway B. This site is located immediately below the proposed construction area where it will yield information on the effects of erosion control measures.

Site 9: Upper reaches of Little Balsam Creek. This site is well above the area planned for bank stabilization and below the proposed flood water retaining structure. Data from this station will be compared with that from site 8.

Site 10: Empire Creek above Douglas County Highway B. Empire Creek occupies an adjacent drainage basin to the Little Balsam. Stream length, watershed size and water quality are very similar. Comparison of fluctuations in the fauna of this undisturbed watershed will allow more meaningful interpretations of changes expected in the Little Balsam.

Site 11: Skunk Creek above the proposed construction area. This will provide information on the undisturbed portion of Skunk Creek.

Site 12: Mouth of Elim Creek. Elim Creek is an intermittent stream which will be monitored when a stream flow exists to assess the effect of the proposed retaining structure.

Site 13: Skunk Creek below the proposed construction area. Comparison with site 11 will provide information on the immediate effects of erosion control measures.

Gradient maps of the Nemadji River and sampled tributaries were prepared to illustrate and compare stations throughout the drainage system (figures 1 and 2). Biologists have found generally comparable fish and invertebrate populations along similar stream gradients when other parameters are comparable (Thorup, 1964). It is thus useful when analyzing differences in stream populations which can be attributable to the natural physical characteristics of the river. Average gradients for the tributaries are: Empire Creek - 74 ft./mile, Little Balsam Creek - 105 ft./mile, and Skunk Creek - 33 ft./mile.

Chemical and Physical Characteristics

Five chemical-physical parameters (dissolved oxygen, conductivity, turbidity, temperature and current velocity) were measured each time a site was visited. Water temperature was measured with a thermister temperature probe, turbidity with a Ecologic Model 102 Turbidimeter, current velocity with a Pygmy Gurley Meter, dissolved oxygen with a Yellow Springs Instrument Model 54 D.O. meter, and conductivity with a Yellow Springs Instrument Model 33 Conductivity Meter.

Estimates were made of average width and depth of the stream at each site.

Qualitative estimates of stream bank erosion, vegetative cover and water color were made at all sites. The substrate of the streams was classified by visual appraisal according to the soil particle size classification described in "Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents" (E.P.A., 1973).

Macrobenthos

Macroinvertebrates were collected with both bottom samplers and artificial substrate samplers at all sites. The use of an artificial substrate allowed comparison of stations without similar substrates and demonstrated the effect

Figure 1. Gradient map of the Nemadji River and tributaries with sampling stations.

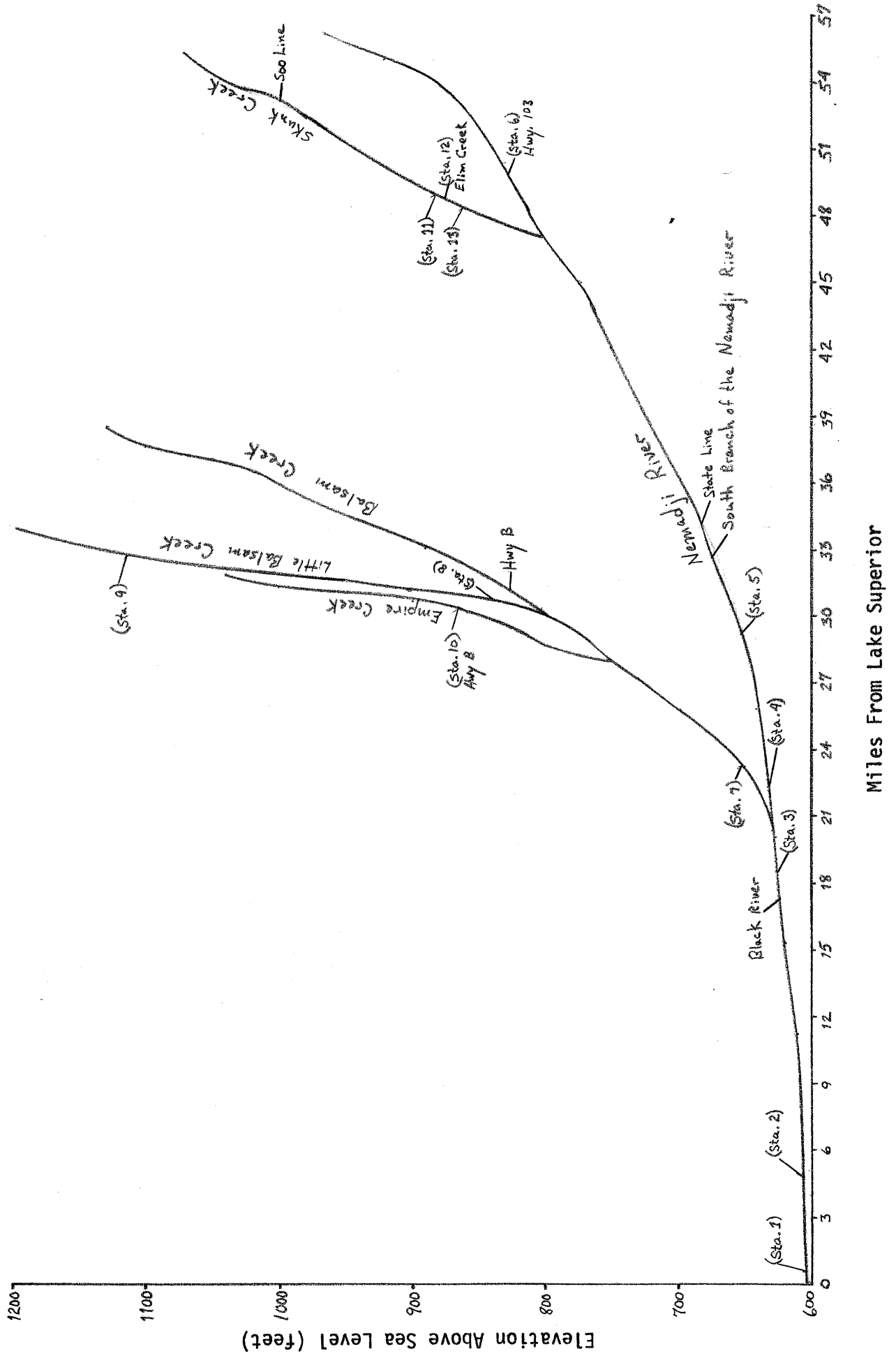
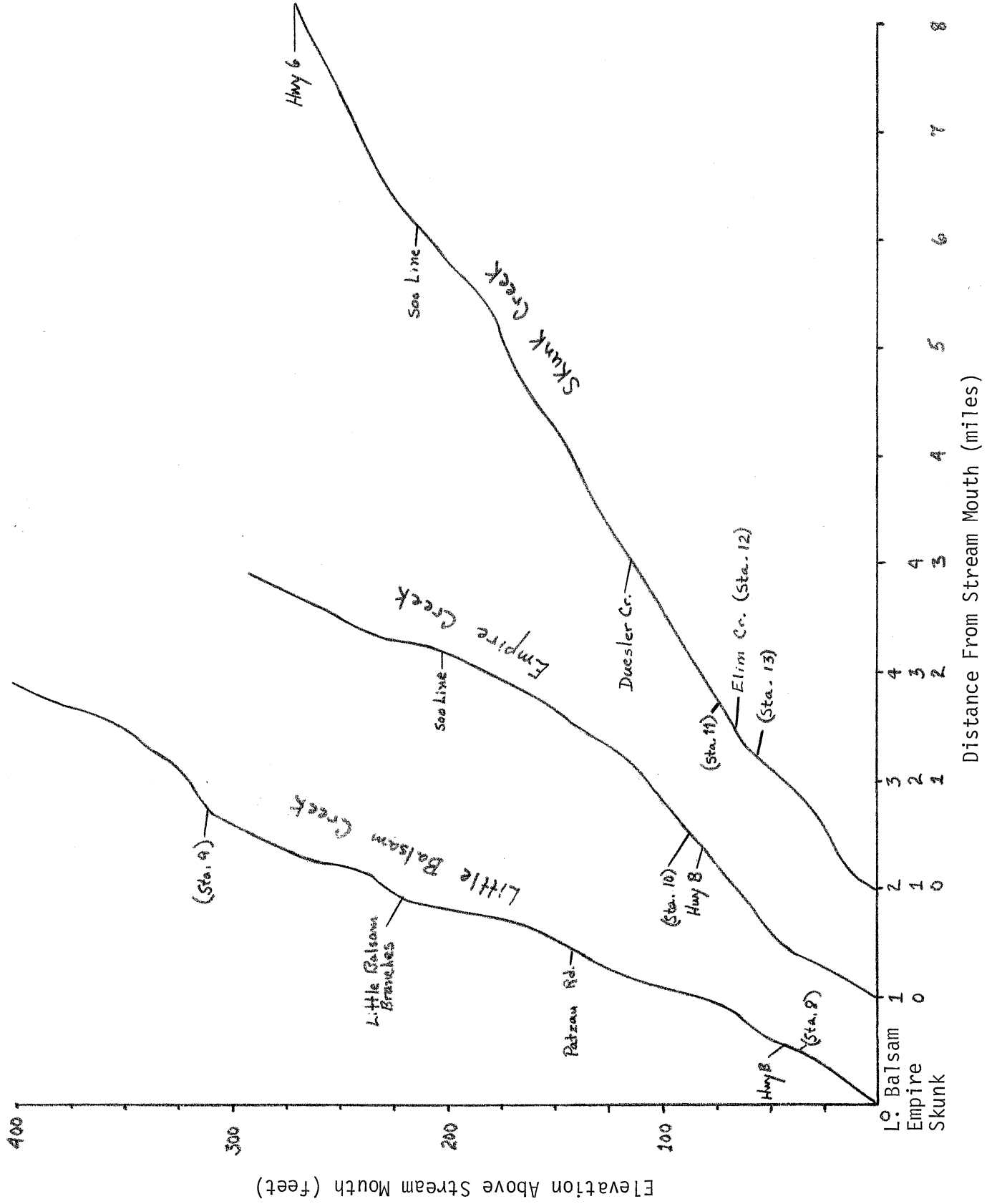


Figure 2. Gradient map from mouth to headwaters of Little Balsam, Empire and Skunk Creeks showing sampling stations and landmarks (zero mile staggered for clarity).



of a stable substrate on insect abundance and diversity.

Six benthic samples were collected from each site during each sampling period. The samples were collected from areas which gave representative measures of current velocity and substrate at each sampling site. Substrate type and channel location were recorded for all samples. A sieving sampler (Surber Square Foot Sampler) was used except at the two sampling sites nearest the mouth where water depth exceeds six feet. A grab sampler (Ponar dredge) was used at these sites.

Artificial substrate samplers (Hester-Dendy type) were placed at each sampling site. Two pairs of samplers were placed in the stream (generally one pair in a pool and one in a riffle area) during late August and early September. The samplers were collected after six weeks by carefully removing over a sieve to prevent loss of insects. The samples were preserved in the field and returned to the laboratory for identification.

All samples were washed in the laboratory through a U.S. Standard No. 35 sieve (32 meshes per inch) and hand picked. Generic identification was performed using keys by Hilsenhoff, Usinger and Pennak.

Fish Studies

Diversity and Distribution: Fish sampling was conducted at each sampling site monthly. Ten sites were sampled with a 300 watt or a 1250 watt portable generating unit in 1975. Samples collected during the spring of 1976 have been collected with newly developed electrofishing units. A 350 watt backpack unit and a 1000 watt stream unit with variable currents have allowed more efficient sampling. The unit used was dependent upon water depth and volume. At the

two sampling sites nearest the mouth sampling was conducted with two Minnesota standard trap nets set for 24 hours. All fish were identified and counted and a random sample of each species weighed and measured to establish length-weight relationships. Scales were taken from salmonids for age and growth estimates.

In the headwater streams of the Nemadji watershed 200 feet of the stream is electrofished to sample a series of successive pool-riffle areas. At the sampling sites where the river is large, a distance of 10 times the average width is sampled to include the different habitat types that exist in the area.

Larval Fish Sampling: In order to estimate the spawning success of the large number of spring spawning fish which run up the Nemadji River, daily drift samples were begun on 8 May to monitor the number and species of larval fish which are drifting downstream. Sampling was begun with a one meter plankton net with a 571 μ mesh. It was found that the distribution of larval fish in the water column was not random, and two 12" by 5.5" drift nets were used to better define distribution and density. All drift samples were collected with 15 minute sets. Current velocity was measured at the mouth of each net. Collection is not complete as the spring spawned fish are still hatching. Samples have not been closely examined and identification is incomplete. Tentative identification is based on the time of the hatch, size of the larval fish, and numbers of spawning fish of the various species which have been collected in the river.

Daily collections are made at the Douglas County Highway C bridge. Upstream locations have been sampled to locate the general areas in which most of the fish spawned.

Egg Incubation

A constant flow, temperature and turbidity controlled apparatus for incubating fish eggs was constructed. The apparatus was essentially a gravity flow system (figure 3). Water entered a common reservoir where temperature modifications were made before clay turbidity was added to the system. One half of the water supply was increased in turbidity to approximately 50 FTU's the other half remained clear (1 FTU). Proportionate mixing of the turbid water with the clear water resulted in the intermediate turbidity values of 10 and 25 FTU's.

The incubation chambers were constructed to simulate stream conditions of substrate and current. Four channels were used (figure 4) for each turbidity level with channels subdivided into four chambers by 530 μ mesh opening stainless steel screen. This provided for replication of samples and the inclusion of up to two species of eggs. Each chamber was 3 cm wide, 2.5 cm deep and 19.0 cm long. Two of the channels were filled to a depth of 2.0 cm with washed sand ($\leq .7$ mm) and the other two filled to the same depth with gravel (≤ 20 mm but ≥ 10 mm). Each of these paired substrates differed in current velocity by a factor of approximately two (table 1).

Mean turbidity values for the 14 day duration of the study were 1.3, 9.2, 23.2 and 48.5 (table 2). Clay used to create the turbidity came from the banks of the Little Balsam Creek (fish monitoring station 8).

Water temperature was maintained near 10.0 C by adding a small amount of heated water to the 9.0 C cold water supply. Mean temperatures were 9.9, 10.0, 10.0 and 10.1 C for the respective nominal turbidities of 1, 10, 25 and 50 FTU. The systematic increase in water temperature with increased turbidity was due to increased retention time and recycling of some of the water over the clay source. This added heat and resulted in a difference of 0.2 C between the two turbidity extremes.

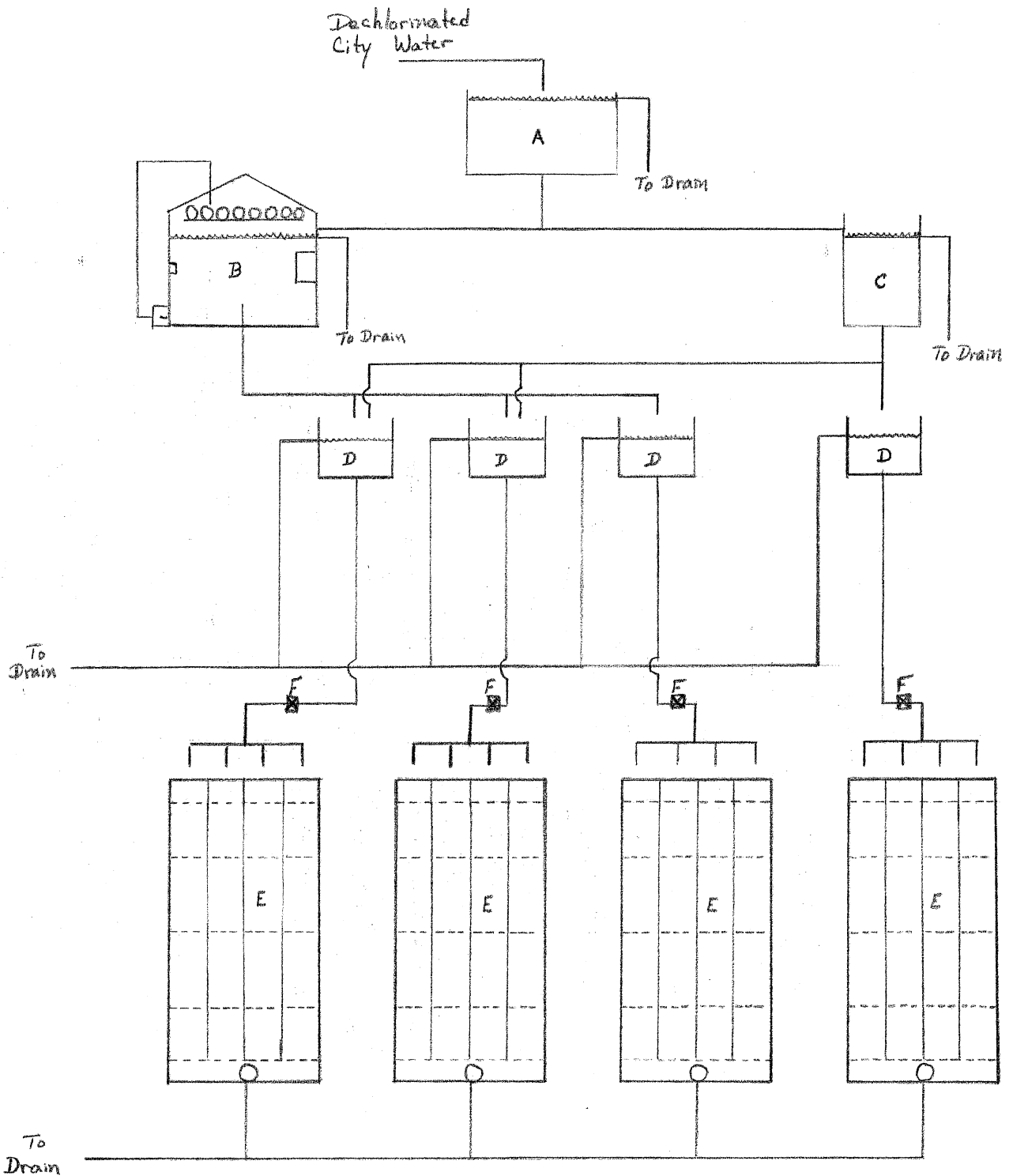


Figure 3. Constant flow egg incubation apparatus. Dechlorinated city water enters the system at tank A where it is modified thermally to the desired temperature before going to the clear water head tank C and the turbidity generating head tank B. Turbidity is developed by pumping water from the head tank B over clayballs suspended above the tank in a polyethylene screen box. When the desired level of turbidity is attained the water darkens and the photocell within the tank responds and activates a relay which turns off the pump. When the water clarity increases enough to activate the photocell the pump is turned on again and water flows over the clayballs. Desired turbidity values are attained in mixing head tanks D by mixing the proper proportions of turbid and clear water. The temperature and turbidity controlled water is then delivered to the incubation chambers E and flow rates are controlled by valves F.

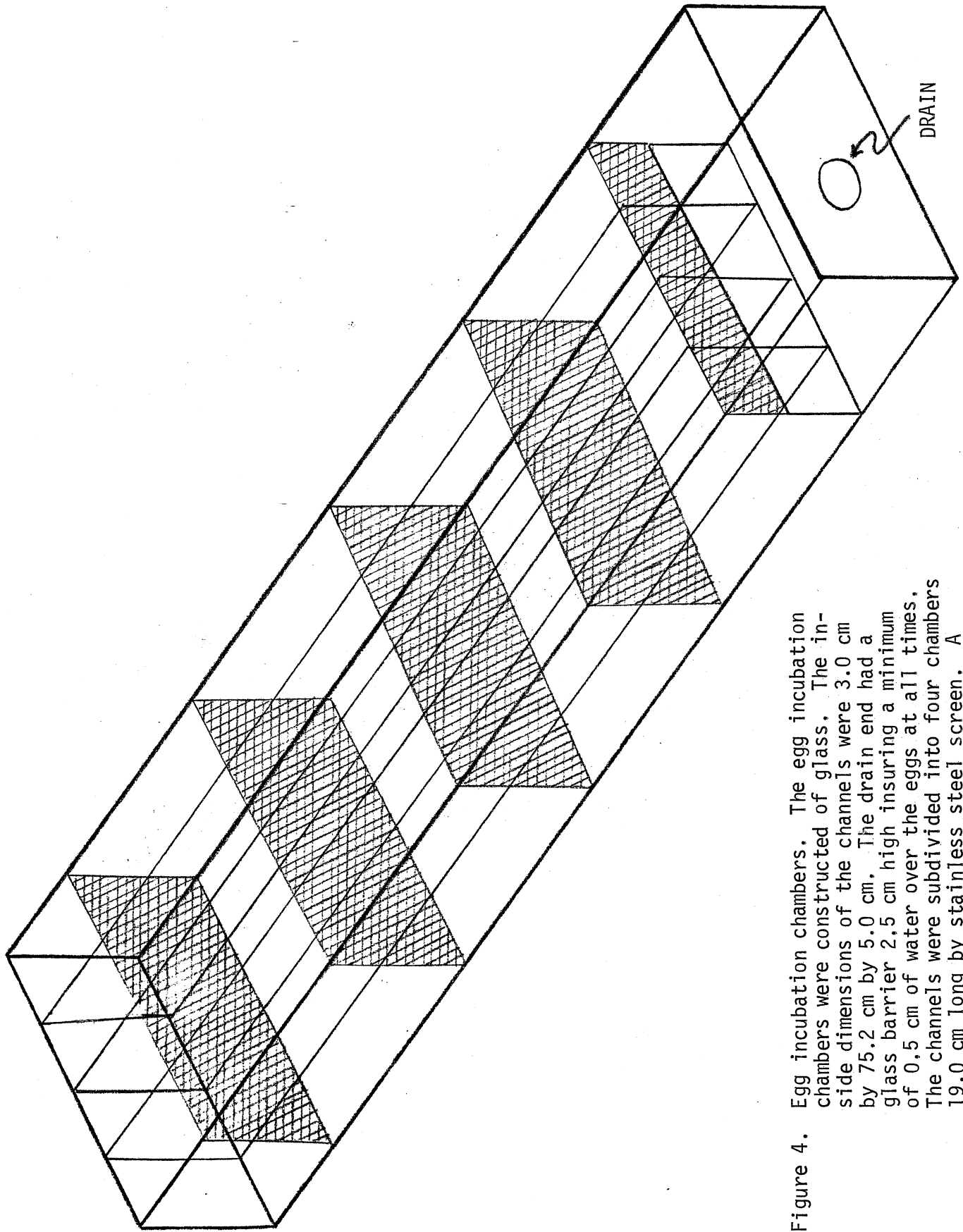


Figure 4. Egg incubation chambers. The egg incubation chambers were constructed of glass. The inside dimensions of the channels were 3.0 cm by 75.2 cm by 5.0 cm. The drain end had a glass barrier 2.5 cm high insuring a minimum of 0.5 cm of water over the eggs at all times. The channels were subdivided into four chambers 19.0 cm long by stainless steel screen. A fifth chamber was needed to add water to the channels and reduce turbulence.

TABLE 1

Calculated water velocities (cm sec^{-1}) within incubation chambers. (Upper and lower values refer to the respective placement of replicate samples within each treatment.)

	1 FTU				10 FTU			
	GRAVEL		SAND		GRAVEL		SAND	
Upper	3.43	1.66	2.96	1.63	3.17	1.77	3.09	2.14
Lower	3.90	1.66	3.76	1.89	3.44	1.77	3.79	1.91
	25 FTU				50 FTU			
	GRAVEL		SAND		GRAVEL		SAND	
Upper	3.68	2.87	3.22	2.58	2.92	1.38	3.08	1.69
Lower	3.45	2.22	3.80	2.14	3.26	1.40	3.63	2.03

TABLE 2

Mean and range (in parenthesis) of turbidity, temperature, dissolved oxygen, pH and total alkalinity values for the rainbow smelt incubation study.

N O M I N A L T U R B I D I T Y V A L U E

	1	10	25	50
Turbidity (FTU)	1.3 (1-2)	9.2 (4-14)	23.2 (11-33)	48.5 (22-63)
Temperature (C)	9.9 (9.4-10.4)	10.0 (9.6-10.3)	10.0 (9.7-10.2)	10.1 (9.7-10.4)
Dissolved Oxygen (ppm)	10.6	10.6	10.6	10.6
pH	6.8	6.8	6.8	6.8
Total Alkalinity (as CaCO ₃)	40.8	41.3	43.5	44.0

Flow volume was measured using a stopwatch and graduated cylinder. Flow velocities were calculated using the formula $R = \frac{V}{DW}$ where R is flow velocity in cm sec⁻¹, V is flow volume in cm³ sec⁻¹, D is the mean water depth in the channel (cm) and W is the width (cm) of the channel. The flow entering the incubation chambers varied from 1.2% to 7.7% for all the incubation chambers. However, velocities within the incubation chamber varied by as much as 14.5%. This was due to a gradual but daily clogging of the screens separating the incubation chambers. As the screens clogged the water level over the substrate rose decreasing the flow rate. The effect was greater in the 50 FTU treatment chambers than the 25 FTU chambers and negligible in the 10 and 1 FTU chambers. The effect was also greater in the upstream chamber of the paired replicates.

Eggs of rainbow smelt (Osmerus mordax) were obtained from adults taken in Allouez Bay of the Duluth-Superior Harbor on the night of 29 April. The adults were transported alive to the laboratory at the bay water temperature (10.6 C). Eggs were used from 5 females and sperm from 8 males. Eggs were hardened for 30 minutes in petri dishes at 10 C before random samples were withdrawn to be placed in the incubation stream chambers.

Due to their small size (1.1 mm diameter), and the problem of pretreatment counting, equal volumes of eggs were placed in each incubating chamber. Numbers of eggs (counted at end of incubation period) per incubation chamber ranged from 134 to 749 with a mean of 374.9 eggs per incubation chamber. There was an unexplained systematic difference between the mean number of eggs per treatments. Mean number of eggs was 573.5, 372.0, 306.2 and 247.8 for the respective nominal turbidity values of 1, 10, 25 and 50 FTU.

Walleye eggs are presently being incubated in the same apparatus. The eggs and sperm were obtained from adults migrating up the Bad River in Ashland

County, Wisconsin. The eggs were fertilized on 7 May at 11.5 C and transported to the Superior, Wisconsin laboratory at the same temperature. Fifty eggs were counted and placed in each incubation chamber. Survival results have not been obtained at this time.

D. RESULTS

Chemical and Physical Characteristics of Sampling Sites

Water temperature tended to increase in the Nemadji River from near its headwaters in Minnesota (station 6 at Minnesota Highway 103) to the mouth during the late summer and autumn months (figure 5). (The highest temperature recorded during the study was 21°C on 19 August at station 1.) Late in October the temperature between stations varied little with the exception of station 1 (near the mouth) which is influenced by lake seiches. Water temperatures from stations in streams tributary to the Nemadji River were lower during the summer months and cooled slower during the autumn than the Nemadji stations.

Conductivity decreased at most stations from late summer until ice cover in November. This is probably in response to dilution of stream flow by autumn rains and later by snow melt water. Dilution from spring snow melt brought about even greater decreases in conductivity. The Nemadji River typically had lower conductivity values at its mouth and headwaters than it did at the intermediate stations 3 and 4 (figure 6).

Dissolved oxygen ranged from 54.6% of saturation to 119.1% during the 19 August to 29 April sampling period. The low value was measured at station 1 on 29 April and the high at station 5 on 11 September.

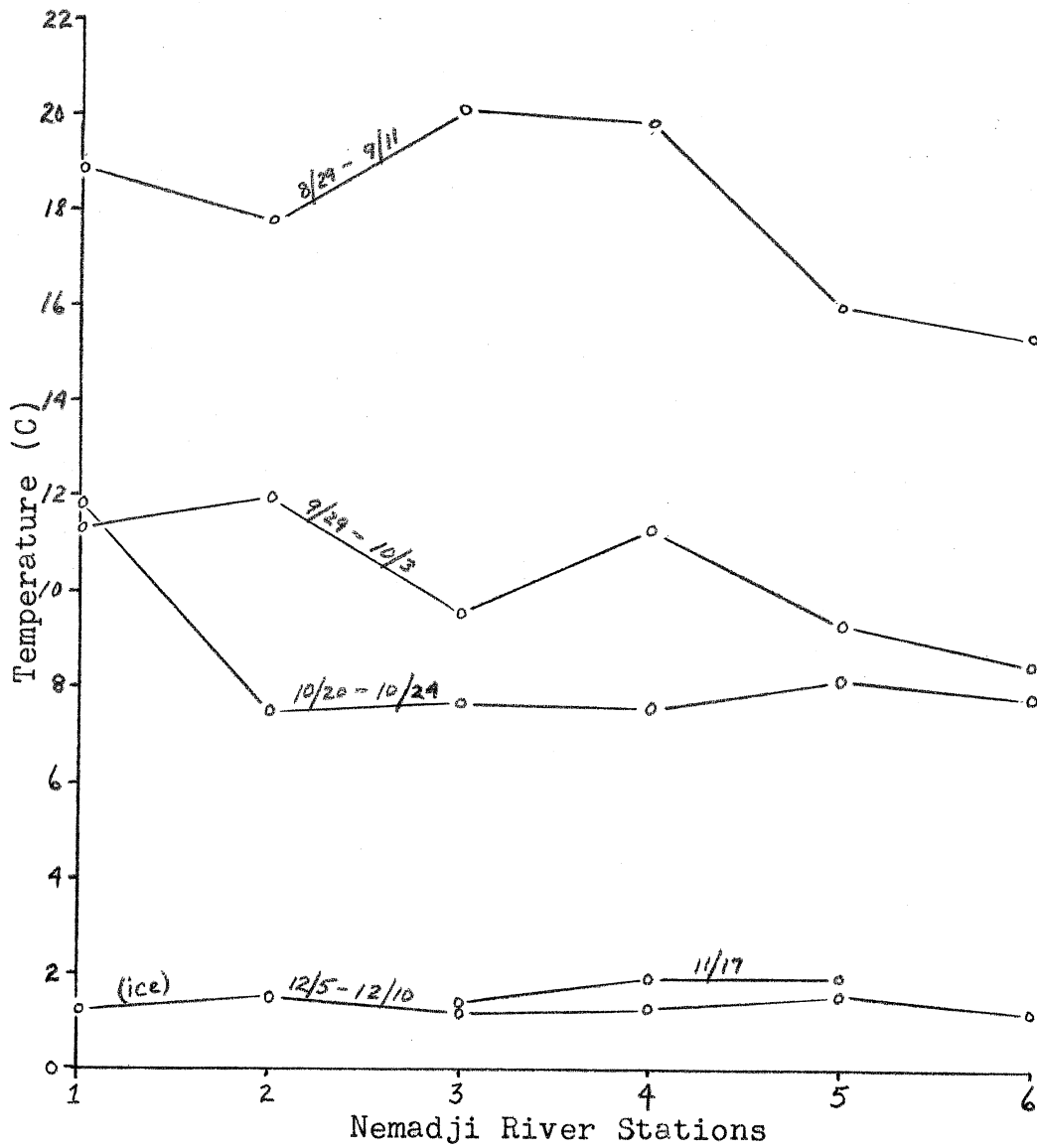


Figure 5. Temperature values at six sampling stations on the Nemadji river during four sampling periods.

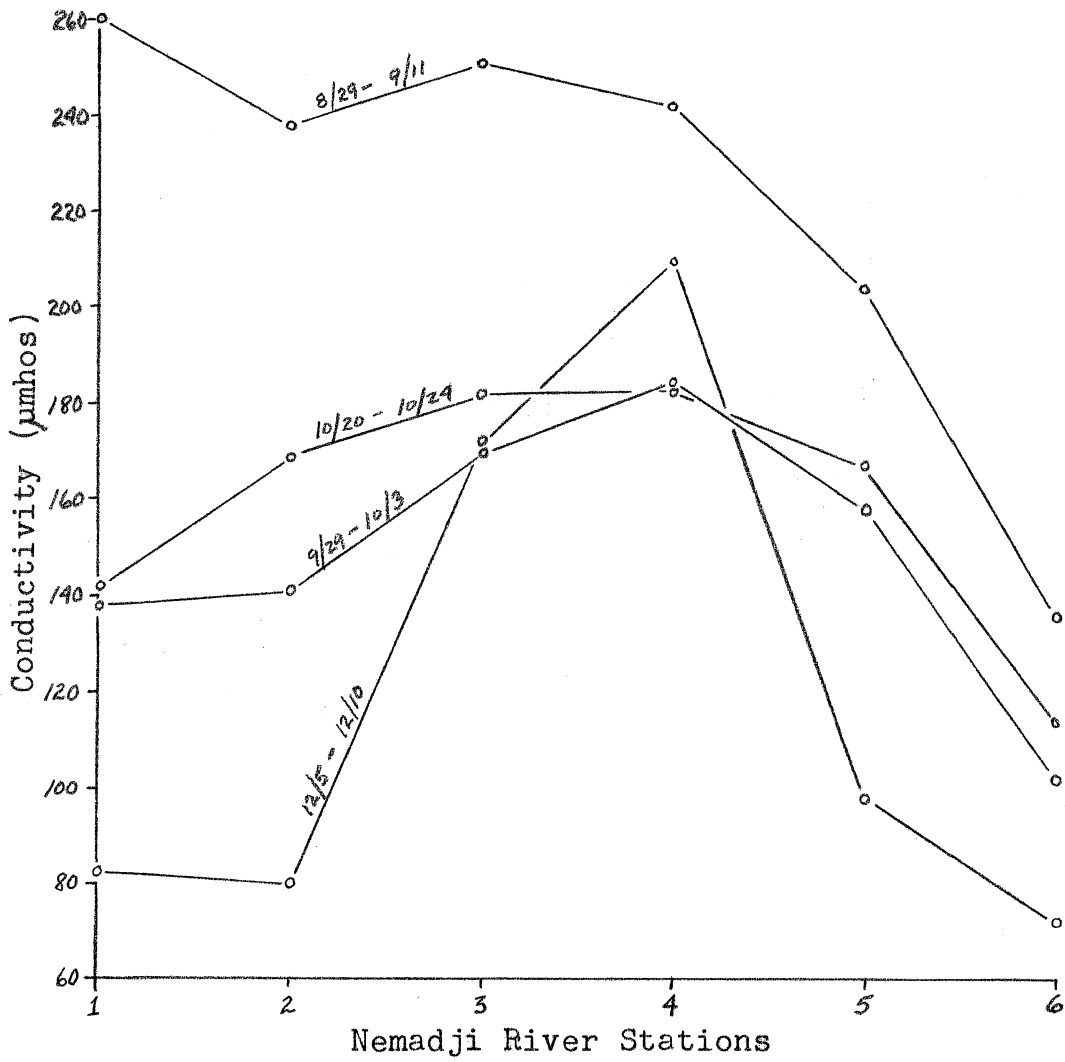


Figure 6. Conductivity values at six sampling stations on the Nemadji river during four sampling periods.

Turbidity in the Nemadji River was quite uniform between stations and relatively low during the late summer and autumn. Heavy rains just before freeze-up on 19 November increased the turbidity and account for the higher values (figure 7) during the 5-10 December sampling period. Spring snow melt increased turbidities in the Nemadji River to their highest levels. Turbidity levels in Skunk Creek were not as high during spring run-off as they were after the storm of the previous fall. Two of the tributary streams (Little Balsam and Empire Creek) have characteristically lower turbidity values (figure 8) than the Nemadji River and are classified as Class I trout streams by the Wisconsin Department of Natural Resources. Two other tributary streams (Balsam and Skunk Creeks) have characteristically higher turbidities than the Nemadji River and both are marginal (Class III) trout streams.

Current velocity was measured in the pool and riffle areas of each site. These values represent the range of water currents at each station. A wide range in velocities is generally indicative of increased habitat diversity. Measured values ranged from <0.05 to 2.75 fps for the thirteen sampling sites during late summer low flow (29 August - 11 September). Chemical-physical data for each station are summarized in Appendix I.

Macroinvertebrates

Identification and quantification is completed for the organisms from the 48 multiplate samplers (Hester-Dendy type) colonized during the fall of 1975. All insects were identified to genus. Ordination techniques have been used in preliminary analysis of the data.

Artificial substrate samplers are useful in situations where similar substrates cannot be sampled (Mason, et al., 1973) as in the sampling of an entire river

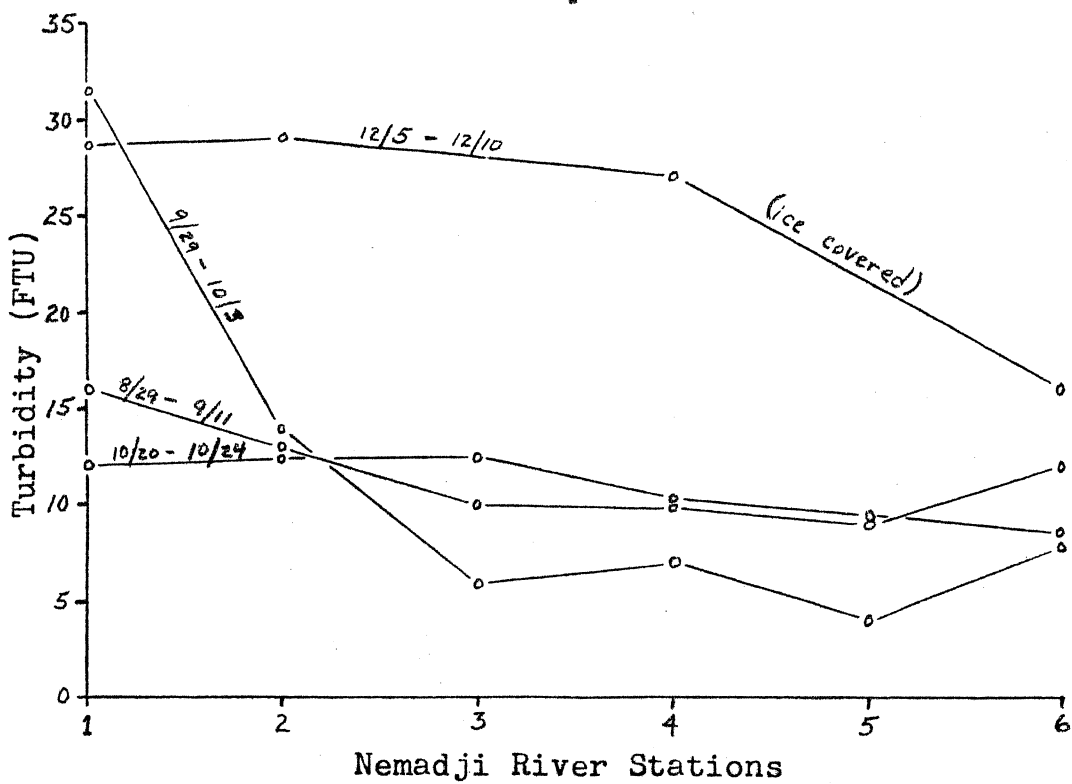


Figure 7. Turbidity values at six sampling stations on the Nemadji river during four sampling periods.

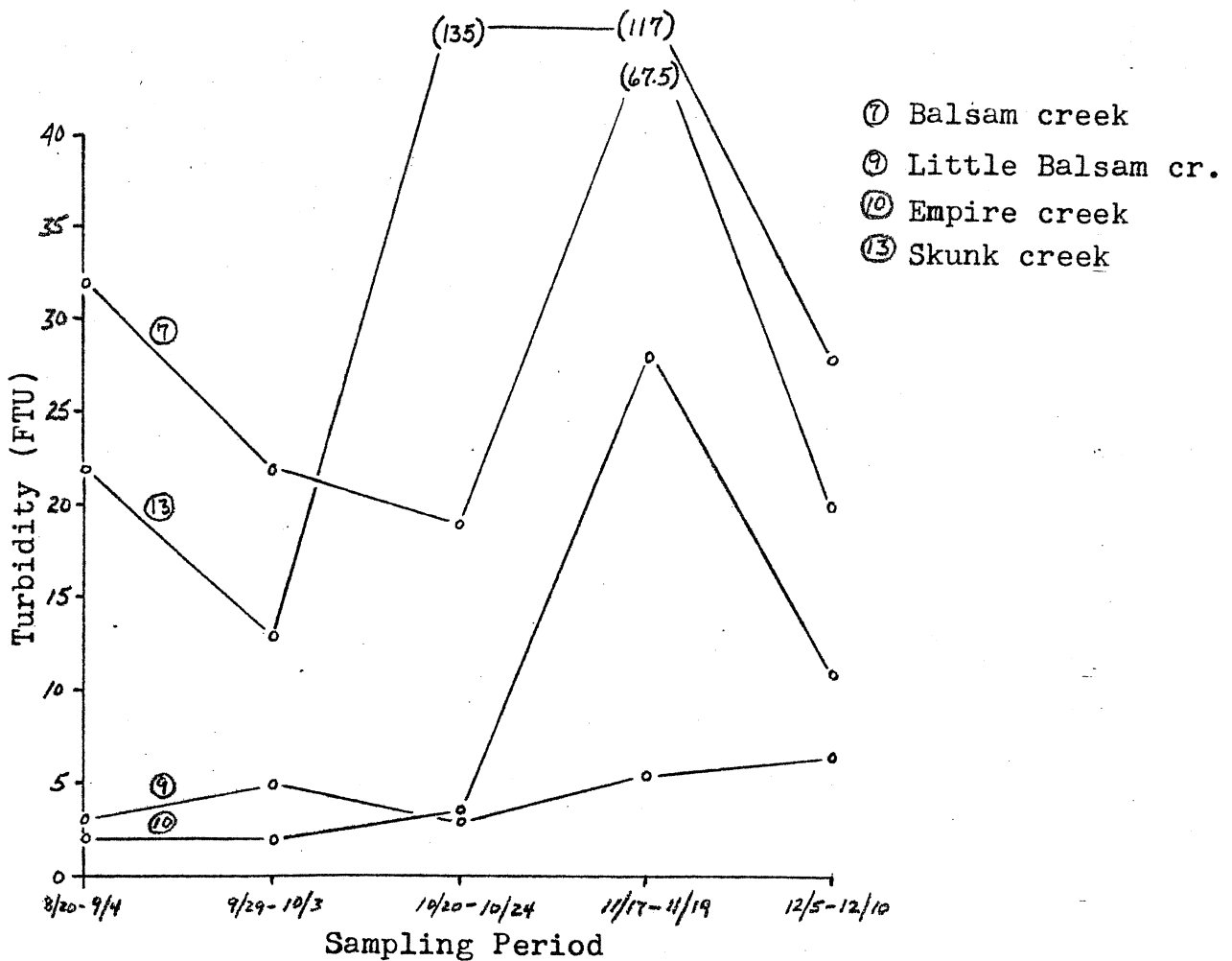


Figure 8. Turbidity values on four tributary streams of the Nemadji river during five sampling periods.

system. Because a solid substrate is foreign to some areas of the Nemadji River, interpretation of the data is best considered in conjunction with benthic samples from the same stations.

Initial analysis of the data has been directed at detecting differences in community characteristics. Ordination techniques have been developed for comparing communities composed of many different taxonomic groups (Gauch and Whittaker, 1972). They have been used primarily for plant communities but are generally effective in comparing communities which exist along an environmental gradient. Ordination gives a display of information which is often useful in relating community composition to environmental factors.

The ordination for the Hester-Dendy samples is based on one sampling period of six weeks. It is therefore not as accurate as it might be if additional sampling periods could be included. It does illustrate a good gradation of stations (figure 9). Position of stations along the axes are a function of similarity of genera to the two end point stations. The family Chironomidae was not included in the ordination as identification was not complete in time for final data analysis.

Pools and riffles for each station were entered into the ordination independently and are designated by a "P" or "R" after the station number (figure 9). The stations as depicted in the ordination grade generally from the most diverse to the least diverse from left to right. The clump of stations on the right-hand portion of the graph are pools in stream areas where there is considerable erosion and/or deposition. The only other stations with true pools are not characterized by excessive sedimentation and these stations are grouped with those more diverse stations in the riffle areas. The diversity of many

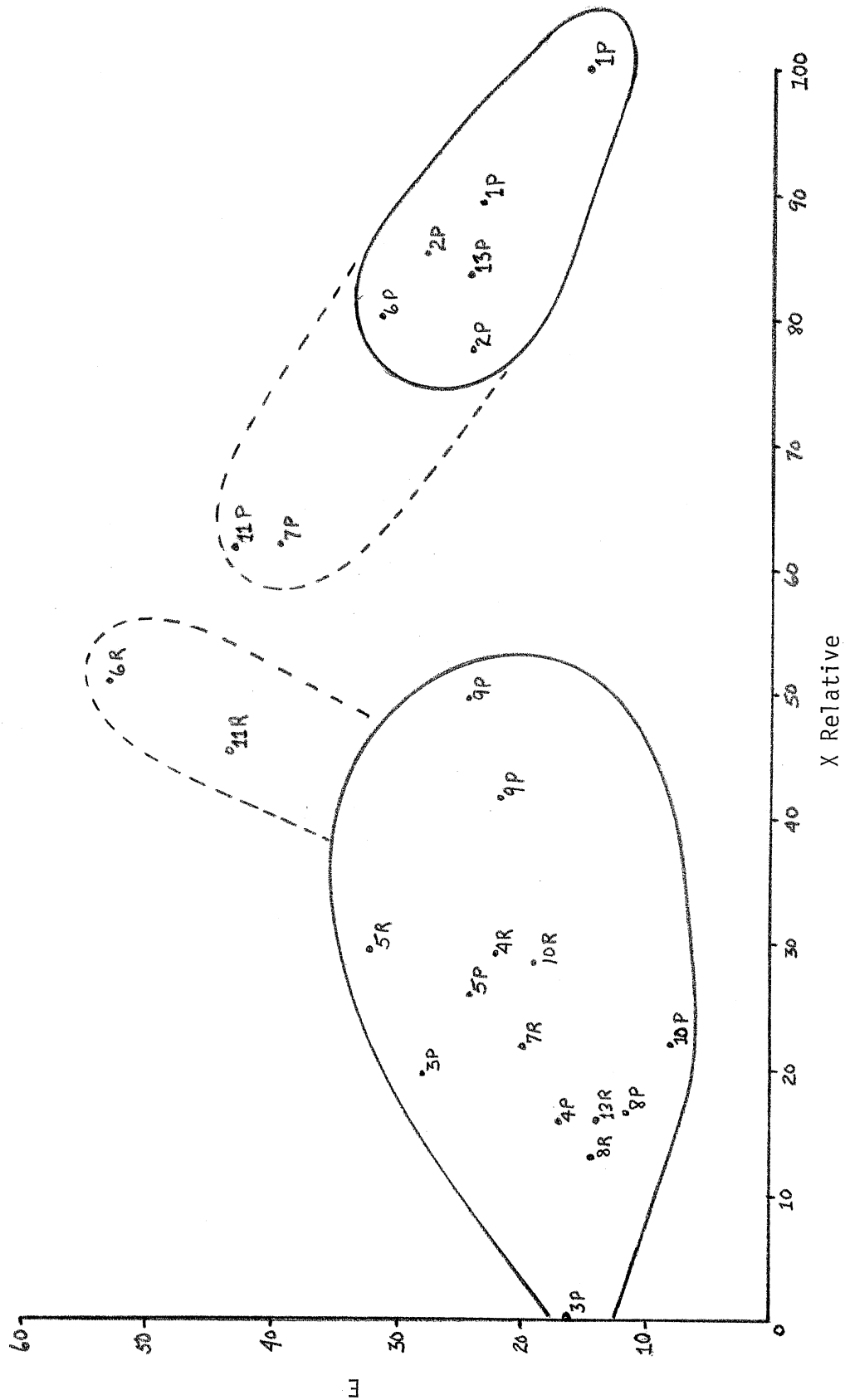


Figure 9. Ordination of 24 Hester-Dendy samples from 12 stations on the Nemadji River system.

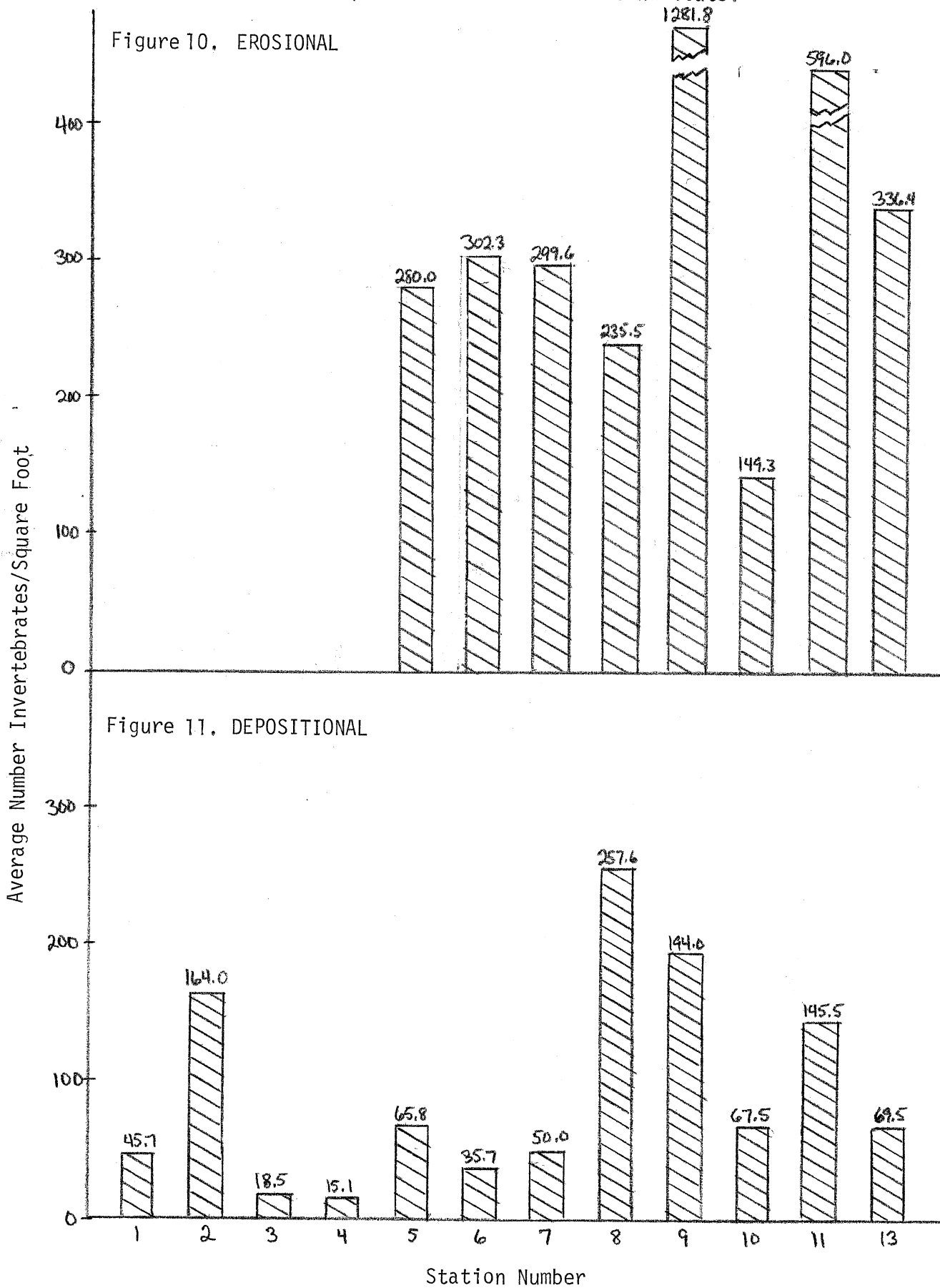
of these stations (e.g. 3, 4 and 5) may not reflect the true macroinvertebrate populations but rather the use of the provided substrate by opportunistic individuals from stream drift or channel edges where some solid substrate is available. Similar results were found with substrate samplers by Wene and Wickliff (1940). These stations generally have an unstable sterile substrate which is hostile to habitation by most species. The diversity of insects on the samplers at these stations demonstrates the importance of a stable substrate.

Benthic sample sorting is completed for the 250 Surber and Ponar samples. Identification is continuing with approximately 150 samples identified to genus. Identification is nearing completion, but in-depth analysis has not been attempted. However, certain trends are evident in total numbers of organisms (figures 10 and 11) and genera (figures 12 and 13) at different stations and stream zones. This data is presented for erosional (riffle) zones and depositional (pool) zones.

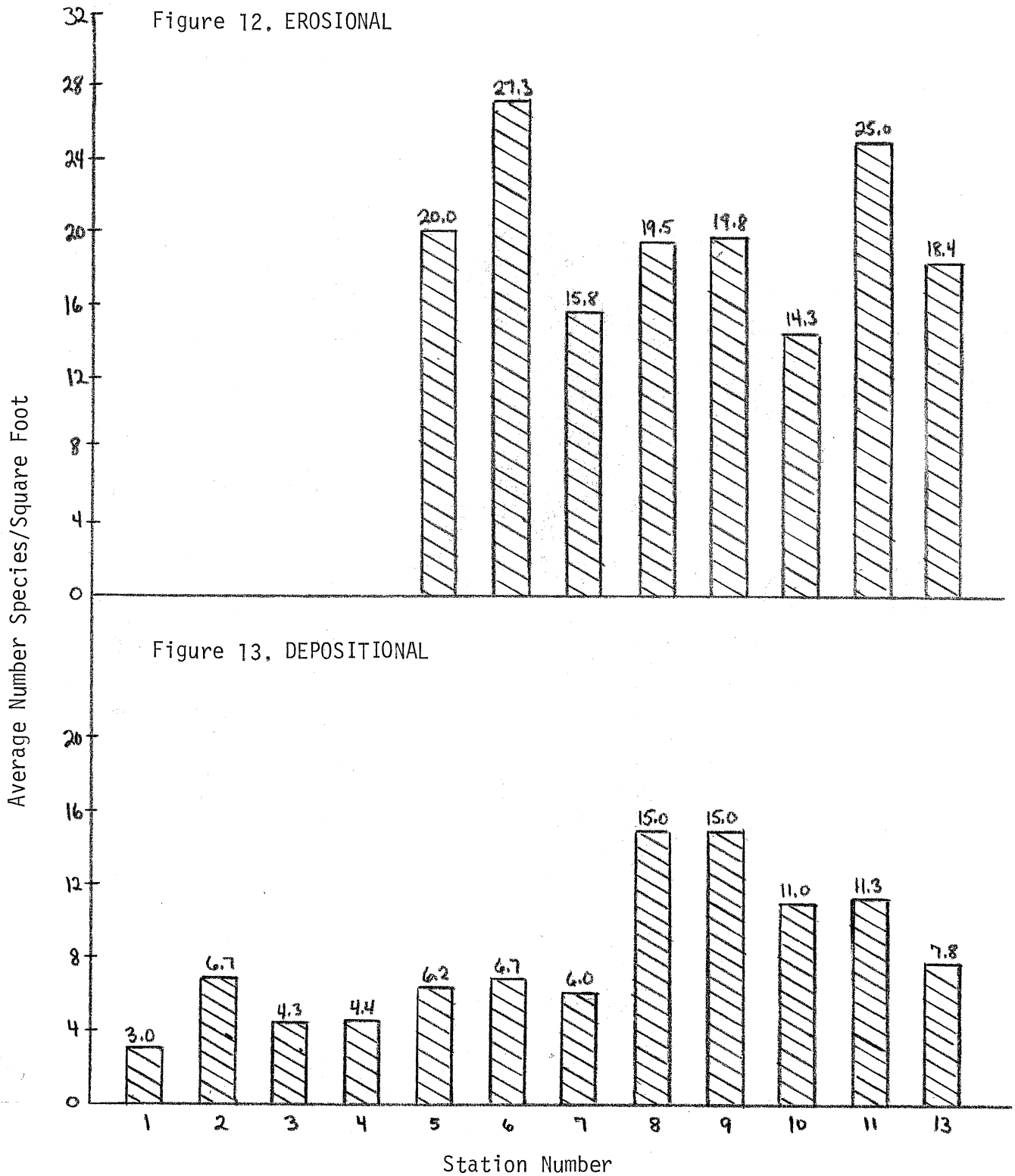
The data as presented in these figures is subject to some error due to the insufficient number of samples considered for communities with such large variances in distribution, but the picture presented is indicative of general population trends.

Many of these differences are the result of the basic character of the central and lower Nemadji River. River systems are generally characterized by a series of depositional and erosional zones (pools and riffles) in the upper regions and a broader deeper zone toward the mouth which is primarily depositional. The lower deep zones of the Nemadji River are presented by stations 1 and 2. Station 1 seems to have more fine silt and clay deposition while station 2

Figures 10 and 11. Average number of invertebrates per square foot sample in depositional and erosional habitats.



Figures 12 and 13. Average number of species per square foot sample in depositional and erosional habitats.



has a fairly stable substrate of clay, sand and some gravel. This substrate is more suitable for benthic communities and this is reflected in the greater number of organisms and genera at station 2 (figures 11 and 13). Stations 3 and 4 are in a portion of the river without many areas which can be properly characterized as erosional or depositional, although they have been included in comparisons to the depositional stations. This portion is fairly broad and shallow but the noticeable lack of a stable substrate (e.g. rubble and large gravel) prevents the formation of a step-like continuum of riffles and pools. The result is large reaches of a fairly unstable sand substrate with silt and clay in the backwaters. This is an extremely poor substrate for a benthic habitat and traps very little of the detritus upon which most of these organisms feed.

The effect of a stable substrate and detritus trap in such situations is demonstrated by a comparison of the organisms in the sand substrate at station 3 with a sample where detritus was trapped and with the Hester-Dendy samplers at the same station (table 3). Mid-channel samples presented a rather severe environment, lacking both food and a stable substrate, and this was reflected in the low number of organisms and genera. The sample with detritus provided abundant food and some protection. Insect biomass in this sample was very high as many of these were the very large stonefly, Pteronarcys sp. The Hester-Dendy samplers were close to rubble associated with a railroad bridge and recruited insects from a substrate not normally in that area of the river. The number of genera are quite high in this sample and again demonstrate the importance of a stable substrate.

TABLE 3

Total number of organisms and genera at station 3 in a Surber sample in detritus, compared with the average numbers for 10 mid-channel samples and a similar area on the Hester-Dendy samplers.

	<u>no. of Genera</u>	<u>no. of Organisms</u>
Detritus	17.0	115.0
Mid-channel	4.3	18.5
Hester-Dendy	26.0	87.5

The overall trend of the data at other stations indicates a reasonably constant number of species in the riffle habitats. Number of insects per sample varies greatly, but interpretation has not been attempted until more samples are analyzed to minimize the error involved in sampling clumped distributions typical of benthic fauna. The number of genera and individuals in the pool habitats is more revealing of stream character. The stations with unstable substrate (stations 3-5) are obviously the poorest habitat (figure 9). Those stations with a predominantly sand substrate which is more stable and traps more detritus have the greatest diversity (stations 8 and 9). Stations where considerable clay erosion and sedimentation occur (stations 6, 7, 11 and 13) have generally reduced diversity and total numbers. It thus seems that the riffle areas may have enough current to prevent detrimental effects of high turbidity and silt loads (at least in total numbers and number of genera, some intolerant organisms may be affected) while pools trap the sediment and inhibit the invertebrate communities. Further studies are needed to separate any independent effects of turbidity and siltation.

Fish

Diversity and Distribution

The combined catch from the thirteen sampling sites for all sampling periods before December 1976 was 1815 fish representing 26 species (table 4). The data show a distinct preference by all salmonids and brook stickleback for clear water. Preference for clear water has also been demonstrated by juvenile Lake Superior lake trout (Salvelinus namaycush; Swenson, unpublished data). The summary also suggests dominance of Cyprinidae and a general lack of large predators in the basin. Studies on Lake Superior walleye (Stizostedion vitreum vitreum) demonstrate a preference for high turbidity conditions (Swenson, unpublished data) and fail to explain low attendance in streams. This year's sampling (1976) is in progress and data has not been summarized. Five additional species have been captured, however, with single specimens of rainbow trout (Salmo gairdneri), tadpole madtom (Noturus gyrinus), muskellunge (Esox masquinongy), lake chub (Couesius plumbeus) and large numbers of longnose suckers (Catostomus catostomus) in recent samples.

Six of the species captured are regarded as game fish. Two of these (brown trout and brook trout) were abundant in the Little Balsam and Empire Creek sampling sites. A single brown trout (lake run spawning adult) was captured at one of the upstream Nemadji River stations. A lake run rainbow trout (steelhead) was captured on 21 May at the mouth of the Nemadji River. This was a spawned out adult and was probably returning from the upper reaches of the Nemadji River system. The other game species are the walleye, northern pike and muskellunge.

During summer and fall 1975 sampling, white suckers, black bullheads, shorthead redhorse and silver redhorse were the most abundant species at the two stations nearest the mouth of the Nemadji River. Members of the minnow family, Cyprinidae, became more numerous as one progressed upstream. Minnows were also abundant

TABLE 4

Total number of fish captured in four sampling periods during August-November, 1975 and the mean turbidity values.

SPECIES	STATION												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Mean Turbidity (FTU)	22	16	13	14	12	12	32	8	4	9	6	--	63
Black Crappie (<u>Pomoxis nigromaculatus</u>)					1								
Central Mudminnow (<u>Umbra limi</u>)			1										
Brook Trout (<u>Salvelinus fontinalis</u>)								26	39	66			
Brown Trout (<u>Salmo trutta</u>)							3	47	2	24			1
Walleye (<u>Stizostedion vitreum</u>)		1	1										
Yellow Perch (<u>Perca flavescens</u>)					1								
Mottled Sculpin (<u>Cottus bairdi</u>)								79	48	32	31		2
White Sucker (<u>Catostomus commersoni</u>)	37	23	1	7	9	8	16		4		38		31
Shorthead Redhorse (<u>Moxostoma macrolepidotum</u>)	1	6	3										
Silver Redhorse (<u>Moxostoma anisurum</u>)	4	16	2	5	3								
Burbot (<u>Lota lota</u>)				3			3						
Black Bullhead (<u>Ictalurus nebulosus</u>)	12	3											
Northern Pike (<u>Esox lucius</u>)			3										
Johnny Darter (<u>Etheostoma nigrum</u>)				1	2	8	2				20		1
Logperch (<u>Percina caprodes</u>)					1	1							
Longnose Dace (<u>Rhinichthys cataractae</u>)				6	25	44	25	34			27		
Blacknose Dace (<u>Rhinichthys atratulus</u>)			1	7	13	13	30	9			67		13
Common Shiner (<u>Notropis cornutus</u>)			12	66	7	33	45				16		7

NO FISH

TABLE 4 Continued

Total number of fish captured in four sampling periods during August-November, 1975 and the mean turbidity values.

SPECIES	STATION												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Pearl Dace (<i>Semotilus margarita</i>)			4								2		4
Creek Chub (<i>Semotilus atromaculatus</i>)			18	35	24	17	25	5			120		66
Rock Bass (<i>Ambloplites rupestris</i>)	6	3	2	6	3								
Fathead Minnow (<i>Pimephales promelas</i>)				3			3						2
Brook Stickleback (<i>Culea inconstans</i>)				1	1			1	100		1		
Troutperch (<i>Percopsis omiscomaycus</i>)				4	2	17	5				18	NO FISH	23
Stonecat Madtom (<i>Noturus flavus</i>)	1				3								
Hornyhead Chub (<i>Nocomis biguttatus</i>)			11	8	35	7	3						

in the lower reaches of Balsam Creek, Little Balsam Creek and Skunk Creek, Empire Creek contained only trout and mottled sculpins.

Spring samples have produced much greater biomass and numbers of fish in the Nemadji River. This is especially evident at station 5. This site has more gravel than is found in other downstream sites and appears to be excellent spawning habitat. This is borne out by the great numbers of spawning suckers and minnows which were captured at this station. A ripe female walleye was also captured. Biomass and numbers were several hundred times greater than that of the previous fall, emphasizing the importance of the river for spawning by Lake Superior fish populations.

Population sizes do not appear to be much different in the smaller tributaries being sampled. Numbers of larger sized trout are reduced. This indicates that these tributaries are utilized for spawning only by resident salmonid populations.

Diversity indices were computed for each sampling station for the summer and fall fish captures using three different methods (table 5). Each method emphasizes different characteristics of the populations and it has not been decided which method is most useful for station comparison in this study. Increased diversity is considered an adaptive response of communities to reduced restraints and we are attempting to ascertain what factor or factors are causing the differences between stations. Generally, diversity increased as the minnow population increased between stations. Stations that were dominated by either trout or rough fish had the lowest diversity indices.

TABLE 5

Fish species, diversity indices and rank (in parenthesis) for thirteen sample sites in the Nemadji River and five tributaries for August through November 1975.

		STATION												
		1	2	3	4	5	6	7	8	9	10	11	12	13
Number of Species		6	5	10	14	14	9	11	7	5	3	10	--	10
$D = \frac{S-1}{\log_{10} N}$	[Richness in Species]	2.80 (8)	2.34 (10)	5.08 (3)	5.95 (2)	6.51 (1)	3.69 (6)	4.33 (4)	2.61 (9)	1.70 (11)	0.96 (12)	3.56 (7)	--	4.13 (5)
$D = -\sum \left[\frac{n_i}{N} \left(\log_{10} \frac{n_i}{N} \right) \right]$	[Shannon-Wiener]	0.507 (10)	0.567 (9)	0.865 (2)	0.790 (4)	0.892 (1)	0.825 (3)	0.688 (7)	0.664 (8)	0.475 (11)	0.435 (12)	0.708 (5)	--	0.699 (6)
$D = \frac{C}{N} (N \log_{10} N - \sum n_i \log_{10} n_i)$	[Shannon-Weaver]	1.68 (10)	1.89 (9)	2.99 (1)	2.65 (5)	2.96 (2)	2.74 (3)	2.28 (7)	2.21 (8)	1.54 (11)	1.44 (12)	2.69 (4)	--	2.32 (6)
$e = \frac{S^1}{S}$	[Lloyd-Gheldardi]	0.66	1.00	1.20	0.64	0.79	1.00	0.54	0.86	0.80	1.00	0.90	--	0.70

D = diversity
 S = number of taxa
 N = total number of individuals
 ni = number of individuals in ith taxa
 C = 3.321928
 e = equitability
 S¹ = number of taxa expected

Rainbow Smelt Egg Incubation

It has been determined that rainbow smelt embryos incubated in clear water require 15 days at 10.0 C to hatch (personal communication with J. Howard McCormick, Environmental Research Laboratory, Duluth, Minnesota). During the 14th day of incubation the eggs were siphoned from the incubation chambers, examined and dead and surviving eggs counted under the dissecting microscope. Termination of the study before hatching was necessary due to the ability of the fry to pass through the 530 μ mesh openings used as barriers between replicate samples. Survival ranged from 30.2% to 74.0% for individual replicates (table 6) with means from 33.1% to 60.4% for paired replicate samples. Without statistical treatment of the data there appears to be no difference in survival due to turbidity values but there appears to be higher survival for embryos incubated in low current velocity on sand substrate.

A question is raised concerning the validity of the test results which necessitates repeating the study in the coming year. It is; Are the total egg counts systematically different between turbidity treatment levels or do they reflect hatched and escaped fry or dead and decomposed eggs? Earlier hatching was possible in the higher turbidity treatments due to the slightly higher (0.2 C) mean incubation temperatures. However, this should result in less than a 24 hour difference in hatching time.

If one assumes hatched fry escaped then the result of the study would be higher survival with increased turbidity. This does not seem likely in light of existing information on sedimentation in spawning areas (Peters 1962, Hausle 1976, Wickett 1954, Coble 1961). Increased turbidity and the resultant sedimentation should decrease survival, not increase it. Using the actual egg counts no difference in survival was observed with turbidity treatments used

TABLE 6

Percentage survivals of rainbow smelt embryos incubated at different values of turbidity and current velocity on sand and gravel. (Values in parenthesis are the means of the replicate samples.)

SUBSTRATE	RELATIVE FLOW VELOCITY	N O M I N A L T U R B I D I T Y V A L U E S				
		1 FTU	10 FTU	25 FTU	50 FTU	
Sand	Low	41.0	41.4 (41.2)	56.8 41.9 (49.4)	47.2 48.1 (47.6)	46.9 74.0 (60.4)
	High	32.4	38.6 (35.5)	44.1 45.5 (44.8)	33.0 33.2 (33.1)	44.7 44.3 (44.5)
Gravel	Low	57.2	32.3 (44.8)	38.8 41.5 (40.2)	40.1 44.1 (42.1)	36.3 38.4 (37.4)
	High	50.7	32.2 (41.4)	30.2 44.6 (37.4)	49.9 42.9 (46.4)	39.6 37.5 (38.6)

in this study. This is very likely an accurate description of the turbidity effect on smelt.

Fish Population Dynamics

Ages were determined for six species of fish. Adequate scale samples were collected from Salmonidae populations to define age structure.

In Balsam Creek (station 7) three trout were captured. All were two year old fish (table 7) with a mean length of 219 mm. Little Balsam (stations 8 and 9) and Empire Creeks (station 10) possessed the lowest average turbidity and represented the only streams with resident trout populations. Empire Creek had a well-balanced population of brown and brook trout ranging in age from young-of-the-year to two-year-olds. Percentage composition of the 0, 1 and two-year-old brown trout population in Empire Creek was 50, 33 and 17, respectively; for brook trout 61, 29 and 10, respectively. Little Balsam Creek was conspicuous for its lack of two-year-old brook trout and for its small population of brown trout (only one was captured) in the upstream sampling site (station 9). Percentages of brown trout at the sampling site nearest the mouth of Little Balsam Creek (station 8) for 0, 1 and two-year-old fish were 74, 23 and 3, respectively; for brook trout 63, 37 and 0, respectively.

Age at maturity was not determined as fish were not sacrificed to observe the gonads. A male brook trout was noted at station 9 on 30 September which was ripe. This individual had a total length of 111 mm and had completed two growth seasons.

It was noticed that the majority of individuals of trout from Little Balsam and Empire Creeks had a high percentage of regenerated scales on portions of

TABLE 7

Mean total length (mm) of brown and brook trout of known age from tributaries of the Nemadji River. Numbers in parenthesis are the number of individuals sampled.

SPECIES	AGE	S T A T I O N			
		7	8	8	10
Brown Trout	2+	219 (3)	248 (1)	----	252 (4)
	1+	----	177 (8)	122 (1)	149 (8)
	0	----	89 (26)	----	68 (12)
Brook Trout	2+	----	----	----	218 (5)
	1+	----	183 (10)	153 (12)	156 (14)
	0	----	83 (17)	84 (19)	84 (30)

their body. This could be due to abrasions from rocks, gravel and sand at high discharge periods. The absence of trout older than two years is not understood but may be due to downstream displacement by floods, active downstream migration when they have outgrown their living space (Jenkins, 1969), or predation by birds or mammals.

Ages were determined for subsamples of three other species in the Nemadji River watershed. Rock bass ranged in age from 5 to 9 years for the respective total lengths of 200 to 265 mm. White suckers ranged in age from young-of-the-year to two year olds which reached a length of 125 mm. Trout-perch were as old as four years and had attained a length of 124 mm. Young-of-the-year white suckers and trout-perch were captured indicating natural reproduction occurs in the turbid water streams where they occurred.

Ordination Analysis

Comparison of the fish populations at each of the twelve sampling sites containing fish (fish were not captured at station 12 in 1975) by ordination analysis (90% internal association) tended to place the populations into three related groups (figure 14). Group one was composed of stations 1 and 2 which had relatively low species diversity composed of black bullheads, white suckers, redhorses, rockbass and stonecat madtoms. Group two was composed of three stations (8, 9 and 10) also of relatively low diversity but comprised primarily of trout, sculpins, dace and sticklebacks. The remaining stations fell into group three which had high to medium relative diversity and included fish populations comprised principally of cyprinids. Two of the three groups (groups 1 and 2) were composed of stations which were very similar in stream or river character. Group 1 (stations 1 and 2) included the lower Nemadji stations

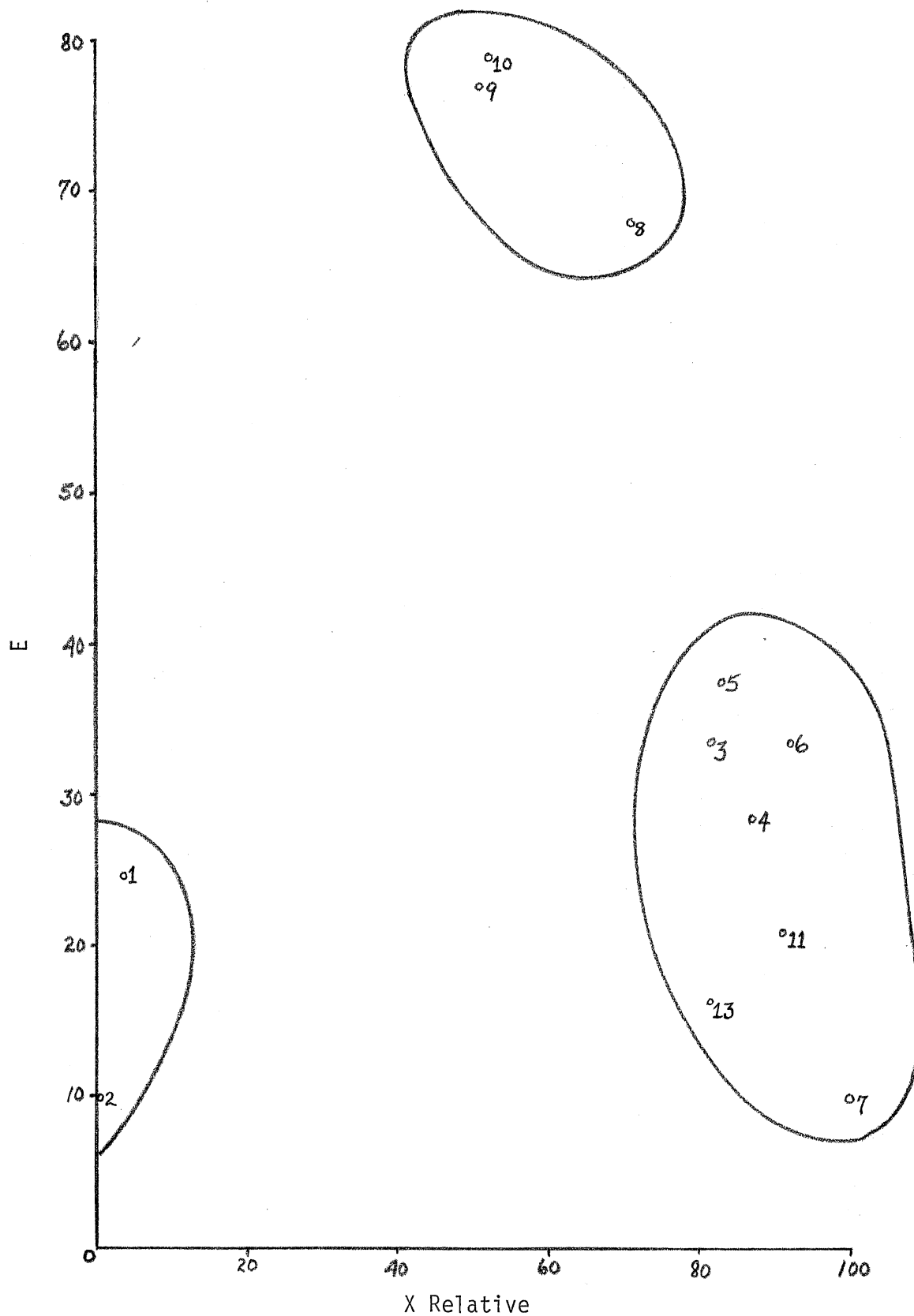


Figure 14. Plot of the percentage difference calculations by ordination analysis of 12 Nemadji River system fish communities.

which are entirely different from all other stations, offering extensive reaches of deep, turbid, slow-moving water. Group 2 was composed of the small trout streams (stations 8, 9 and 10). These offer a relatively non-turbid pool-riffle environment. The third group of turbid water upstream areas are characterized by Cyprinidae species and low density of large predatory fish species.

Larval Fish Sampling

Sampling of stream drift for larval fish is not complete at this time, but two distinct populations appear to have hatched and drifted back to Lake Superior as of 23 May. Another type of fry is appearing at this time (23 May).

The first group of larval fish to appear were rainbow smelt. They were first noted on 10 May. The hatch was essentially complete at the last sampling on 23 May (figure 15). Fry density was calculated in fry/ft³. Sampling at two different depths (top of nets at surface and 15") after 17 May indicates a reasonably random distribution in the water column. Discharge estimates have not been made at this time, but a reasonably good estimate of the number of smelt hatching in the Nemadji River Basin above County Road C will be possible.

The second group of larval fish was composed of suckers (white suckers, long-nose suckers, shorthead redhorse and silver redhorse have been found as spawning adults). The hatch was essentially complete on 23 May as were the smelt, but the duration was much shorter (figure 16). Sucker fry did not appear in any number until 17 May and were present in fairly large numbers until 21 May. The fry were restricted almost entirely to the top 2 or 3 inches of the water column (figure 16). Estimates of total numbers will not be complete until surface discharge is calculated.

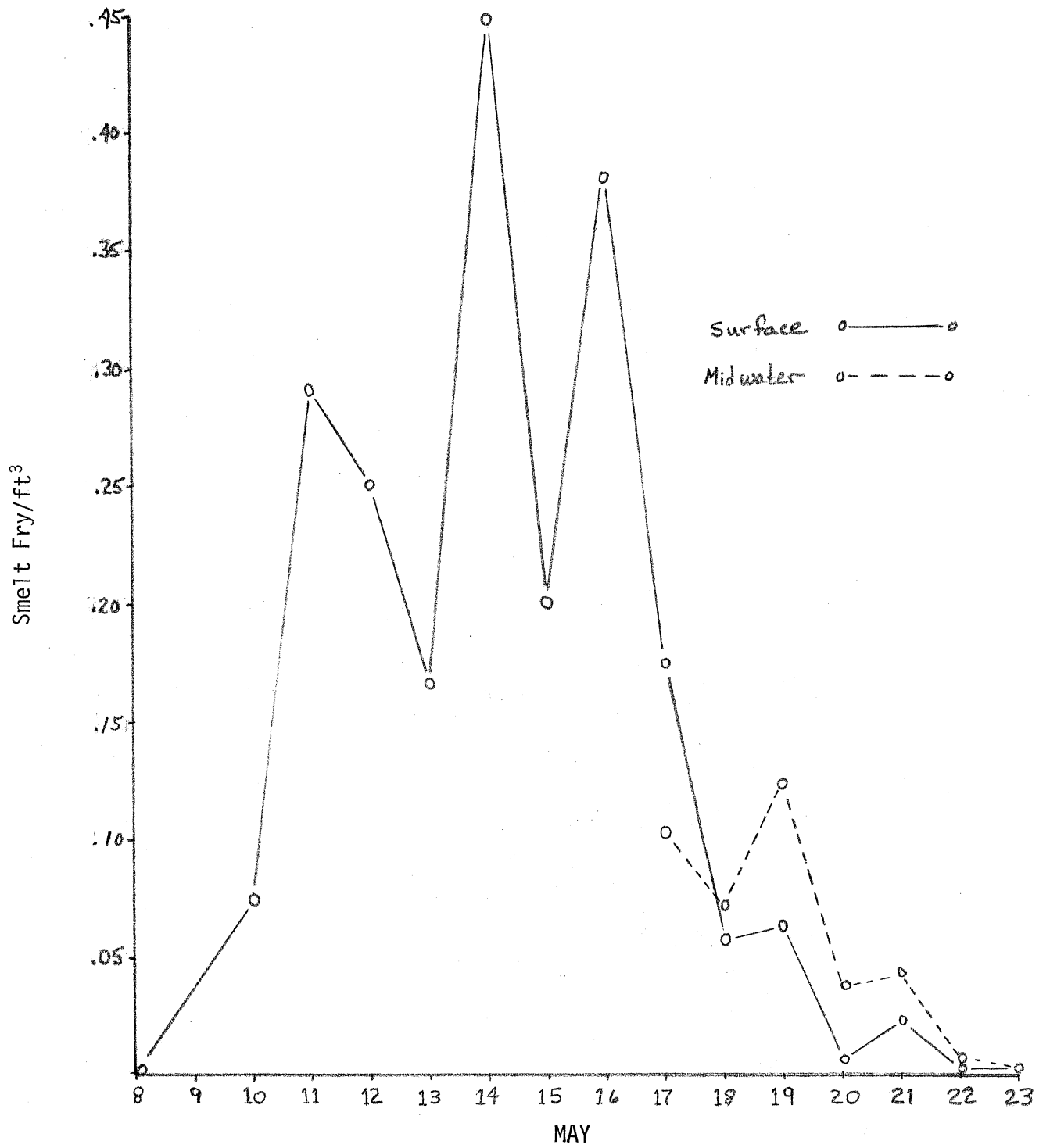


Figure 15. Number of smelt fry/ft³ captured at Douglas County Road C on the Nemadji River.

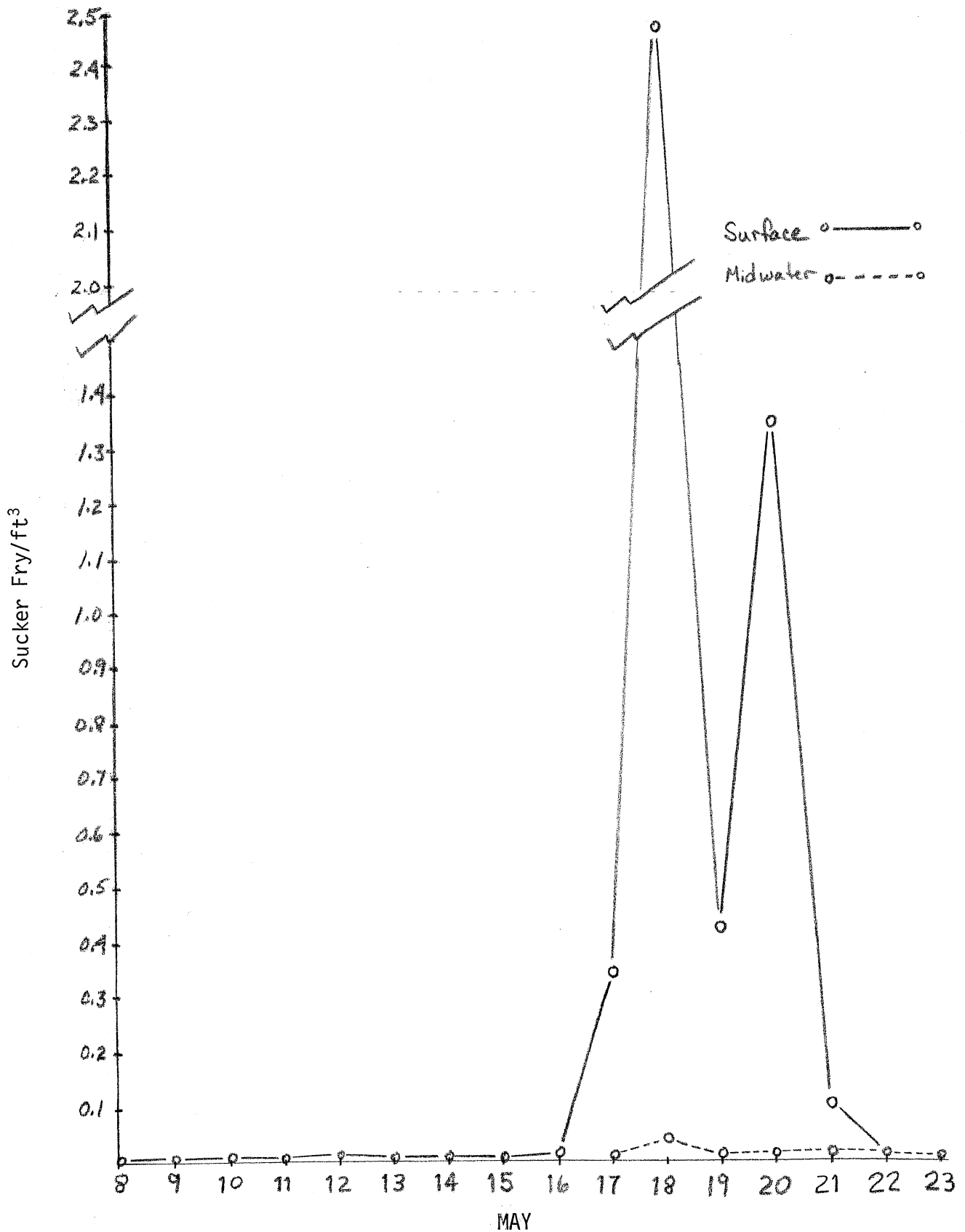


Figure 16. Number of sucker fry/ ft^3 captured at Douglas County Road C on the Nemadji River.

The number of fry drifting downstream indicates a significant number of fish are successfully using the Nemadji River for spawning. Analysis of upstream samples is not complete, but numbers of fry were much lower, indicating that most of the fry hatch in the turbid water areas of the Nemadji River drainage. Eyed smelt eggs were found in a drift net at Douglas County Road C, indicating reproduction in this portion of the river,

C. INTEGRATION - PROGRESS AND PLANNING

Results from the first three quarters have provided basic insight into the major factors limiting production of benthos and fish in the Nemadji River system. Analysis of variation between sampling sites are significant to planning continued research on the effects of erosion control on aquatic life in the basin.

Because stations in the main channel showed a high degree of similarity, future studies will place emphasis on more intensive analysis of representative "type" stations. Emphasis can also be directed at sites where intensive erosion control work is to occur, now that these locations have been accurately identified.

During the next sampling season more emphasis will be placed upon quantifying the standing crop biomass of various fish species at the various "type" stations of the study area. This should reflect the influence of substrate type and turbidity upon species selectivity and fish production.

In addition to describing abundance and diversity of benthic organisms in riffle areas, existing results suggest a need for more detailed analysis to

predict effects of turbidity on production of benthic invertebrates. Because drift behavior is associated with production, discharge and water quality, analysis of drift should be included in the more intensive analysis planned for the second budget period. Drift analysis may also be significant in defining availability of benthos to resident fish populations,

The reduction in the number of locations to be sampled will also make it possible to initiate studies on effects of erosion control on primary productivity. Primary production is of significance to the benthic community as a food source and should be influenced by turbidity and sedimentation. Relative population levels and effects can be measured by determination of chlorophyll a content of samples collected on standard glass plate substrates.

LITERATURE CITED

- Coble, D. W. 1961. Influence of Water Exchange and Dissolved Oxygen in Redds on Survival of Steelhead Trout Embryos. *Trans. Am. Fish. Soc.* 90(4): 469-474.
- Gauch, H. G. and R. H. Whittaker, 1972. Comparison of Ordination Techniques. *Ecology* 53(5):868-875.
- Hausle, Donald A. and Daniel W. Coble. 1976. Influence of Sand in Redds on Survival and Emergence of Brook Trout (Salvelinus fontinalis). *Trans. Am. Fish. Soc.* 105(1):57-63.
- Jenkins, T. M. Jr. 1969. Social Structure, Position Choice and Microdistribution of Two Trout Species (Salmo trutta and Salmo gairdneri) in Mountain Streams. *Anim. Behav. Monographs* 2(2):57-123.
- Mason, W. T., C. I. Weber, P. A. Lewis and E. C. Julian. 1972. Factors Affecting the Performance of Basket and Multiplate Macroinvertebrate Samplers. *Freshwater Biology*, 3:409-436.
- Peters, John C. 1962. The Effects of Stream Sedimentation on Trout Embryo Survival. In: Dr. Clarence M. Tarzwell ed. *Biological Problems in Water Pollution*. U. S. Dept. of Health, Education and Welfare, pp. 275-279.
- Thorup, J. 1964. Substrate Type and its Value as a Basis for the Delimitation of Bottom Fauna Communities in Running Waters. pp. 59-74, In: Cummins, K. W. ed. *Organism-Substrate Relationships in Streams*, Spec. Publ. Pymatuning Lab.Fld. Biol., 4.

Wene, George and E. L. Wickliff. 1940. Modification of a Stream Bottom and its Effect on Insect Fauna, Can. Ent. 72:131-135.

Wickett, W. P. 1954, The Oxygen Supply to Salmon Eggs in Spawning Beds. J. Fish. Res. Board Can. 11(6):933-953.

APPENDIX I

SUMMARY OF PHYSICAL AND CHEMICAL CHARACTERISTICS
OF SAMPLING STATIONS, 1975-1976

STATION 1 - NEMADJI RIVER

Bank Erosion - None

Streambank Vegetation - 30% grass, 70% brush

Normal Water Color - Brown

Average Width - 150'

Average Depth - 8.5'

Date	8/19 1975	8/29 1975	9/29 1975	10/20 1975	12/8 1975	4/16 1976	4/29 1976
Pool Velocity (fps)	<0.05	<0.05	0.13	---	---	---	---
Riffle Velocity (fps)	---	---	---	---	---	---	---
Turbidity (ftu)	---	16	31.5	12	28.5	101	95
Dissolved Oxygen (ppm)	6.0	7.9	8.9	8.8	11.7	9.3	6.0
Temperature (°C)	21.0	18.9	11.3	11.8	1.2	10.5	11.2
Conductivity (µmho)	295	260	138	142	82	85	123
% Oxygen Saturation	67.8	85.6	81.4	81.5	82.6	83.0	54.6
pH	---	---	---	---	7.43	6.95	---

Substrate - clay, silt, sand, some detritus

STATION 2 - NEMADJI RIVER

Bank Erosion - Moderate to Severe

Streambank Vegetation - 18% grass, 50% brush, 10% deciduous, 30% barren

Normal Water Color - Brown

Average Width - 72'

Average Depth - 8'

Date	8/19 1975	8/29 1975	9/29 1975	10/20 1975	12/8 1975
Pool Velocity (fps)	---	<0.05	<0.05	0.4	---
Riffle Velocity (fps)	---	---	---	---	---
Turbidity (ftu)	7	13	14	12.5	29
Dissolved Oxygen (ppm)	6.7	8.6	9.1	10.6	11.9
Temperature (°C)	19.5	17.8	12.0	7.5	1.5
Conductivity (µmho)	263	238	141	169	80
% Oxygen Saturation	73.5	91.1	84.7	88.4	84.7
pH	---	---	---	---	7.35

Substrate - mostly sand, some clay, fine gravel, rubble

STATION 3 - NEMADJI RIVER

Bank Erosion - Slight

Streambank Vegetation - 35% grasses, 55% brush, 10% barren

Normal Water Color - Brown

Average Width - 37'

Average Depth - 16"

Date	9/4 1975	9/17 1975	10/1 1975	10/20 1975	11/17 1975	12/8 1975
Thalweg Velocity	1.24	---	1.26	1.43	1.93	---
Turbidity (ftu)	10	10	6	12.5	54	222.5 (slush)
Dissolved Oxygen (ppm)	9.9	---	10.4	10.9	13.3	12.1
Temperature (°C)	20.1	14.9	9.6	7.7	1.3	1.2
Conductivity (µmho)	251	220	170	182	95	172
% Oxygen Saturation	110	---	91.4	91.4	94.1	85.4
pH	---	---	---	---	---	7.8

Substrate - 10% fine gravel
90% sand

STATION 4 - NEMADJI RIVER

Bank Erosion - Slight to Moderate

Streambank Vegetation - 25% grass, 70% brush, 5% barren

Normal Water Color - Brown

Average Width - 42'

Average Depth - 12"

Date	9/4 1975	9/17 1975	10/2 1975	10/22 1975	11/17 1975	12/5 1975	4/16 1976	4/30 1976
Thalweg Velocity	1.48	---	0.95	1.38	1.83	---	---	---
Turbidity (ftu)	10	10	7	10	73.5	27	92.5	95
Dissolved Oxygen (ppm)	10.1	---	10.6	11.5	13.4	12.0	9.2	6.0
Temperature (°C)	19.9	13.3	11.3	7.6	1.9	1.3	10.3	11.2
Conductivity (µmho)	242	223	185	183	110	210	99	123
% Oxygen Saturation	112	---	97	96.2	96.4	84.9	82.1	54.6
pH	---	---	---	---	---	7.35	6.75	---

Substrate - 12% fine gravel
88% sand

STATION 5 - NEMADJI RIVER

Bank Erosion - Slight

Streambank Vegetation - 30% grass, 60% brush, 5% deciduous, 5% barren

Normal Water Color - Brown

Average Width - 68'

Average Depth - 19"

Date	9/11 1975	10/1 1975	10/22 1975	11/17 1975	12/10 1975	4/16 1976	4/30 1976
Pool Velocity (fps)	0.84	0.97	1.08	1.83	---	---	---
Riffle Velocity (fps)	2.75	2.96	3.27	---	---	---	---
Turbidity (ftu)	9	4	9	73.5	82	89.5	87
Dissolved Oxygen (ppm)	11.7	10.4	11.4	13.4	12.2	9.8	7.0
Temperature (°C)	16.0	9.5	8.2	1.9	1.6	10.3	10.9
Conductivity (µmho)	204	158	167	110	98	110	123
% Oxygen Saturation	119.1	91.1	96.8	96.4	87.0	87.5	64.2
pH	---	---	---	---	7.7	6.62	---

Substrate - 5% rubble
 20% coarse gravel
 15% medium gravel
 15% fine gravel
 45% sand

STATION 6 - NEMADJI RIVER

Bank Erosion - Slight

Streambank Vegetation - 20% grass, 40% brush, 5% herbaceous, 10% coniferous,
20% deciduous, 5% barren

Normal Water Color - Brown

Average Width - 35'

Average Depth - 20"

Date	9/11 1975	10/3 1975	10/24 1975	11/19 1975	12/10 1975
Pool Velocity (fps)	---	<0.05	0.1	---	---
Riffle Velocity (fps)	---	2.28	2.58	---	---
Turbidity (ftu)	12	8	8.5	62.5	16
Dissolved Oxygen (ppm)	10.6	10.0	10.4	---	12.4
Temperature (°C)	15.4	8.5	7.8	---	1.2
Conductivity (µmho)	136	102	114	---	72
% Oxygen Saturation	106.5	85.5	87.4	---	87.5
pH	---	---	---	---	7.3

Substrate - 15% boulder
30% rubble
20% coarse gravel
10% medium gravel
5% fine gravel
20% sand

STATION 7 - BALSAM CREEK

Bank Erosion - Moderate

Streambank Vegetation - 10% grass, 60% brush, 5% herbaceous, 5% coniferous,
10% deciduous, 10% barren

Normal Water Color - Brown

Average Width - 26'

Average Depth - 24"

Date	9/4 1975	9/17 1975	10/2 1975	10/22 1975	11/17 1975	12/5 1975
Pool Velocity (fps)	0.44	---	0.43	0.27	1.80	---
Riffle Velocity (fps)	---	---	1.75	2.55	5.40	---
Turbidity (ftu)	32	---	22	19	67.5	20
Dissolved Oxygen (ppm)	9.5	---	10.0	10.9	13.4	12.4
Temperature (°C)	16.7	11.0	8.3	7.8	1.7	1.2
Conductivity (µmho)	171	169	127	138	75	245
% Oxygen Saturation	98.2	---	85.1	91.6	95.9	87.5
pH	---	---	---	---	---	7.6

Substrate - 60% rubble
5% coarse gravel
20% sand
10% silt
5% clay

STATION 8 - LITTLE BALSAM CREEK

Bank Erosion - Slight to Moderate

Streambank Vegetation - 20% grass, 35% brush, 15% herbaceous, 25% deciduous,
5% barren

Normal Water Color - Clear

Average Width - 12'

Average Depth - 10"

Date	8/19 1975	8/27 1975	9/30 1975	10/21 1975	11/18 1975	12/5 1975	4/16 1976	4/27 1976
Pool Velocity (fps)	---	---	0.35	0.28	1.53	---	---	---
Riffle Velocity (fps)	---	---	2.67	2.12	4.90	---	---	---
Turbidity (ftu)	---	2	2	2.5	63	6	10	3.5
Dissolved Oxygen (ppm)	9.3	10.2	10.5	11.2	12.2	12.6	10.9	9.8
Temperature (°C)	18.2	15	10.6	9.3	3.1	1.8	10.3	11.3
Conductivity (µmho)	165	179	148	144	79	116	48	70
% Oxygen Saturation	99.4	101.7	94.5	97.6	90.6	90.4	97.3	89.0
pH	---	---	---	---	---	7.7	6.65	---

Substrate - 25% rubble
15% coarse gravel
5% medium gravel
10% fine gravel
35% sand
10% silt

STATION 9 - LITTLE BALSAM CREEK

Bank Erosion - Slight

Streambank Vegetation - 25% grass, 30% brush, 30% herbaceous, 5% deciduous,
5% coniferous, 5% barren

Normal Water Color - Clear

Average Width - 6'

Average Depth - 6"

Date	8/19 1975	8/27 1975	9/30 1975	10/21 1975	11/18 1975	12/5 1975	4/16 1976	4/27 1976
Pool Velocity (fps)	---	---	0.13	0.07	0.5	---	---	---
Riffle Velocity (fps)	---	---	1.07	1.45	2.67	---	---	---
Turbidity (ftu)	---	3	5	3	5.5	6.5	4	4
Dissolved Oxygen (ppm)	7.4	9.2	8.3	8.85	12.2	12.1	9.7	9.9
Temperature (°C)	12.7	12.7	10.2	9.0	3.2	1.5	10.2	9.2
Conductivity (µmho)	150	139	100	91	47	39	30	33
% Oxygen Saturation	70.0	87.0	74.0	76.6	90.9	86.1	86.6	86.0
pH	---	---	---	---	---	7.45	6.65	---

Substrate - 20% rubble
10% coarse gravel
5% medium gravel
5% fine gravel
55% sand
5% silt

STATION 10 - EMPIRE CREEK

Bank Erosion - Slight

Streambank Vegetation - 20% grass, 5% brush, 30% herbaceous, 5% Coniferous,
40% deciduous

Normal Water Color - Clear

Average Width - 6.5'

Average Depth - 10"

Date	8/27 1975	9/29 1975	10/23 1975	11/18 1975	12/5 1975	4/16 1976	4/27 1976
Pool Velocity (fps)	---	0.3	0.45	1.03	---	---	---
Riffle Velocity (fps)	---	2.72	2.18	1.83	---	---	---
Turbidity (ftu)	2	2	3.5	28	11	5.5	5
Dissolved Oxygen (ppm)	10.4	9.8	10.4	11.4	12.8	10.0	9.8
Temperature (°C)	12.1	10.5	7	4.1	1.5	9.0	9.1
Conductivity (µmho)	135	133	122	70	60	47	66
% Oxygen Saturation	97.0	88.0	85.7	87.0	91.1	86.2	86.2
pH	---	---	---	---	8.0	6.85	---

Substrate - 5% coarse gravel
10% medium gravel
15% fine gravel
70% sand

STATION 11 - SKUNK CREEK

Bank Erosion - Moderate to Severe

Streambank Vegetation - 35% grass, 35% brush, 5% coniferous, 10% deciduous,
15% barren

Normal Water Color - Brown

Average Width - 10'

Average Depth - 18"

Date	8/20 1975	9/11 1975	10/3 1975	10/23 1975	11/19 1975	12/10 1975	4/16 1976	4/28 1976
Pool Velocity (fps)	---	<0.05	<0.05	<0.05	1.33	---	---	---
Riffle Velocity (fps)	---	---	1.12	2.25	4.75	---	---	---
Turbidity (ftu)	18	12	12	11.5	114.5	28.5	30.5	54
Dissolved Oxygen (ppm)	8.8	10.4	10	10.6	12.3	12.4	10.1	11.0
Temperature (°C)	16.9	12.4	7.6	7.4	3.4	1.7	9.8	8.1
Conductivity (µmho)	190	165	145	132	98	98	80	90
% Oxygen Saturation	91.4	97.7	83.6	88.2	92.1	88.7	88.6	88.6
pH	---	---	---	---	---	7.7	6.55	---

Substrate - 35% rubble
5% coarse gravel
10% sand
40% silt
10% clay

STATION 12 - ELIM CREEK

Bank Erosion - Moderate

Streambank Vegetation - 40% grass, 45% brush, 5% coniferous, 5% deciduous,
5% barren

Normal Water Color - Clear

Average Width - Intermittent

Average Depth - Intermittent

Date	9/10 1975	10/3 1975	10/24 1975	11/19 1975	12/10 1975	4/16 1976	4/28 1976
Pool Velocity (fps)	dry	---	---	2.03	---	---	---
Riffle Velocity (fps)	dry	---	---	4.12	---	---	---
Turbidity (ftu)	dry	4	140	107.5	18	18.5	18.5
Dissolved Oxygen (ppm)	dry	---	---	12.3	12.2	10.3	10.7
Temperature (°C)	dry	---	---	4.8	1.9	10.1	8.9
Conductivity (µmho)	dry	---	---	111	125	118	140
% Oxygen Saturation	---	---	---	95.6	87.8	91.1	92.2
pH	---	---	---	---	7.3	6.7	---

Substrate - 20% rubble
40% coarse gravel
20% medium gravel
10% sand
10% clay

STATION 13 - SKUNK CREEK

Bank Erosion - Slight to Severe

Streambank Vegetation - 5% grass, 35% brush, 20% coniferous, 25% deciduous,
15% barren

Normal Water Color - Brown

Average Width - 16'

Average Depth - 24"

Date	8/20 1975	9/10 1975	10/3 1975	10/24 1975	11/19 1975	12/10 1975	4/16 1976	4/28 1976
Pool Velocity (fps)	---	<0.05	<0.05	0.32	---	---	---	---
Riffle Velocity (fps)	---	---	0.71	2.11	---	---	---	---
Turbidity (ftu)	22	21	13	135	117	28	36	38
Dissolved Oxygen (ppm)	7.8	10.1	10.1	11.0	---	12.2	9.4	10.6
Temperature (°C)	16.7	13.0	10.3	7.6	---	1.8	10.0	6.8
Conductivity (µmho)	190	178	170	152	---	150	98	100
% Oxygen Saturation	80.1	96.2	90.3	92.0	---	87.5	83.2	86.9
pH	---	---	---	---	---	7.1	6.65	---

Substrate - 30% rubble
5% sand
20% silt
45% clay